STEEL — FRAMING THE FUTURE

The University of Sydney
Project Report
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- Reg Hobbs
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THE EXECUTIVE SUMMARY

The Steel – Framing the Future project findings, addressing the multi-storey building sector, have the unmistakable ring of a call for industry reform. Robust investigation of the status of the steel construction industry over two and a half years has revealed a sector that is well behind its counterparts in the US, UK and New Zealand, with dwindling skills and average capabilities. To contrast the Australian industry’s status quo with, for example, the UK, is to understand that ignoring the call for reform signals the nation’s divestment of what could be a thriving, innovative industry with export potential.

THE ISSUE: A STRATEGIC SECTOR CAUGHT IN A ‘VICIOUS CIRCLE’

The steel-framed building sector of Australia’s construction industry has strategic importance to the nation’s economic health. Though small, its supply chain spans a wide array of skills, including architects and designers, engineers, detailers, steel and metal deck suppliers, fabricators, surface applicators and builders. Expertise in this sector not only contributes to a competitive commercial construction sector, but also flows through to industrial, resources and infrastructure construction activity.

At 13 per cent of the market, steel framing's share of Australian building construction significantly lags behind that of the UK (70 per cent) and US (50 per cent). The reward for greater market share is immense – each per cent recaptured equates to some 2500 tonnes of steel to be processed by the sector annually.

However, low market share creates its own obstacles to change: development is curtailed and the availability of skills supporting steel framing dwindles. A vicious circle exists that leaves the sector exposed to the growing inflow of imported steel sections and ultimately, solutions.

In 2004, The Warren Centre for Advanced Engineering initiated the Steel – Framing the Future project to investigate these issues, focusing on the multi-storey building sector.

Over the course of the two and a half year project, it became clear that some members of the steel-framed construction value chain were addressing some of the issues identified, pursuing courses of action concomitant with the project’s recommendations.

Most notably, companies such as Alfasi, Epic Steel, Sebastian Engineering and BlueScope Lysaght’s Design and Construction Division have packaged procurement, steel fabrication, detailing and erection into a single offer and point of responsibility, streamlining a previously disjointed process and creating compelling, lower-risk solutions for the commercial construction market.

With these organisations in the vanguard, steel framing for multi-storey buildings in Australia is becoming cheaper, faster and less risky than at any time in the past. It has the potential to yield substantial rewards for its value chain players and the Australian economy as the recommendations from this project continue to be implemented.

THE CAUSE: PERCEPTION OF RISK PUTS STEEL AT DISADVANTAGE

Using case studies of multi-storey CBD, suburban and industrial park developments, early assessment identified five root causes affecting the steel-frame construction industry’s performance:

- lack of strong leadership
- inability to provide reliably accurate cost estimates
- non-integrated supply chain

Steel framed buildings are, in fact, steel and concrete composites where the structural properties are delivered by the beneficial interaction of both materials.
Steel – Framing the Future

Executive Summary

Inability to articulate the value proposition for steel framing
• poor take-up and integration of proven technology.

Each issue was examined in depth, calling on the expertise of some 50 senior executives from organisations across the steel and construction value chains.

Australia has an efficient, competitive and well-established concrete-framing industry. By comparison, one of the earliest insights of the Steel – Framing the Future project was that builders and developers considered the use of steel to be a far riskier option than concrete. The perception of high risk was based on: apparent price volatility, poor access to consistently reliable data impacting on costs and estimates, concerns about safety on site, confusion about steel’s sustainability credentials and exposure to additional supply chain complexity.

Other findings specific to the steel-framed value chain that emerged over the course of the project included the following:
• Decision makers in the preliminary design phase of construction rarely considered a steel-framed solution unless it was a stipulation of the design or if concrete was not viable, and when selected, rarely involved fabricators at the design stage.
• Engineers were largely unaware of the improvements brought about by modern fabrication technology.
• Few projects exploited the benefits of an integrated steel design and manufacture process, which can significantly reduce both cost and time to completion.
• The accuracy of cost estimating for steel-framed structures suffered from a lack of reliable cost data and an absence of regular communication between quantity surveyors, fabricators and engineers.
• There was a lack of critical-size fabricators providing the builder/developer with pricing and delivery confidence.

There were also general construction value chain issues which contributed to the problem:
• Adversarial contract structures, with parties locked into fixed price contracts, provided no incentive to collaborate to achieve better results during the construction process.
• The take-up of 3D modelling and 3D documentation, enabling broad and accurate access to project information, is poor.

These and other insights from the work of the Steel – Framing the Future teams suggested three drivers of change:

COMMUNICATION: Articulate steel framing’s value proposition in a compelling way to the decision makers early in a project’s development cycle. Share commercial information where that can improve efficiencies and reduce risks.

COLLABORATION: Develop relationships within and along the steel-framed value chain and develop effective collaboration models, and agreed frameworks within which to quote, share information and models, share risks and share profits.

CAPABILITY: Continuously improve productivity; adopt proven technology, in particular automation and management systems in the fabrication process; embrace innovation.

Much of this is not new. Other sectors of the Australian steel products industry are benefiting from these technologies, as are overseas competitors.

The project found overwhelmingly that the steel-framed value chain suffered from a broken value-delivery system across its many disconnected parts, which, if mended, could offer real advantages over the concrete alternative.

THE SOLUTION: TIME TO EMBRACE TECHNOLOGY AND A ‘ONE-STOP SHOP’

The cornerstone of the project’s recommendations is its support of the Design and Construct, or ‘steelwork contracting’ business model. This ‘one-stop shop’ entity (as perceived by the builder or developer) could offer a complete steel-framing solution including engineering, detailing and project management capabilities. Certain skills may be outsourced, but the responsibility rests with a single entity and the extent of the contract, while flexible, can embrace the entire building frame and facade (i.e. the weatherproof shell).

2 These risks may be defined, for example, as relating to cost, time, quality, safety and sustainability.
Supporting this model is the necessary application of current and emerging manufacturing and information technologies. Building Information Modelling software radically streamlines the existing design process by enabling the close integration of procurement, design and fabrication. Beamlines, robots and other advanced fabrication technology have yielded dramatic benefits for steelwork contractors in the UK where output per person per annum has risen from 30 tonnes to 240 tonnes in the past 13 years, a 35 per cent increase annually.

A national supply chain measurement system that is independently operated, gathering real data from construction projects and harnessing web interfaces to enhance accessibility, creates greater transparency and cost estimation accuracy for the steel-framed value chain.

The Australian Steel Institute is now undertaking several initiatives that align well with the project’s recommendations, such as addressing steel’s sustainability credentials and resolving perceived fire-engineering hurdles. The Institute’s role in stewarding these changes in the steel-framed value chain is noted, as well as that of the first mover entrepreneurs, referred to as Key Leaders, who are making or will make the initial investments to transform the sector from within. It is anticipated the development of new processes and standards for the entire value chain will arise from the contributions of these Key Leaders in collaborative forums, such as those facilitated by the Australian Steel Institute.

CONCLUSION: STEEL FRAMING CAN BE FASTER, CHEAPER AND RELIABLE

A strong steel-framed construction value chain is essential to the Australian construction industry, and the business case for radical change in the sector has never been more apparent. The Steel – Framing the Future project has focused its investigation on multi-storey buildings; however, the ramifications of the project’s recommendations extend right across the multi-storey steel and construction value chains. The results from the two and a half year, collaborative and consultative process shows how faster, cheaper and less risky steel-framed construction solutions may be in an imminent future in Australia.

This project found new technologies can be applied to steel-framing that make it easier to design and alter, and allow builders to fully capitalise on the new collaborative business models delivering steel-framed structures to the market. The steelwork contracting model consolidates the value chain to give a single point of responsibility that reduces risk, ensures a flow from one part of the building process to the next and retains rather than loses innovative processes and experience. Virtual buildings are designed in a digital space and key players such as fabricators, quantity surveyors and estimators are able to give accurate cost forecasts using shared value-chain information. While these practices are far from the norm, their existence amongst the emerging Key Leaders shows the new deal with steel is real.

Since the inception of the Steel – Framing the Future project the share of steel in multi-storey buildings in Australia has risen from 3 per cent to 13 per cent and many initiatives put forward in the project documents are being adopted. The experience of some of the Australian steel construction sector’s international counterparts shows the ‘size of the prize’ for adopting the recommendations of this project is substantial. Some supply chain participants are well under way in their transformation, while others make incremental movements and the cost of steel framing, in real price terms, continues to fall worldwide.

If this continues, as is the objective of this project, the future of steel in Australian building construction will be secured.
R.J. Hobbs
20th August 2007
Mr Robert A.H. Mitchell
Chief Executive Officer
The Warren Centre for Advanced Engineering
University of Sydney NSW 2006

Dear Robert

You have asked me to write this letter outlining concerns I have raised regarding the 'Executive Summary' of the 'Framing the Future' report, from the perspective of my chairmanship of the leadership working group.

While the 'Findings' and the 'Recommendations' contain many sound 'housekeeping' issues for the steel sector, I find it disappointing that many opportunities to deliver better value through use of structural steel in conjunction with concrete elements in buildings in the Australian market have not been given due emphasis. I find it disappointing that although the Warren Centre (in conjunction with 'steel industry' participants) had identified the stated 'root causes' in early 2005; over two years later the 'Executive Summary' has not articulated more profound options to improve the sectors potential in the current market.

Where, in my opinion, the 'Executive Summary' is significantly deficient is that it fails to give due emphasis to the many salient issues discussed during the course of the study that represent the needs of the potential owners, tenants and specifiers of a building. These include matters such as flatness of floors to allow modern glazed fit-out systems, sustainability, 'Green Star' ratings, vibration and footfall attenuation, services reticulation, façade details etc. There has been undue focus on 'seller side' and manufacturing issues rather than all of the study participants 'standing in the shoes of the potential buyers'.

The "cornerstone" recommendation of the "one-stop-shop" delivery model is in my view a concept that has been proposed by some members of the 'Framing the Future' project without rigorous analysis or a validated survey of the wider 'building head contractor' community. I believe that this concept fails to take account of the complex relationships between the structural, services and building trades (the last two comprising over 50% of the cost of a building). The examples cited are not representative of the broader Australian building industry and having checked during recent weeks I have determined that there is scepticism of such initiatives among senior steel industry personnel and building contractors in the Melbourne market.

This study provided an opportunity to focus on delivering buildings that maximise the value of the delivered structure, in terms that are important to the customer, by widening the knowledge in Australia of examples where the combined properties of steel and concrete have successfully delivered value in other parts of the world. While some of the discussions during the study did address those issues, that approach is not evident in the 'Executive Summary'. Instead the language and recorded approach appears to reinforce the tired and valueless "steel versus concrete" debate. The reference to "steel framed" essentially depicts
buildings featuring steel primary beams, metal decking, shear studs and concrete slabs acting in composite action. This is a model that has been promoted for over 35 years; however it no longer reflects best practice or the needs and preferences of the majority of Australian builders. More innovative composite steel – concrete systems are in use in Australia and many other countries.

While reference to ‘composite construction’ has now been included, the draft omits description of opportunities for considerable innovation in this area identified during Leadership working group discussions and the possibilities noted in Mr Emil Zyhajlo’s paper for improving codes and design aids to make such designs accessible to a wider range of consulting engineers. I noted that various discussions regarding the concept of using steel sections with full or partial concrete pre-encasement (such as those produced by firms such as Stahl + Verbundbau GmbH of Germany) appeared to ‘pass right over the heads’ of key steel industry people. Pre-encasement of steel sections with concrete in a steel fabrication workshop may be a challenging but rewarding concept.

Many contemporary buildings use ‘composites’ of reinforced, prestressed or post tensioned concrete primary beams in conjunction with metal decking and a wide range of other steel products. In Melbourne, Bluescope Steel provides an excellent technical service to the concrete construction sector, working with concrete formworkers to achieve optimum interaction of concrete primary beams and steel decking. I remain intrigued that I visited OneSteel Limited’s Internet site today and under ‘End Use Applications’, ‘Construction – Buildings’, ‘Office’ noted reference to composite construction with the predominant marketing information being for concrete reinforcing bar.

The ‘Executive Summary’ also fails to report the opportunities identified by the Leadership working group in the smaller suburban office building market by developing solutions using steel framing for the first floor as well as the roof (which is generally steel framed anyhow). It appears that this did not capture the attention of key participants in spite of the potential. In the concrete sector it was realised over 35 years ago that the market volume was in concrete slabs under houses, not in ‘trophy high rise buildings’.

The absence from the ‘Executive Summary’ and ‘Recommendations’ of detailed discussion of the significance of Sustainability, Greenhouse Gas Emissions and ‘Green Star’ ratings; or the manner in which the ‘steel industry’ could respond to these challenges is an issue that diminishes the credibility of the ‘Framing the Future’ project. During various discussions I was presented with arguments that it was not possible for the sector to discuss this at the time as the ASI needed to convene a working group and there were issues such as establishing which rating system was relevant. Given the widespread adoption of the Green Building Council of Australia rating systems by many investors, developers and tenants over the two years of the study I consider that it should have been possible for the study to develop an objective analysis of whether ‘steel framed’ buildings suit the objectives described by the ‘rating tools’.

I am disappointed that I am left in the position that I find the ‘Executive Summary’ to be an inappropriate representation of all of the issues considered and the input of so many people who contributed their expertise.

Yours sincerely

Reg Hobbs
1.0 INTRODUCTION

1.1 BACKGROUND

By Sandy Longworth
For The Warren Centre

In Australia over the past 20 years there has been a pronounced reduction in structural steel framing for multi-storey buildings when compared with concrete, and in particular pre-stressed concrete.

This decline has been enhanced by a well developed and appropriately capitalised concrete industry, which contrasts with a poorly led and generally, fragmented fabricating industry. Fabricating businesses are relatively devoid of public financial participation and, with a few exceptions, are not strong re-investors, which is in part due to the lack of stable earnings growth.

While it might be said that the industry's predicament is a manifestation of normal market forces, this is not borne out by other markets. In the United Kingdom, United States and New Zealand building structural steel has approximately 70 per cent, 50 per cent and 40 per cent market share respectively compared with Australia's current take-up of 13 per cent.

The progressive decline has brought with it a loss of fabricating know-how and skills in addition to a decline in construction management personnel with experience in the control of major structural steel projects. This has all occurred at a time of relatively rapid advancement in a spectrum of technologies available to the engineering and fabricating industries.

The building structures fabricators have traditionally been slow to take up technology pioneered by the more capital-intensive industries. It became apparent to the Steel – Framing the Future project promoters that there was ongoing potential for significant reduction in fabricated steel real costs through these technology advancements. Structural steel therefore has the potential to remain competitive, which further endorsed the need to restore its market position.

In the past decade there have been significant advances made in design documentation and detailing software, 3D modelling, NC output and fabricating shop automation by way of beam lines incorporating automated cutting, coping, drilling and welding. Automation, at all levels of fabrication, is being driven by the more capital-intensive industries, such as shipbuilding, heavy mobile plant manufacture, bridge and infrastructure construction.

There has been, in parallel with design and fabrication technology advances, development of structural steel metal deck, which has opened up the field of composite construction. The renewed interest in fire engineering, with a focus on performance-based outcomes, has also been a significant catalyst to the enhanced competitiveness of multi-storey composite construction.

A reasoned argument and proposal, with supporting budget for the Steel – Framing The Future project, was prepared and presented to industry and government for support, both in direct finance and by way of project work input in kind. The project was progressively funded financially and in kind and acknowledgements are recorded in 5.3 of this report.

Australia's fabricated steel output is predominantly resources and industrial in form, i.e. approximately 65 per cent being resources and industrial with 35 per cent building construction. Why then, has the Steel – Framing the Future project elected to focus on the building sector? Such a course was adopted, after considerable debate, primarily because the multi-storey sector contained high levels of repetition. The erected cost of this form of beam and column construction (stick construction) should therefore be in the lower cost quartile, being relatively simple and repetitive. Furthermore there was a relative value proposition to be advanced, given the competitor pre-stressed and pre-cast concrete alternatives: a factor not at all clear-cut with most industrial structures that generally embrace steel solutions as a single candidate.

It became apparent, after The Warren Centre's consultation with sectors of the building construction industry, that there was a lack of knowledge of the benefits of composite steel construction. There was one narrow well-informed sector of the industry and another sector, which freely admitted lacking the experienced personnel to confidently adopt a structural steel composite system, choosing to work in concrete.
Before committing to the project, The Warren Centre questioned whether its involvement was directed at increasing steel’s market share versus concrete and as such, commercial in character – a task that was not compatible with The Warren Centre’s objectives. If on the other hand it was directed at correcting a loss of skills base and capability in the construction industry, then it was acceptable. The latter view was accepted and the project began in earnest in October 2004.

The work program focused on a series of case studies of current or recently completed projects that were all structural steel composite construction with the exception of one reinforced concrete project. These projects comprised:

- Emirates Tower, Dubai
- Latitude building, Sydney
- BMW building, 209 Kings Way, Melbourne
- BHP-Billiton headquarters, Queen Victoria Village, Melbourne
- Carrington House, Sydney (Concrete)
- Brisbane Airport carpark extension
- Rhodes Waterside shopping centre, Sydney
- Adelaide Airport Terminal
- Flinders Connection, Adelaide
- Southern Cross office complex, Melbourne
- Lonsdale Street office building, Melbourne.

Case studies included an interactive session with between 15 to 30 attendees. Notes for each case study are on record and available through The Warren Centre website at www.warren.usyd.edu.au (click on Projects: Framing the Future, then Project Team pages and access using Name: warrenc1, Password: SFTF0507).

Towards the end of the case study sessions in December 2005, a roundtable interactive session was held with a professional facilitator that resulted in the identification of six root causes, listed below, which were the key roadblocks to steel’s poor market acceptability:

- leadership
- value chain complexity
- costing
- relative value proposition
- technology
- standards/codes

As is the custom on many Warren Centre projects of this type a series of Issues Groups were formed to investigate the root causes in more detail, with the objective of generating recommendations for change. This methodology, discussed in greater detail in section 6, while time consuming, involves members of the various segments of the steel value chain in formulating ideas for change. There is therefore a strong sense of ownership from the creators, which gives the concepts for change a greater chance of implementation, or at least trial.

In March and May 2006 the respective appointments of Peter Thompson and Richard Barrett as Visiting Fellows to the project were made. Mr Thompson is a retired Australian principal of Arup and Mr Barrett is managing director of Barrett Steel Buildings, a long-established, respected UK fabricator. Mr Thompson and Mr Barrett have had wide experience in the design fabrication and erection of structural steel works for buildings. During the latter period of the project, they made valuable input and mentored our Issues Groups, and also actively participated in the November workshop presentation meetings.

It was determined at the Issues Group formation that, on reflection, the absence of up-to-date Australian standards relating to composite construction was not the barrier it was thought to be to the application of design principles. Experienced Australian engineers were in fact working to applicable, more modern overseas standards and steel producers had invested heavily in providing proprietary design data for application of their products. The Issues Groups were therefore reduced to five, standards and codes being eliminated.

Issues Groups established their terms of reference and through group meetings analysed barriers within their area in more detail. During this period, starting in 2006, a number of interactive group meetings were held to enable groups to exchange material and ideas and to avoid duplication of input.

In August 2006 a final workshop meeting was held at which a hypothesis framework was tabled which focused on the themes:

- communication
- capability
- collaboration.

The workshop split into teams, which for each theme confirmed the issues that had been previously raised, identified any pre-conditions or related activities required for implementation of suggested changes and developed ideas and concepts for change. Section 3 of the report summarises the recommended actions, which were further scrutinised and endorsed at the November series of workshops in Sydney, Melbourne and Brisbane.
It is appropriate to mention a number of omissions and a matter that has been raised by a respected Issues Group member.

With reference to omissions, the subject of sustainability is most relevant to all forms of today’s buildings, particularly multi-storey steel structures. The report makes mention of this aspect of steel construction, but as the nation’s major producers have not yet released their user guidelines, it was considered inappropriate for the Steel – Framing the Future team to pre-empt any directives from the industry, as relevant as the subject might be.

The Technology Group has not been able, in the time available, to identify suitable expert views on the direction of technology developments, specifically relating to steel erection. Research and development of self-positioning steel component grippers and self-aligning and securing connections are clearly areas that will improve steel’s cost position and workplace safety.

Finally, with reference to case studies, constructive comment was made that to fully evaluate the relative value proposition and to better understand competitor products to steel, the Steel – Framing the Future case studies should have included more concrete examples. We are not arguing with the logic of this comment. The project managers had difficulty coming to grips with how they would identify case study material in steel and concrete of relatively similar scale and building contemporaneously. There were also budgetary constraints on the number of case studies that could be covered in the time available.

1.2 SITUATION ANALYSIS

By Anthony Ng

OneSteel Market Mills for The Warren Centre

It is appropriate in considering the structural steel multi-storey building sector to understand the market distribution of product and what are the drivers. This market sector of the steel industry is characterised by the involvement of a steel fabricator. Typically the steel fabricator will be contracted by the client to supply, fabricate, deliver and in some cases erect the steel.

The market segments to which a steel fabricator will supply its services can be broadly divided into the following:

- mining and resources structures
- factories and warehouses
- domestic construction (houses)
- single-level offices and retail
- multi-level offices and retail
- education, health and social buildings
- transport and infrastructure.

Most steel fabricators will have a preference or specialty in one of these market segments. However, given that each segment has its own cycle that is not necessarily dependent or in phase with each other, a fabricator will offer services to the segment based on demand from market forces.

The aspects that a steel fabricator will consider when deciding on a particular segment in which to develop and promote as a specialist include:

1. **Steel intensity.** A fabricator’s profitability is usually (rightly or wrongly) measured in tonnes of throughput. Mark-up of steel supply, transport and handling are calculated by the tonne. While fabrication hours is the main product sold by the fabricator, it too is related back to the tonne, and will appear to be more competitive for heavier simple construction compared with light complex detailing. As a result a small increase to the tonnage rate of a heavy project with high steel intensity will result in a significant increase in profit relative to the light complex structures.

2. **The relative value of the steelwork in the total project cost.** In mining and resource projects the cost of the steelwork is relatively small in relation to the total cost of the project. The mechanical or plant costs are significantly greater than the steelwork costs. As a result the steelwork cost is...
Steel – Framing the Future

less of a consideration for the client, leaving the opportunity for better margins with this sort of work.

3. **Return on investment.** The return on the investment on steelwork for a client varies significantly from segment to segment. The return per tonne of steel from a mining project is generally greater than the return per tonne of steel in a multi-level project.

4. **Simplicity of project.** Changes in project documentation after the commencement of a project reduce a fabricator’s throughput. As noted in (1), throughput for a fabricator generally equates to profitability. Mining and resource projects that have minimal, client-led variations after awarding the tender are preferred over commercial projects that would have client-led variations driven by the needs of the tenant. In general, mining projects are fully dimensioned when tendered and may even be fully detailed, reducing Requests for Information (RFI) and enabling more confident project programming. Factory and warehouse projects also tend to have fewer variations as they are either custom built or are able to accommodate a tenant with little alteration.

5. **Expertise and experience.** Over a period of time fabricators have developed an expertise which, coupled with their experience in certain segments, makes them more competitive and profitable in those segments. Gaining expertise in other segments represents a cost and a risk, which many fabricators may only be prepared to undertake in times when demand for their services are low. This timing corresponds precisely with the time when they are least likely to be in a position to take on the added risk. Even when the market is slow fabricators will still see a steady flow of documents come in for tender; the only difference is they are more difficult to win. These factors prohibit most fabricators wanting to develop new markets.

If we take into account the considerations outlined above it is evident that unless there is a significant shift in the way the steel industry approaches the multi-level building market other market segments will be more attractive to fabricators.

In Australia at present, there is very strong demand for fabricated steelwork for infrastructure and resources projects, with national annual output estimated at 150,000 tonnes. Despite this, there are significant imports of fabricated steelwork to make up demand shortfall. In comparison, the current steel usage in steel-framed buildings with suspended floors is estimated at 30,000 tonnes.

Steelwork pricing is therefore driven to a large degree by the tempo of the mining segment and therefore by commodity prices, although there is the inevitable lag, given construction times.

![Figure 2: Source: Australian Steel Institute survey, Market Intelligence Company](image)
1.3 SKILLS DEFICIENCY – A CHANGING SCENE

By Sandy Longworth
For The Warren Centre

1.3.1 GENERAL OBSERVATIONS

There is a worldwide shortage of skilled personnel in the steel construction and fabrication industries, as is evident from worldwide press and major resources company reports. This is consistent with other industries and professions associated with infrastructure, resources and general project construction.

In Australia, these pressures are thought to be greater, due in part to the strong general economy and unprecedented development in the resources sector. While the skills deficiency is more pronounced in the fabricating shop than on the construction site, the Steel – Framing the Future project identified, quite early in the program, a shortage of construction management personnel with structural steel experience. This conclusion was reached after discussion with a number of senior executives from major construction companies (Baulderstone Hornibrook, Leighton’s, Mirvac). These executives said their companies had few senior project management staff with a good working knowledge of the structural steel supply chain and who also had experience with steel multi-storey construction and were confident in working with this material.

It became apparent that the shortage of experienced personnel at the senior level of the construction hierarchy was to a degree impacting adversely on decision-making with regard to the steel solution.

1.3.2 FABRICATION AND THE STEEL SUPPLY CHAIN

Technology in its various forms is having a progressive influence in shaping the future worker skill base. There will remain a hardcore need for manual skills, as with all trades, but this will be progressively overshadowed by a need for personnel with a sound knowledge of fabricating processes and supply chain knowledge supported by IT proficiency. This briefly defines the future ‘white collar boilermaker’.

While there has been the progressive introduction of beam lines, automated equipment for cutting, drilling and end preparation of plate material, as well as continuously improving welding technology, there still remains a large need for skilled worker input for marking, setting up and welding of the finished product. It is still the tape, string line, marking and punching which accounts for a big component of labour inputs. This can range from 20 hours per tonne for traditional fabrication methods to four hours per tonne in a modern UK automated shop (Appendix A8). There is the opportunity for further continuous improvement, if the productivity of the shipbuilding industry can be taken as a benchmark. This progressive improvement will manifest itself in the quality of the finished product, resulting in improved dimensional accuracy and fewer shop-floor errors.

In Australia, there has been a gradual introduction of technology to handle NC data but not at the expected rate, given the current demand pressures on the industry and what are generally considered to be prosperous times for this industry.

Automated processes are progressively being applied to plate profiling, line marking, identification marking, hole drilling (tapping countersinking) and, where required, weld preparation. These tasks are clearly transferring trade skills from the shop floor to the detailing phase of the project. There is significant potential, utilising available tried and proven technology, to immediately assist in making some reduction to the skills deficiency (Section 4.5.9). Unfortunately there has been limited take-up of this technology as evidenced from the Technology Group’s survey of NSW fabricators (cf approximately 12 per cent equipped with NC compatible equipment). Hopefully this skills gap will be narrowed.

1.3.3 CHANGING SKILLS

The introduction of technology and in particular, the digital flow of information is progressively reducing the need for skills on the shop floor. As previously mentioned, there is a shift of the skills base back up the line from the shop floor to the detailing and engineering phases of the project flow, before the capital intensive phase of manufacture. This is evidenced by the project’s survey, which showed detailers were more active in investing in 3D software technology and adopting a range of programs and tools to enhance the flow of digital information to the shop floor of fabricators equipped to handle the data. In a sense detailers were the leaders in effecting change in this link of the value chain.

Technology is progressively encroaching on manual skills, resulting in improved quality control in the form of increased dimensional accuracy resulting in less rework and faster, more reliable, erection (Section 4.5.6). What is progressively happening in the steel building fabricating industry has been firmly entrenched
in the shipbuilding industry for the past five years.
There is evidence (ASI report that there are currently
19 beam lines on order for Australia) of increased
automated equipment purchases, which is encouraging.
Custom beam fabrication is taking place principally for
sizes outside the rolled section range (Fabricated beam
outstanding orders, BlueScope).

UK practice is moving to wider use of custom-fabricated
beams, where there is greater scope for more efficient,
innovative design. The project Technology Group
believes that at some point, an innovative fabricator
will trial the use of a gantry robot to undertake the
attachment of connections, splice plates, base plates
and outrigger brackets to beams and columns processed
through a beam line. This technology has been in
use in the UK and Europe for construction of bridge
girders for some years. Once this happens, it is likely
to be followed by the introduction of automated jig
positioners, in conjunction with gantry robots, to
produce straight and tapered sections.

Technology change is in a sense infectious once it starts
it moves quickly. While the steel fabricating industry in
Australia has not yet availed itself of tried and proven
technologies available in the market, other industries,
such as the automotive and heavy earthmoving
equipment, have taken up the challenge. There is
therefore a developing robot programming skills base
in the Australian motor industry and other industries,
which once re-acclimatised to the steel fabricating
scene will readily adapt to providing this essential link
in the automated process.

It is therefore apparent, if the steel fabricating industry
is going to move into the upper quartile of world’s best
practice and, to follow Japan, the UK and USA, that
there will be a need for additional training programs
for the digital IT flow technicians who will constitute a
significant sector of the industry workforce.

1.4 CONTRASTING THE STEEL CONSTRUCTION INDUSTRY IN
THE UK AND AUSTRALIA

By Richard B Barrett
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Deputy President, British Constructional Steelwork
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1.4.1 INTRODUCTION

This paper details the trends in the UK steel
construction market over the past 25 years. It is
intended to give an insight into the potential for steel-
framed construction in Australia, and to feed into The
Warren Centre Steel – Framing the Future project.

Table 1. Steel’s Penetration of the UK

<table>
<thead>
<tr>
<th>Year</th>
<th>Steel (%)</th>
<th>Other materials (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>1985</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>1990</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>1995</td>
<td>56</td>
<td>44</td>
</tr>
<tr>
<td>2000</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td>2005</td>
<td>71</td>
<td>29</td>
</tr>
</tbody>
</table>

Source: Corus Market Research) market-share figures in the UK for steel
compared with all other materials

Note: Other materials to include – concrete, masonry and timber – for
multi-storey, non-residential buildings.

In 1980 one third of UK buildings were framed in steel,
the rest in other materials, predominately concrete. The
UK was principally a concrete-using country. During
the next 25 years the picture changed completely. The
main framing material is now steel, with a massive 71
per cent market share, and just 29 per cent of buildings
being built in all other materials (Corus).

In Australia, by comparison, the market share for steel
in 2005 was just 13 per cent, up from 3 per cent in 2003
(Australian Steel Institute). Whilst there is therefore
an indication that the market share may be beginning
to return to steel, this is from a very low base.

This paper looks at the key drivers for change in the
UK, drivers that caused it to switch from being a
predominantly concrete market to a predominantly
steel market. Hopefully, these are ideas that may be
beneficial for the Australian construction industry and
its competitiveness in the world.
1.4.2 TECHNICAL ISSUES

Fire

One key event was the formation of the Steel Construction Institute (SCI) in 1981. The SCI, with staff who are experts in many fields of steel construction, is very effective in serving the technical needs of the sector.

In particular, in the early days a lot of work was done on fire. A number of tests were carried out on steel in fire, the largest of which was a full-scale fire test on an eight-storey building, built at Cardington specifically for fire testing. The result of this testing is that guidance was produced to show how to protect steel from fire, so that fire is no longer a major issue for steel in construction. Just as the automotive industry builds cars protected from rust by applying appropriate surface protection, in steel construction we apply intumescent paint that protects the steel in the event of fire. Straightforward guides enable engineers to quickly design the fire protection requirements for a project, and it can be applied at relatively low cost; this is described in more detail towards the end of this paper.

Composite construction

Wide use is made of composite floor construction, where the concrete in the floor slab acts in conjunction with the steel beam to optimise the design, giving a highly competitive building solution.

Sound and vibration

The other topic, which can be perceived as being an issue for steel, is sound and vibration. Again, as with fire, it is relatively straightforward to deal with. Part E of the Building Regulations (England & Wales) specifies quite stringent requirements, especially for residential apartments and schools. Standard details, known as Robust Standard Details (published by the House Builders Federation), have been developed to achieve the sound attenuation between adjacent units. Interestingly, the details for steel look almost identical to those for concrete buildings, as both require similar actions to meet the regulations.

Design guides

The industry has also prepared numerous comprehensive design guides for use by engineers. There are also a large number of excellent design programs, prepared by commercial software houses, (see SCI publications list). The guides and software make it easy to design in steel. Additionally, the sector does quite a bit to support universities. For example, every architecture and civil engineering undergraduate student receives a student pack in their first year at university. This DVD pack gives advice and examples on architectural, technical, manufacturing and practical aspects of steel in structures. More than 10,000 of these packs are sent out each year by the British Constructional Steelwork Association (BCSA).
Supply chain

The supply chain for the structural steelwork sector is competitive, vibrant, diverse and deep. The growing size of the industry has helped to create a virtuous circle – a large number of competitive fabricators, making the industry even more successful. There are 15 or 20 companies that are capable of doing substantial jobs nationally, each of which has capacity in excess of 10,000 tonnes per year, in many cases substantially more.

Using data from BCSA’s biannual State of Trade report, it can be calculated that output per worker has risen on average by 6.1 per cent per annum in the period since 1983. The compounding effect of this increase is truly dramatic – from just 30 tonnes per worker per annum in 1983 to 240 tonnes per worker per annum in 2006.

Steel fabricators also have around them a deep chain of suppliers. The raw material can be sourced from the steel mill, or from steel stockholders offering JIT delivery, directly into fabricators production lines. Additionally, numerous specialists provide bending services, specialist beams such as Fabsec and Cellforms, and coatings such as off-site intumescent fire protection.

The competitiveness and size of the sector has led to increasing specialisation by fabricators. This can be specialisation by structure type (e.g. bridges, single-storey, multi-storey etc) or by procurement route (e.g. Design & Build or traditional). Increasingly, it is unlikely that a fabricator, who is not specialising in a particular work type, will be competitive when bidding against those who are working everyday on that type of project.

Design & Build

By ‘Design & Build’, I am referring to the structural design being carried out by the steel fabricator. These contracts have fixed lump-sum prices for the steelwork on the project, rather than the traditional cost per tonne for a bid using consulting engineer’s drawings. Because the term ‘fabricator’ is not appropriate for this type of work, in the UK the expression ‘steelwork contractor’ is now normally used, as this more accurately reflects the scope of work carried out under this type of contract.

There are a number of advantages in using this approach. The main benefit is that the design is usually more competitive: the steelwork contractor will only win an order if he/she has an excellent design, the design itself being a key part of the competitive offer. Additionally, the steelwork can be designed to suit the contractor’s production resources and the selection of steel sections can be optimised for price and availability.

IT integration

Steel is a major beneficiary of modern IT integration. High degrees of IT integration are possible with steelwork on traditional projects, but it is a greater challenge between different organisations because of the need to have compatible IT systems. It is therefore easier on Design & Build projects, as the design process and subsequent operations are all carried out by the in-house steelwork contractor.

The table above shows the sequencing of the integrated IT system at Barrett Steel Buildings. At each stage, information is added to the process, but no earlier information is re-input. This reduces the chances of errors, and of course speeds up the process, and reduces costs and time.

First we have the structural design program, CSC Fastrak™ – this is a 3D design package for all types of steel-framed buildings. Data is then passed through to the 3D drawing package, Tekla™ Structures. This program is used to build up all the steelwork details such as welded and bolted connections and secondary steelwork. The steel is divided into transportable loads (‘lots’) at this stage. Additionally the program automatically generates machine data files, known as DSTV files.
FabtrolT™ MRP is the program that we use to help plan fabrication in the workshop. It automatically routes steel to the appropriate machine, and allows us to batch and prioritise production. A ‘nesting’ suite allows steel to be allocated to the project, minimising material usage.

Data is then passed through the Steel Projects division where scribing information is added, before being downloaded into the CNC machinery in the workshop – in Barrett’s case this is predominantly FICEP™ machinery. The machine then makes the steelwork from the data passed from the 3D model – ensuring a very high degree of accuracy.

Two particularly hot topics in the UK currently are Occupational Health & Safety and Sustainability.

OH&S

One of the big drivers for OH&S is off-site manufacture, thereby minimising the amount of work done at height on site. Steel is a major beneficiary of this trend.

BSCA research shows that, compared with a concrete structure, a steel one uses approximately a fifth of the workers on-site to erect it.

Safe off-loading of vehicles is a particular area of focus at present. If a man is standing on the back of a loaded trailer, he will be up to 5 metres above the ground. Provision has to be made to ensure the safety of this operation. The preferred method is to use a telehandler to offload steel so that no-one is physically on top of the load. This is not always possible with city centre sites and complex pieces of steel. There are a number of alternatives, two of which are shown here. The first shows a man using the proprietary ‘Off-Load Safe’ system; the second shows a loading dock using air bags. Off-loading on sites without a solution similar to these is no longer acceptable with most major contractors.

A similar initiative in place today is called positive lifting. The traditional way to lift steel on-site is to wrap the lifting chain around the steel member and form a noose which ‘bites’ into the steel. Clearly there is a risk the steel may slip, and so now we have switched to ‘positive lifting’. This is lifting the steel from a suitable lifting point, either through purpose-made holes using a shackle or by adding a bracket specifically for lifting purposes. Additionally, there are a number of proprietary devices to achieve the same objective.
Sustainability

People have been talking about sustainability for years, but its impact on real construction was minimal. Suddenly, in the past 12 months, this has all changed. Real hard-nosed commercial reality is finally driving sustainability forward. In some cases property developers cannot get permission to build without demonstrating excellent sustainability performance of their project, to bodies such as the Mayor of London Sustainable Development Commission. In particular, the carbon footprint is of critical importance. Steel has a big advantage here; steel is the world’s most recycled material, so at the end of a building’s life you can safely assume it will nearly all be recycled. Recycling however still carries a carbon cost, as energy is used to re-melt the steel in the production process. Therefore, it is even better if steel is made more reusable. Barrett recently carried out a demonstration project near Heathrow Airport (Unit B, Prologis Park, 2006) where, by careful design, we achieved more than 70 per cent reusable steel. In this way the carbon footprint of a steel frame can be minimised.

Besides designing steelwork in a sustainable way, it is important to demonstrate that the supply chain is operating sustainably. The BCSA recently set up a Sustainability Charter that member companies can sign up to. To become a member of the charter, companies have to demonstrate compliance with 12 indicators, such as ISO9001 and an Ethical Trading policy. Accreditation is achieved through a third party audit.

Speed of construction

As in Australia, we are using fast-track construction, where various trades are following each other up or across the building, overlapping as they go through. With large capacities available at a number of fabricators, it is possible to put on site very substantial tonnages, up to a 1000 tonnes per week, if the need arises.

Steelwork contractors have considerable project management skills in-house. The old days of the main contractor preparing a construction program in isolation are no longer viable. The programme should be a joint effort between the main contractor, steelwork contractor and other major specialist contractors to optimise the building process. Working together in this way can be extremely effective.

Further benefit to the speed of construction can be achieved by integrating more items into the steelwork package. Increasingly steelwork contractors in the UK are offering ‘whole frame solutions’ – not only providing the structural steelwork, but also, for example, the metal decking and its associated concrete, or pre-cast floor planks complete with concrete grouting and screeding. Adding these items into one supply package is an effective way of improving co-ordination on site.

1.4.3 Cost and market share

The above factors have helped to reduce the cost of building in steel, and increased its competitiveness with other forms of construction, particularly concrete. Corus commissioned independent engineers and quantity surveyors to carry out a detailed design and costing exercise on a substantial commercial office building. One design was in steel, the other in concrete. Each year, over the past 10 years, the figures have been updated. In this way, we can see how the competitiveness of the two materials has changed over recent years.

The first graph shows the main raw material costs relative to inflation. Over the whole period the real cost of steel sections has dropped slightly, whilst the two main components in concrete, ready mix concrete and reinforcement bar, have risen by about 20 per cent.

The second graph builds in the full cost of the constructed component, in particular the on-site labour costs. The rise in real labour costs over time is offset to some extent by rises in labour productivity. Interestingly, the real cost of steel decking has declined by nearly 10 per cent. Most importantly for steel, the biggest improvement has been the cost of fire protection, which has fallen by 40 per cent over the past 10 years. Fire protection has now become quite easy and cheap to apply.

When these factors are all combined on the example building, the full extent of the improvement of steel’s competitiveness becomes clear.

The last graph shows the actual costs, the dotted lines indicating the inflation tracker over the same period. The steelwork cost has increased from around £80/m²
In the past 25 years, the UK has seen a major shift from concrete-framed buildings to steel-framed buildings. The final graph shows the full extent of the shift. It is apparent from the research that the two main framing materials, steelwork and concrete, are outstripping timber and masonry. The cross-over point was somewhere around 1985 when both methods had a 45 per cent market share, but now, if you are building a multi-storey building in the UK, it’s three and a half times more likely to be in steel than in concrete.

1.4.4 CONCLUSIONS

The table shows the current market shares for steel frames for various different types of construction (Corus). There is a very high market share in all non-residential categories, of between 68 per cent and 72 per cent. Even in Residential (multi-storey), a sector traditionally dominated by concrete construction, steel now has a respectable 26 per cent of the market. Apartment buildings represent a growth opportunity for steelwork.

<table>
<thead>
<tr>
<th>Sector</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>71.9</td>
</tr>
<tr>
<td>Retail</td>
<td>70</td>
</tr>
<tr>
<td>Leisure</td>
<td>70.1</td>
</tr>
<tr>
<td>Education</td>
<td>68.9</td>
</tr>
<tr>
<td>Health</td>
<td>68.3</td>
</tr>
<tr>
<td>Residential (multi-storey)</td>
<td>26</td>
</tr>
</tbody>
</table>
1.5 STEEL AND CONCRETE ALTERNATIVES

By Peter Thompson
For The Warren Centre

Investigations and decisions as to the material and methods to be utilised for the structural framing of a building are made and confirmed very early on in the design process. Consideration should ideally be given to steel framing in the investigation process but, in my experience, this is rarely the case.

It would be true to say that steel-framed construction is always considered at the high-rise end of the multi-storey scale and for substantial buildings where the advantages of steel relative to concrete, such as reductions in construction times and site workforce, may be anticipated. It is the run of the mill, low to mid-range buildings where steel is largely overlooked. Why is this so? There are, in my opinion, a number of reasons.

The Australian concrete industry right through from Codes of Practice, material capacity and construction techniques is very advanced in a technical sense and could be considered a world leader. It is relatively easy to prepare sketch designs in reinforced concrete and its affiliates, pre-stressed and pre-cast concrete. Designers in concrete have confidence their initial designs will have long-term credibility. Concrete frames have become the norm.

Structural engineers do not provide costs for the work they design. This is a disadvantage for design in steel as it keeps them at arms length from the fabrication and erection industry. A number of structural schemes may be prepared for a project and a steel solution may be among them. These schemes are costed by either the project quantity surveyor or the builder. Concrete schemes are readily costed using material data that is almost entirely transferable from project to project with preliminaries costed separately on an individual project basis. This may be done almost without reference to the supply chain.

This is not the case with steel as reference must be made to the supply chain. Estimates prepared on a cost per tonne of steel basis, sourced from previous projects, are not accurate. A more detailed input from the engineer, relative to concrete-based schemes, plus advice from fabricators and suppliers is necessary to arrive at competitive estimates for steel-framed construction. Connection design is vitally important to arriving at a competitive cost and preferred connections may vary from fabricator to fabricator. This process is more expensive and time consuming than estimating in concrete and something, unless specifically requested by the client, unlikely to be undertaken.

The structural designer’s main reference when designing in steel is the Safe Load Tables (readily available through the ASI). It would be assumed by the inexperienced designer that all steel sections shown in this book are readily available, which is not the case. Designs using “uncommon” sections will be penalised. The length of commonly available sections is also an unknown in most structural design offices.

There was a time when most components of steel frames were required to be encased with concrete of varying thickness in order to conform with fire regulations. Fortunately these days have passed, but there can remain the thought in the designer’s mind that steel must be protected by some means whereas concrete is fundamentally fireproof. Whilst the emergence of fire engineering utilising passive fire resistance techniques has lessened the need for fire protection of members it is still necessary and an expensive ‘add-on’ to the structural cost. There is still an element of the ‘unknown’ with fire engineering resulting in some engineers and estimators providing conservative estimates.

In his paper, Richard Barrett has shown that fire protection costs in the UK have fallen dramatically during the past decade. This has been due to the progressive reduction of ‘deemed to satisfy’ provisions in the local building codes and the extensive use made of intumescent paints for protection. It would appear that many fire engineers in Australia need to gain a better knowledge of contemporary practice for the fire protection of steel structures.

Approximately 15 per cent of a structural consultant’s fee is devoted to preliminary design when the decisions as to how the building is to be built are made. For small to medium-size buildings it is therefore economically prudent for the engineer to propose structural schemes which he knows may be accurately costed, rather than those which need working up from first principles and consume a disproportionate amount of the preliminary design fee. Reference to a fire engineer may also be necessary.

The situation would be improved by keeping the design community up to date with the information it needs to have at its fingertips to assess a steel structure with the same facility as a concrete one. This would include section availability, preferred connection types, fire protection and a rational costing method. To this end a
system should be introduced whereby fabricators, metal deck suppliers, stud welders, erectors, intumescent paint suppliers and applicators may provide information on a regular on-going basis to engineers, quantity surveyors and estimators. This matter will be addressed further in this report.

1.6 SUSTAINABILITY – OVERVIEW

By Sandy Longworth
For The Warren Centre

1.6.1 SUMMARY

The emerging significance of the sustainability credentials of all building materials in a variety of environmental performance rating systems brings focus to steel’s environmental sustainability characteristics. The extent to which this factor will play a role in the success of structural steel in the Australian multi-storey building sector was studied in the Leadership Issues Group under the chairmanship of Reg Hobbs, and has led to the recommendations discussed below.

The Green Star building rating system of the Green Building Council of Australia was early identified as a relevant factor influencing building proponents’ decision making and steel’s relatively poor ranking was noted. This prompted subsequent research, and discussion with local leaders and academics in the area of sustainability, as well as research within the Australian steel industry, competitor construction material industries and international research by reference to manufacturers’ web sites. It was concluded that, without a significant increase in the Steel – Framing the Future budget, it was beyond the scope of the project to effectively address the subject of sustainability with reference to structural steel in buildings. After extensive networking with key players in the field, it was agreed to present an overview of the Australian scene, with specific reference to the structural steel construction sector. This decision was in a sense inevitable, as the steel producers have not yet given an industry directive regarding sustainability, which would have made a more detailed consideration of the subject impossible in the time available.

A series of meetings took place with leaders in the Australian field and a number of written submissions were invited from interviewees to provide Steel – Framing the Future management with representative opinion on the subject.

During the latter part of the project, the steel producers, through the ASI, set up a Sustainability Committee to establish the environmental credentials for steel. At the time of report compilation, while a preliminary statement referring to the “Life Cycle Performance of Steel in the Built Environment” (Herbertson & Strezov 2006) has been published, there is yet to be a formal report issued by this committee.
The Steel – Framing the Future management has considered it appropriate to make some recommendations, with reference to ongoing work in this field, in order to provide decision makers with a more succinct statement regarding the structural steel construction medium in the context of the life cycle of a building.

1.6.2 BACKGROUND

Sustainability generated early comment and debate within the Leadership Group workshop sessions. It was concluded that the pace of change in the adoption of various Green Building rating systems had accelerated. The Property Council of Australia (PCA), which publishes standards observed by property investors and tenants for grading of office buildings, deems four-star and 4.5-star GBCA ratings as requirements for Premium and Grade A office buildings. Major tenants including government instrumentalities are now specifying levels of green ratings in leasing contracts.

The Leadership Group, which comprised very wide representation from the construction industry, devoted considerable time to the rating system of GBCA, which is considered to be the best-known Australian accreditation body. It was concluded that the rating system was complex, subjective and not based on flow-through logic. With particular reference to the points system, it appears that the concrete industry has established for itself a more favourable rating treatment than the Australian steel industry.

While there is a great deal of accurate technical information available relating to steel’s sustainability and recycling, it does not appear to be well presented to government and users.

As a result of the work of the Leadership Group, contact was initiated with the GBCA’s chief executive Romilly Madew and director Che Wall, international consultant Nigel Howard, Melbourne University’s Professor of Sustainable Technology, Markus Reuter, and the RMIT School of Design’s Sustainable Materials Program Manager Andrew Walker-Morison.

1.6.3 NETWORKING

It was apparent from discussions undertaken during the networking phase that there were different models and methods being adopted for sustainability ratings. This is to be expected given the number of organisations offering accreditation and auditing services.

Concerns over the GBCA rating system were somewhat allayed after Mr Walker-Morison revealed that RMIT’s Centre for Design, with support from the GBCA, CRC for Construction Innovation and various Victorian State bodies, was developing a Building Assemblies Materials Scorecard (BAMS) which involves the development of a Life Cycle Assessment (LCA) scoring methodology. There did appear to be a scientifically based plan driving this project which has the potential to bring a semblance of uniformity into any LCA assessment outcomes. A report by Mr Walker-Morison and Dr Ralph Horne (Walker-Morison & Horne 2006) has since been issued addressing sustainability and the construction industry with particular reference to BAMS, which remains in the project planning stage. The report, while not providing any detailed methodology for LCA does provide a detailed schedule of international sustainability rating and accreditation bodies. RMIT under Mr Walker-Morison also submitted a brief status report following The Warren Centre’s meeting with him (Appendix A9).

An informative discussion session was held in October 2006 with BRE UK’s former director of sustainable construction, Nigel Howard. Before taking up his current role in Australia with building consultants BRANZ, Mr Howard was vice-president of the US Green Building Council where he was responsible for the development of the LEED (Leadership in Energy and Environmental Design) program. While Mr Howard has an in-depth knowledge of sustainability issues in the Australian building industry, discussions with him were confined, in the main, to the status of developments in the UK and US. Mr Howard was contracted to prepare a short position paper to introduce outside ideas on the subject and provide some counsel in formulating recommendations for ongoing work by steel producers (Howard 2006).

Mr Howard stressed the need to establish nationally, a consistent methodology for LCA. He also felt, from his knowledge of GBCA’s assessment methods, that materials impacts were not thoroughly assessed, particularly with reference to recycled content.

The meeting with Mr Wall, who is also Chairman of the World Green Building Council, was helpful but indicated a need for better understanding and dialogue on the subject of recycled steel. Steel is globally the most recycled construction material in use, there being 75 per cent (Strezov & Scaife 2004) recycled with the amount rising. The GBCA’s view is that credits will only be available if steel specified for a job is recycled. This policy fails to recognise the international performance of the industry and the incentive to further increase the recycled content and benefit global
emissions generally. Global warming is not an isolated phenomenon. All cars are now recycled even though the scrap from vehicles in the country of manufacture rarely remains in that country for re-working and potential sustainability credits.

Mr Wall’s advice to the Steel – Framing the Future team was that steel was a versatile material, adaptable to large spans and novel space creation. He was also quite enthusiastic about the “chilled beam” concept (a system of passing chilled water through fabricated beams for climate control), having adopted this on a number of current jobs. The system impacts on LCA favourably.

The final meeting in this series was held with Professor Reuter. While this meeting was not of direct relevance to the sustainability of steel structures it served to place steel in the context of the completed building product and the building LCA picture. Professor Reuter, a metallurgist and expert on recycling and the motor industry, expressed the view that there were similar principles applicable to both industries. There will be more common interest emerging given the trend to pre-fabrication in the building industry and the inter-relation of components to one another and in particular the steel frame.

A key feature of modern sustainable construction is design for disassembly of the product and the efficient separation of the recycled component materials. Comparison of post-stressed concrete and composite steel structures from the demolition/disassembly/reuse operations has relevance to the LCA of these two construction media and should be considered in any ongoing assessment of steel’s sustainability. It was felt, given Professor Reuter’s broad knowledge of industry, that his input to the assessment of steel’s sustainability in the building construction industry would be worthy of consideration.

1.6.4 CURRENT POSITION

The ASI has recently co-ordinated the establishment of a Sustainability Committee to establish and promote the environmental credentials of steel. This committee will be the contact point with government, the construction industry and steel users generally and was initially set up to respond to the Australian Government’s Department of Environment Science & Training Scoping Study which was undertaken by the CSIRO and RMIT in 2006.

Its aim will be to bring together the ASI’s agreed and verified sustainability data as well as relevant international information. Using this, it intends to become an active participant in the work of the various bodies developing rating and eco-labelling systems to ensure that steel’s credentials are fully taken into account.

Its further aim is to establish and promote the ASI as the recognised source of steel sustainability information for the construction and other industries, government and the public.

1.6.5 RECOMMENDATIONS

The work of the ASI Sustainability Committee is to be strongly encouraged.

The current focus on embodied energy as a main criteria for evaluating the environmental performance of buildings needs to be broadened so that recycling, reuse, disassembly, future modification and other factors which come into play during a building’s life expectancy are given proper weighting.

Much of the steel sustainability discussion has centred on the recyclability of steel, but the emerging debate on greenhouse gas emissions and carbon trading indicates the steel industry will need to develop a long-term defensible position on this issue if structural steel is going to succeed in multi-storey construction in Australia.

Many misconceptions about steel sustainability arise from the oversimplification found in many of the models developed by international steel producers to argue sustainability. The steel industry will have to take on board that the steel case is not simple and will have therefore to undertake a considerable education/promotion campaign to explain its position to the many participants in the construction industry.

While the steel industry’s Sustainability Committee is considering usage of steel in the overall national context, it is felt, with reference to structural steel in buildings in general and composite multi-storey structures in particular, that its work should consider:

- the adaptability of steel structures
- encouraging the design of multi-storey composite buildings, with or without modification for significantly longer lives than the initial usage phase
- LCA being assessed in the context of structure life
- stressing steel’s position as the most recycled construction material and addressing the need to better manage recycling on a regional basis
- design for de-construction and re-use or recycling, cf de-constructed composite structures versus post-stressed concrete
• applying the steel industry’s extensive data base to LCA for composite steel buildings along the lines adopted by the Australian CRC for Construction Innovation (Sustainability and the Building Code of Australia, 2003a, 2003b), whereby data from 3D CAD modelling (BIM) is collated to systematically assess the LCA weighting of the framing system compared to entire building.

REFERENCES


Herbertson J & Strezov L 2006 Life Cycle Performance of Steel in the Built Environment, compiled for ASI.

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2.0 RECOMMENDATIONS

By David Ansley
Ansley & Associates for The Warren Centre

2.1 INTRODUCTION

The Framing the Future project set out to uncover the reasons for Australia's relatively low use of steel framing in multi-storey buildings when compared with other developed nations. In Australia there is currently approximately 13 per cent of the multi-storey building construction framed in steel composite construction compared with 70 per cent in the UK, 50 per cent in the US and 40 per cent in NZ.

The Warren Centre's reason for undertaking the project was a grave concern that this low use of steel is leading to an erosion of capability in an area where the skill levels and technology associated with this industry are important for Australia's economy and international competitiveness. If the multi-storey building construction industry could be more efficient through greater use of more efficient steel-framing construction, the entire Australian economy would benefit.

Based on initial investigation the project proponents anticipated that much of the disparity could result from failings in the structural steel fabrication and construction value chain, as opposed to the popular view that steel is just more expensive than concrete.

After working for more than 2.5 years with some 50 industry participants from across the value chain and with experience in Australia and other countries that have much more robust steel-framing industries (see methodology section 5.0), the Framing the Future Steering Committee has concluded that, with infusion of technology and strong, entrepreneurial leadership, there is substantial scope for a resurgence in the steel multi-storey sector.

The committee has distilled three key recommendations.

The steel fabrication and construction value chain participants in Australia must:

1. be able to put forward a compelling value proposition for steel framing to their customers (developers and builders) to avoid the default concrete solution being adopted.

2. improve their capability to deliver efficiently and effectively to capture the advantages of steel framing in multi-storey buildings, thus enhancing the incentive for architects, engineers, builders/developers to promote/choose steel framing and take the associated risk.

3. continue to support the Australian Steel Institute's current programs addressing key marketing, technical, sustainability and fire protection issues to improve the relative value proposition of steel framing.

A number of entrepreneurial enterprises have already made changes along the lines recommended. Sebastian Engineering has participated with Lysaght Design & Construction in a number of significant projects using this model. Alfasi in Melbourne has been providing a prime contractor role for many years while Epic Steel in Queensland is setting up a business model to provide a more comprehensive service to the builder, and there are others joining the fray. However, it will require significant change by hundreds of value chain participants to have a major impact on steel framing's market share.

Some of this change must come from the commercial activities, and potential willingness to share insights, of the first mover entrepreneurs (Key Leaders), while other, more ‘environmental’ improvements are best suited to well-targeted industry association initiatives. The Australian Steel Institute, a major contributor to the Framing the Future project, has already instituted several initiatives that align well with many of the recommendations. Many of the implementation suggestions involve extensions of the ASI's activities, expected to be sponsored by their Steel in Buildings Marketing Committee and Steel in Buildings Fabricator Group. The implementation suggestions focus on the additional actions required, rather than describing things already underway.

Ultimately, those value chain participants with the most to gain or lose are expected to drive the focus and level of activity of any collaborative initiatives. Based on experience in other countries and other industry groups, this may result in the formation of new, independent associations over time.

The recommendations are described so that the intent of each action can be understood, but without presuming that the Steering Committee has the
ability or authority to define their scope and plan their execution, which in our view should be directed by those who take on the responsibility of delivering the results. Similarly, implementation suggestions are provided – ultimately it will be up to the individuals and organisations involved to decide if, by whom and how the recommendations are followed.

The recommendations and suggested implementation approaches are explained in more detail below.

### 2.2 RECOMMENDATIONS

#### 2.2.1 BE ABLE TO PUT FORWARD A COMPPELLING VALUE PROPOSITION

It is clear from the project that this failure is a fundamental barrier to increasing the market share of steel framing in multi-storey buildings. Unless the value chain participants have the capability to present compelling value propositions to their customers, steel framing will be chosen only for those relatively few building projects where it is a more obvious choice (due to architectural, construction timing, or other individual criteria). Currently there are few members of the value chain with the required experience and capability to present a convincing value proposition.

The Management Committee believes there are four actions required to overcome this failure:

a. **Provide robust cost and time information**

Collect and make available to decision makers on a regular basis, appropriately detailed data from a wide range of projects and present robust analysis of steel-frame construction projects to overcome traditional industry perceptions that steel costs more than concrete and involves higher risk. Greater price and time transparency in the market for multi-storey building construction will help to overcome traditional risk perceptions associated with steel framing.

This supporting information should address key builder and developer concerns including:

- The need to be more conservative when costing steel-frame solutions.
- Steel price variance during the project.
- The high cost of variations (often resulting from design development after tenders for fabrication have been let) compared with concrete which can be changed at short notice, provided the concrete has not yet been poured.

b. **Introduce new collaboration models**

Adopt new collaboration models that overcome the up-front cost and difficulty involved in estimating the cost of a reasonable steel-frame solution.

If a steel-frame option is to be considered, the current accepted practice is for an engineer to prepare preliminary designs for both concrete and steel-framing systems and to rely on a quantity surveyor or building estimator to prepare framing prices for comparison. Experience has show that, unless the engineer, quantity surveyor/estimator and project manager are experienced in steel-frame construction and an experienced fabricator is involved to confirm the practicality of the design and provide estimating data, experience has shown the design, construction programming and estimating is conservative, resulting more times than not in the steel option being discarded.

- The potential for delays due to fabrication errors and/or required design changes.

**Suggested implementation**

The ASI is already active in developing case studies of successful steel-framed building projects, disseminating them to members and using them to support marketing activities with members. The ASI is also undertaking a project to widely disseminate this information, and the conclusions and recommendations of the Framing the Future project, via a series of seminars. ICIP Project #3 (funded partly by a Federal Government ICIP grant, in conjunction with Rider Hunt) is tasked with producing a representative comparative cost estimate of a standard building framed in concrete and in steel. It is suggested the cost estimate and models should be updated every two years.

However, there is a need for more regular and rigorous reporting of:

- a) actual prices paid for steel sections and plate, fabrication and erected steel frames (including the cost of variations and delays);
- b) the availability of steel sections and actual time to deliver data;
- c) the actual time taken to fabricate and erect steel-framed structures.

The ASI has indicated it would be willing to sponsor and arrange funding for an independent provider to collect and report this information publicly. Based on experience during the Steel – Framing the Future project, builders, engineers and quantity surveyors appear willing to provide actual project data on a confidential basis provided resulting reports don’t allow the individual projects and companies to be identified. Dissemination of current in-situ cost information for various framing elements could be by way of the ASI website and selected publications.
Suggested implementation

The ASI is already active in developing case studies of successful steel-framed building projects, disseminating the publicly available information to members and using them to support marketing activities with members. Unfortunately these case studies do not provide any costing information.

However, much of the innovation in collaboration models for efficient steel-frame estimation is considered confidential by the entrepreneurial organisations leading this innovation. It will be up to these Key Leaders whether they share confidential information such as the roles of each collaboration participant and how they interact, the cost and risk they each carry, and the reward terms for each of them. Many Key Leaders will choose to keep the information confidential for their own commercial benefit, so that dissemination occurs slowly through the future commercial activities of the individuals and enterprises that collaborate with them. Other Key Leaders may see a benefit in enlightening others, so that there is wider adoption of new collaboration models. This in turn will lead to greater acceptance among builders and developers and increased capability to deliver among engineers, detailers, fabricators and erectors, thereby facilitating the attraction of newcomers to the industry and enhancing builders’ and developers’ confidence in steel framing.

c. Form new ‘solution provider’ contracting models

Adopt new contracting models that address builders’ and developers’ desire to avoid the responsibility and risk of managing the less familiar steel-frame value chain during design, fabrication and construction.

Steel-frame solution suppliers have not been active in the Australian multi-storey sector – in stark contrast to the UK where ‘steelwork contractors’ offer total steel-frame solutions, including metal decking and concreting with a single point of responsibility. Also, this situation contrasts with the very successful post-tensioned concrete solution providers in Australia.

Since the commencement of the project there has been some change in the situation with Lysaght Design & Construct adopting the role of ‘steelwork contractor’ for Multiplex Constructions (the builder) on the Latitude East project in Sydney.

Suggested implementation

The implementation issues are virtually the same as for action b. The ASI’s activities spread the word about such contracting models, but are limited to non-confidential information.

However, much of the innovation in contracting models for delivery of steel-frame structures is considered confidential by the entrepreneurial organisations leading this innovation. Again, the choice to share confidential information will be up to Key Leaders (refer to suggested implementation in action b). Where available, the information on innovation and contracting models should appear not only in Steel Australia but selected business media.

d. Encourage new entrants to build ‘critical mass’

In general builders and developers are not comfortable with the limited range and small scale of potential steel-frame fabricators underpinning steel-framing solution offerings. Therefore, the Management Committee considers it important that new entrants be encouraged into the steelwork contractor sector.

Suggested implementation

The ASI has indicated it will encourage new entrants to the steel contractor model through its Steel in Buildings Fabricator Group. Again, however the ASI is limited to using non-confidential information to inform and entice potential new entrants.

The most influential recruiters of new entrants would be those Key Leaders who have gained real project experience through their own entrepreneurial activities. These Key Leaders may decide the advantages of greater credibility and capability to deliver on the steel contractor value proposition outweigh the competitive advantage of restricting such capability to themselves and their commercial partners. A robust and competitive steel contractor sector will unquestionably attract more business and even position some players for export.
2.2.2 IMPROVE THE CAPABILITY TO DELIVER EFFICIENTLY AND EFFECTIVELY

The steel fabrication and construction value chain in Australia is not well positioned to deliver efficiently and effectively to capture the advantages of steel framing in multi-storey buildings. This reduces the incentive for architects, engineers, builders/developers to promote/choose steel framing and take the associated risks.

Each step along the path to more efficient and effective delivery of steel-framing solutions will improve the value proposition to customers, setting up a virtuous cycle of raising margins, reducing costs and increasing market share, thus attracting more investment to improve the value chain efficiency and effectiveness.

The Management Committee believes there are four actions required to improve the efficiency and effectiveness of steel-framing delivery:

a. Adopt more collaborative contractual arrangements
   The traditional “hard money” contracts used in the industry lead to each participant attempting to optimise his/her financial outcome in the common event of a need for a design change or opportunity to make a design improvement. This behaviour often creates barriers to optimising the whole project and best meeting the needs of the ultimate customer (developer or tenant). In addition the resulting commercial tension does not enhance relationships, does little to foster collaboration and often leads to protracted expensive court battles. More collaborative contractual arrangements between builder, engineer, detailer, fabricator, erector and others could reduce these barriers, resulting in lower total cost and faster total construction time, while best meeting the ultimate customer’s needs.

Suggested implementation

The ASI is already active in developing case studies of successful steel-framed building projects, disseminating them to members and using them to support marketing activities with members. The ASI is also undertaking a project to widely disseminate this information, and the conclusions and recommendations of the Framing the Future project, via a series of seminars. These ASI activities are likely to encourage some value chain participants to experiment with more collaborative contractual arrangements.

The most effective change agents for collaborative contractual arrangements, however, would be the Key Leaders who have gained practical experience through their own entrepreneurial activities. These Key Leaders may decide the advantages of greater credibility and familiarity with such contracts outweigh the competitive advantage of restricting such confidential information to themselves and their commercial partners.

b. Adopt cross value chain documentation technology and processes
   There is limited use of proven 3D modelling and document publication/sharing technology and processes along the value chain from concept design through to structural design, detailing, fabrication, delivery and erection (there are ‘point solutions’ in use by individual value chain players, but few cases where more than two participants work on a common or integrated platform). Full Building Information Modelling (BIM) is not known to have been used in Australia but is a system that will ultimately benefit the steel solution, particularly on large complex projects.

   A study by Engineers Australia (2005) estimated that poor documentation, in particular, professional responsibility for dimensioning, typically adds 5–10 per cent to the cost of a project.

   Value chain participants need to work together to establish standards and protocols for advanced documentation technology and processes to build shared understanding and avoid fragmentation as individual enterprises invest in these initiatives.

Suggested implementation

This action would affect how all multi-storey building design and construction is delivered, no matter what framing material is used. Therefore to gain agreement on standards will require the involvement and commitment of a majority of participants throughout the building design and construction value chain. While the ASI has stated it will support this recommended action, and is encouraging greater use of ICT in steel design and construction via its ICIP Project #2 it is not well placed to lead participants who are not involved in steel construction (the majority).

The CRC for Construction Innovation is conducting research in this area through its Program C – Delivery and Management of Built Assets.

Again, however, it is likely the Key Leaders will have a significant impact on the success of initiatives to establish common processes and protocols. They are the ones who are best able to recognise the potential
benefits of such initiatives and to influence others to adopt them on their projects and through outsourcing, as well as their involvement in the ASI’s Steel in Buildings Fabricators Group.

c. **Invest in key fabrication process and technology improvements**

Although there is some evidence of recent investment, Australia’s steel fabricators have typically not invested in the automated equipment and business process optimisation to the degree that has enabled UK fabricators to reduce their shop labour costs by up to 80 per cent, levels well below the best in Australia.

**Suggested implementation**

The ASI currently conducts a range of activities to increase awareness of process and technology options for its members including international visits to best practice fabricators, presentations by leading fabricators, and providing contacts to relevant consultants and advisors.

A key element in convincing a fabricator to invest in process and technology improvements is gaining confidence in the commercial return they will generate (amount and timing). The ASI has indicated it would support the development of appropriate template ‘business case’ methodologies, informing and educating fabricators, publishing data on application of automation with cost information and identifying methods of obtaining robust cost and benefit estimating tools and data.

d. **Provide information to encourage change**

Many industry participants are not confident to make investments to improve delivery capability or take the risk to challenge traditional industry practices, often because they do not recognise the potential rewards.

By providing robust information about the potential cost and time available across the building value chain, individual enterprises will be better placed to match the rewards with the risks.

Informing value chain participants widely about the actual successes (and hurdles) resulting from innovative approaches will encourage them to be receptive to investing in such approaches. The Lysaght Design & Construct approach on the Latitude East project is a candidate to report on.

**Suggested implementation**

As noted previously, the ASI currently conducts a range of activities to increase awareness of innovative process, technology, collaboration and contractual options for its members. However, due to a lack of transparency of actual costs and prices throughout the value chain and limited use of relevant supply chain measures in the industry, it is often very difficult for individual enterprises to understand the potential value of such options, and even more difficult to demonstrate a business case to potential partners that would be required to achieve the identified gains.

There is an opportunity to collect and report regular, robust supply chain measures from across the value chain, including drivers and their impact on prices, timing and margins achieved at different stages of the value chain. The ASI has indicated it would be willing to sponsor and arrange funding for an appropriately skilled independent provider to collect and report this information publicly. Based on experience during the Steel – Framing the Future project, builders appear willing to provide actual project data on a confidential basis provided resulting reports don’t allow the individual projects and companies to be identified. The ability to collect information from other value chain participants is yet to be tested.

2.2.3 **CONTINUE SUPPORT FOR THE ASI’S PROGRAMS ADDRESSING KEY MARKETING, TECHNICAL AND SUSTAINABILITY ISSUES**

Steel framing suffers a number of disadvantages resulting from lack of information and its credible dissemination to key parties in the value chain.

The Management Committee believes there are a number of actions required to improve this situation:

a. **Communicate sustainability advantages**

- improve the understanding and communication of steel’s environmental sustainability benefits, including:
  - steel’s adaptability, and high order of recyclability
  - versatility for refurbishment resulting in longer life buildings, with asset preservation, resale value and low carbon footprints.
Suggested implementation

The ASI has recently established a Sustainability Committee to pursue this action. Andrew Marjoribanks, a key contributor to the Framing the Future project, has been appointed as chair.

b. Reduce perceived fire-engineering hurdles

Improve the understanding of fire-engineering implications (options and costs) for steel framing across the value chain, and seek improvements in regulations to reduce uncertainty.

Suggested implementation

The ASI has recently formed a task team to pursue this action.

Input from fabricated steel supply chain participants is expected to greatly assist in identifying and promoting the most commercially attractive approaches to fire protection methods.

c. Upgrade steel design capability

Many engineering consulting firms have limited experience and skill in designing efficient steel-frame structures (particularly smaller firms that are often engaged for low- to mid-rise commercial structures, where a significant market exists).

Furthermore as Peter Thompson, a project Visiting Fellow says, “These engineers are more comfortable with concrete as are their clients”.

Recommended focus areas include:

- Short-term measures to improve engineers’ design capabilities including design aids and information services.
- Longer-term initiatives to attract young people into the profession and to maintain and progress the teaching and advancement in steel design at the tertiary education level.

Suggested implementation

The ASI has been pursuing this action for many years. Further refinement and a greater focus on the short-term measures via the ASI is suggested.

d. Continue marketing activities

Promoting the use of structural steel in building will continue to be critical to market success and all parts of the value chain should continue to support ASI’s promotional work. Publication of case studies, holding of seminars, organising international conferences and study tours, bringing together interest groups and representing the industry in a variety of forums are all activities that strongly support steel’s value proposition.

Suggested implementation

The ASI has been pursuing this action for many years – ongoing support for and enhancement of these activities is suggested.

REFERENCES

3.0  ISSUES GROUP SUMMARIES

3.1  LEADERSHIP

By Reg Hobbs
Flagstaff Consulting Group for The Warren Centre

3.1.1  TERMS OF REFERENCE

Risk Management

Considering the industry leadership necessary to develop solutions to satisfy the realistic contractual and risk management needs of a client base that is increasingly reliant on private sector finance (banks, mezzanine financiers, equity markets and super funds dictating terms) for private sector developments and government works (Public Private Partnerships, office leases etc).

Sustainability

Considering the industry leadership necessary to respond to increasing demand by all types of clients for sustainability in design and materials use – noting that steel may not be perceived as offering the best solutions at the present time.

Changing perceptions

Considering whether steel industry leadership should begin promoting best use of the combined advantages of steel and concrete rather than the old steel versus concrete mindset.

Education

Considering how the steel industry may foster new initiatives to enhance education of architects, engineers, para-professionals and others to gain the earliest possible familiarity and comfort with the uses, applications and technology of steel as an everyday construction material.

Safety

Considering whether there is a need for greater leadership in temporary works design and responding to recent and future changes in Occupational Health & Safety (OH&S) legislation affecting use of steel.

3.1.2  DISCUSSION

Time and resources did not permit consideration of the education issue in any detail, however it is considered to be an important matter for the steel industry to consider further and is worthy of development of long-term strategies.

The issue of sustainability generated a significant amount of discussion. The most important task for the group was to form a view on whether it was an issue that had real potential to affect the adoption of steel for building framing. The group concluded it is a major issue and that the pace of change in adoption of the various ‘green building’ rating systems in Australia by government, property investors and commercial developers has been very significant during the past two years.

The need to focus on leveraging the best features of steel and concrete in a building design and not continuing the eternal steel versus concrete debate was quickly and unanimously agreed upon by the group.

A workshop, held in Melbourne, with construction industry leaders from the government, finance, developer and legal sectors gave great insight into influences on the decision-making process used by developers, building owners, financiers and tenants. A salient example was that developers do not care whether a building is framed using steel or concrete; what they want is a solution that minimises construction time across all trades (not just the frame), is more economical to construct, will achieve ‘Green Star’ ratings or other environmental criteria and is a flexible asset that ensures a high return on investment. Also noted were current trends for the government sector to use outcome-based contracts to procure accommodation in buildings, under a variety of innovative procurement models, which demand high standards of functional performance, environmental sustainability and life cycles.

The workshop also produced some strident feedback for the steel sector in relation to the level of resistance to the use of steel framing expressed by a number of leading Victorian building industry executives and one of the lawyer participants during his research prior to the workshop.
Somewhat inclusive waste discussion of the issues involved with skill levels in temporary works design and limited discussion of aspects of engineering education and development. Some areas of concern were noted, however no obvious means of addressing these could be formulated in the limited time available for this study.

Some surprising outcomes of the meeting with leading consultant engineers, Russell Keays and Emil Zyhajlo, were the observations of the latter after his recent three-month assignment in the UK.

Mr Zyhajlo suggested that one of the reasons that steel framing is more prevalent in the UK may be that British concrete design and construction techniques are significantly less developed than in Australia and other countries. He presented a number of specific examples of pre-stressing design issues, outdated approaches to formwork, limited use of high-performance concretes (prevalent in Australia for more than 20 years) and industry mindsets regarding costing, which indicated that his view had significant merit. In many respects what is “state of the art” in UK concrete frame construction is 10 or more years behind Australia. It is possible then that over the next 10 years the market share for concrete in the UK may grow and the relative usage of steel framing may fall1.

The key question raised at meetings was where the leadership will come from to address the issues that so clearly affect the use of steel in buildings. In every case the issues group concluded it was not reasonable to expect the major steel manufacturers to be the sole leaders or to simply provide increased funds for industry development and reform, rather leadership and change must come from all levels of the sector.

The Group also discussed whether the steel sector could develop a larger market share in the low rise and typical suburban commercial market and noted this type of structure should be ideal in steel framing as the upper level and roof of a typical suburban office building is already usually steel framed. It was suggested engineers who typically design the structures of such buildings might have inhibitions about using steel because they do not enjoy the benefit of adequate composite design standards. Many will not be prepared to develop designs involving composite details or moment continuity where there is not an explicit standard for building regulation compliance and liability reasons.

Appendix A3 to this report presents a fairly uncompromising discussion of issues arising from the manner in which the steel construction sector presents itself to the potential specifier and client base noting how there appears to be a significant mismatch of expectations by both.

It is considered important to put these positions as there are no indications of the “take up” of steel framing for office buildings improving, particularly in the Melbourne market. When the Leadership Group began its deliberations there were two major steel-framed buildings under construction in Melbourne, both the subject of case studies by The Warren Centre and reported as being “state of the art” examples. In the 12 months since, a significant number of major office buildings2 have started construction in Melbourne or are now being designed. Most of these buildings have not adopted steel framing and it is unlikely there will be any, even those being constructed by the builder, Multiplex Constructions, who adopted steel for the buildings that were the subject of the case studies.

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1 Formwork for post-tensioned (PT) concrete construction is not overly complex either, and reinforcing steel and cable assemblies also bear relatively fixed ratios to concrete volume for specific types of structures.

2 The Cbus Property development in Bourke Street, the AXA Building at Docklands, the Ericsson building at Docklands, Waterfront City Docklands (mixed use), 399 Bourke Street (mixed use) and, it appears, the very large ANZ headquarters are most likely to be concrete framed.
3.2 VALUE CHAIN

By Aruna Pavithran
Lucis Pty Ltd for The Warren Centre

3.2.1 OBJECTIVE

As mentioned in Section 1, steel-framed construction has a much lower share of the multi-storey construction market in Australia than it does in the US or UK. This assessment was conducted to better understand the steel-framed construction value chain for medium-rise commercial buildings in Australia and where there might be opportunities to improve it. The medium-rise market was selected by the Steering Committee as a sizeable market with good potential for growth in steel usage.

3.2.2 METHODOLOGY

A case study approach was adopted to produce an empirical and factual analysis, in the style of an internal benchmarking analysis. The quantitative analysis for the assessment was conducted in three parts – cost, time and risk – to determine how each of these impinged on the efficiency and effectiveness of the value chain.

The sample assessed comprised four steel-framed buildings and one concrete-framed building, as discussed in detail in section 4.3.

3.2.3 FINDINGS

The analysis of this sample showed no systematic effect in the use of a structural steel frame on overall construction outcomes when compared to a similar concrete-framed building. The case studies show a range of steel-framed construction outcomes, some that are more cost- and time-effective relative to concrete, some that are similar and some less. The findings contradict a fundamental perception held in the market that steel framing is consistently more expensive and difficult to implement.

Cost

Three of four steel-framed cases studied were less expensive per square metre of Gross Floor Area (GFA) than the concrete comparison. Where steel was less expensive, detailed cost analysis showed that structural steel added 6–13 per cent of Total Construction Cost to the relative cost of a frame, and saved 7–12 per cent of Total Construction Cost in preliminaries and wages compared with the concrete case study, summing to little or no effect on relative cost in each case. This suggests that the additional costs in steel framing are saved in people-related site costs.

Time

Analysis of construction time showed no observable relationship between the use of steel or concrete framing and the time efficiency of construction. It also showed that the use of techniques such as the ‘jump-start’ do not always result in a comparatively faster time to completion. With consistent affirmation from project managers of the speed of steel-frame erection and jump-starts, this suggests that the benefits of these strategies are not fully realised in practice.

Risk

Issues considered to be common difficulties in the use of structural steel, such as long lead times, had no observable impact on the value chain. Of the realised risks observed in the case studies, the greatest source of ‘normal’ risk in the construction value chain is in the way the builder chooses to program erection. This is referred to in this report as Building Proposition Risk, and encompasses builder competencies such as the sequencing of tasks, the use of process innovations and the choice of suppliers. Of the proportion of these risks attributed to the accuracy and reliability of the steel supply chain, perceived risks were much greater than actual risks realised.

Other findings

As well as these findings, various characteristics contributing to the performance of the construction value chain were noted. First, not one of the cases observed was finished on the original completion date, showing a remarkable tolerance for unpredictability in timeliness in construction in Australia. This tolerance extends to variations, where steel framing is considered unviable due to its unresponsive supply chain. In fact, only ‘structural variations’, such as adding a stairway, are more difficult with steel framing, whilst other variations that are unviable in concrete are achievable in steel.

The case studies also showed that builders create contingencies in construction budgets by up to 5 per cent of total, to allow for possible additional or unforeseen costs that cannot be recouped under a typical fixed price contract. Any difference between these contingencies and the final cost overrun effectively constitutes a ‘builder’s reward’ over and above the imputed profit margin of 4-6 per cent (in these case studies). Interfacing between steel and other construction activities arose as an area of difficulty, and estimation does not favour innovation in construction processes or materials.
3.2.4 CONCLUSIONS

The opportunities identified in the construction value chain are founded on reducing the risk burden to the builder and releasing the contingencies held in construction budgets. The first of these opportunities is repackaging the construction process into risk-minimising components. This strategy involves placing the risk where the skills exist to best handle it (e.g. making riggers/fabricators responsible for interfacing steel columns with the slab) and may not work where dramatic variations or highly aggressive timeframes will be tolerated. Using web-enabled collaborative planning will create a more transparent information environment and aid the seamless collaboration required to reduce the builder’s risk burden. Finally, the measures currently used to gauge construction performance, e.g. floor cycle time, are not always directly related to value chain outcomes. Industry-wide measurement for performance is strongly recommended to create more visibility and focus on value chain performance.

For the steel industry, a focus on creating a highly responsive supply chain for structural steel will reduce the perceived and actual risk in steel supply. In this context, the responsiveness required is the swift delivery and installation of the correct product to site where a ‘structural variation’ is incurred. Addressing this aspect of the supply chain will improve the overall performance of steel supply in construction.

But, why change? The issues affecting value chain performance identified in this assessment of five case studies are largely known and tolerated across the industry, at an estimated cost of up to 5 per cent of turnover (i.e. up to $3 billion of the $57 billion commercial construction industry). The true opportunity forgone in this status quo is effective process innovation and the opportunity to reallocate productive resources, at an incalculable cost to the Australian industry. Ultimately, it is up to the leaders of industry to decide in favour of transformational change.

A more extensive study, assessing a larger number and spread of buildings, is recommended to validate the findings in this report.

3.3 COSTING

By Andrew Marjoribanks
Venlaw Park Pty Ltd for The Warren Centre

3.3.1 BACKGROUND

The costing of steelwork for construction is heavily influenced by design requirements so that there can be large variations in cost between different designs for the same building, and between one building and another. Designs calling for many complicated connections, for instance, are much more expensive than those needing a minimal number of simple connections. In the current Australian construction industry environment where steelwork costing is simplistically expressed in terms of dollars per tonne, a complicated design can be as much as twice the dollar rate per tonne of a simple design, causing frustration to would-be users of steel and leading to the perception that steelwork pricing varies irrationally, and consequently the perception that using steel carries a high cost risk.

The Costing Group of the Steel – Framing the Future project therefore examined the factors involved in the process of costing fabricated steelwork for construction, and reviewed developments that will improve this process and lead to more cost-competitive designs and solutions in steel.

3.3.2 THE CONCRETE FACTOR

Concrete is the dominant material in the Australian construction industry, having about 87 per cent of the market. (Until two years ago it was even higher, around 95 per cent.) Consequently builders, designers and quantity surveyors have great familiarity with concrete and understand its costing very well. In addition concrete designs are less sensitive to complexity in that the main variable is formwork which can be constructed to give a variety of shapes without necessarily requiring large increases in labour costs. Concrete itself and its attendant reinforcing steel is reasonably standard in cost and the ratio of steel to concrete well understood so that cost-estimating for a project is comparatively simple. Quantity surveyors are therefore able to give reliable cost estimates at the inception of a project and even if all of the design has not been finalised, can be reasonably sure of their ground, given that whatever the final configuration happens to be, the quantity of concrete plus reinforcing is unlikely to vary dramatically. Even if it does, estimating the cost of the final design and any variations that occur is largely a calculation based on the volume of concrete plus the reinforcing. The cubic metre cost of concrete and the per tonne rate of reinforcing steel are usually fixed and
the quantities can be adjusted quite readily to suit the complexity of design, or later changes to design, and formwork is usually quoted per square metre of building, allowing considerable latitude for design evolution as the project proceeds.

Formwork for post-tensioned concrete construction is not overly complex either, and reinforcing steel and cable assemblies also bear relatively fixed ratios to concrete volume for specific types of structures.

### 3.3.3 THE STEEL ISSUES

By contrast, steel, while it can offer clients superior cost-effective solutions in many situations, requires a construction sequence fundamentally different from concrete.

Steelwork has to be designed and the designs then translated into a format (shop detailing and shop drawings), which the fabricator can use to manufacture the elements of the structure in the factory. This process takes an amount of time, but does take place off site. When completed the components are capable of being delivered to site and immediately erected with little on-site labour.

However, engineering firms have varying levels of expertise in structural steel design, which is not surprising given the low market share of steel. It is therefore essential to engage firms with the experience and appropriate technology not only in design, but also in documentation. It is also essential to have early engagement of such firms. Steel construction requires much earlier resolution of issues such as air-conditioning ductwork layout, fixing for curtain walling and the like, and in this respect imposes a tight discipline on design and fabrication.

With the appropriate level of cost-effective design, documentation and planning, steel can be highly competitive on price and capable of speedy erection, which can be a further economic bonus. A desk study undertaken in Melbourne by Rider Hunt (Quantity Surveyors) in late 2005 for the ASI showed that for a 40m x 40m five-storey office building the price for a steel solution was between $230 and $250 per square metre as against a range of $250 to $290 for post-tensioned concrete. Also, for the recently completed 34-storey, $200 million Urban Workshop at 50 Lonsdale Street in Melbourne, a steel frame was chosen, after both concrete and steel designs had been commissioned and evaluated. Multiplex, the builder, said (2005) that steel presented less risk to the building program and a significant reduction in labour costs.

Fabricated steel work typically contains up to six cost elements:
- steel (plate, channel, beams etc) ex-mill or ex-distributor
- shop detailing
- fabrication (largely labour)
- surface treatment
- transport to site
- erection.

Very often it also includes metal decking, stud fixing and even concrete emplacement.

Of these steel itself is the least variable. The price of steel has risen in the past two or three years, but even so, usually accounts for about one-third of the cost of erected fabricated steelwork and does not vary with the complexity of the design.

Shop detailing and fabrication vary enormously in response to the intricacies or simplicity of the design, and the repetitive nature or otherwise of the building module. A paper by Watson et al (1996) indicated, from a wide spread of constructions, a range of detailing costs between $50 and $500 per tonne, and fabrication cost ranging between $200 and $2000 per tonne. The same paper also showed erection costs varying between $150 and $700 per tonne, again showing the effect of complexity.

In many instances quantity surveyors and builders apply arbitrary additions to steelwork costs and estimates. Typically, we were told, $60 per square metre is applied to cover extra cranes, penetrations and floor levelling when steel is used.

Many builders are also perplexed by what one described as “the mystery of fire engineering” which can still cause major cost additions to steel construction if the specific regulations applying to particular constructions are not fully understood, and excessive or unnecessary fire protection applied.

It is not surprising therefore, that rates for fabricated steelwork quoted on a per tonne basis vary widely, and that a rate once established for a particular project is not transferable to another project where the design approach might be quite different. To a community of developers, architects, builders, quantity surveyors and clients accustomed to the standardised price per cubic metre of concrete, this is a major frustration, and deterrent to the adoption of steel.

Unfortunately in many projects designs are not fully complete at the time the builder takes the tender and
in any event variations usually arise as the building proceeds. This is more difficult to manage with a steel structure, because the greater volume of design work and detailing needed for steel requires time, as does the purchase of steel and its fabrication. In these situations where detailed pre-planning has not been done, it is difficult to make accurate estimates of allowances needed to cover design development and also to cover variations, and this is a further frustration. One builder allows 3 per cent of tender for the design development of a concrete structure and 7 per cent for steel, when starting with an incomplete design. The extra for steel covers the extra design time needed, and the likelihood of complex connections and penetrations. This again underlines the advantage of early commitment of design effort and the resolution of issues at design stage. It also points to the fact noted in the work of Aruna Pavithran (Section 3.2) that variations are costly whether in steel or concrete, and that attention paid ahead of time to design detailing and the programming of fabrication, surface treatment delivery and erection is needed to achieve optimum performance and cost in either material.

Added to this is the understandable, but misinformed notion that if fabricated steelwork is costed by the tonne, then reducing the tonnes involved in a project will lead to a reduction in cost. As a result, a great deal of engineering creativity is devoted to reducing tonnes. This frequently leads to complexity, and the net effect is to drive the price upwards. Often a more cost-effective solution is to use simpler connections and other design elements, even if it means more steel.

### 3.3.4 THE WAY FORWARD

Steel offers a number of benefits to developers, builders and owners alike. To the developer there is the benefit of faster erection times and a shorter path to completion, to the builder a smaller site workforce and to the owner a high degree of flexibility to meet future changing needs. The steel community therefore needs to better articulate the relative value proposition of steel to make fabricated steelwork more accessible and less of a perceived risk to those who are attracted by these benefits. Part of the way forward will be by involving steelwork expertise from fabricators and steel designers at an early stage of the process so that the most cost-effective designs are put forward for client consideration. Another important step will be changing the costing methodology so that developers and builders can understand and rely on steelwork costing information when they set out to commit to a project.

Integral to this will be the establishment of a reliable set of regularly updated cost data covering materials, labour, design, detailing, surface protection and other cost elements so that quantity surveyors and others can rapidly assemble reliable cost estimates. Updating the data base and having it relevant for the different states and regions will be vital if it is to become authoritative and widely used. This could possibly be done through the offices of the ASI in collaboration with fabricator members.

The steel industry has already done a considerable amount in this area and has embarked on plans to improve and extend this work greatly. A major issue for the industry will be promulgating the database and overseeing its adoption.

In 1996 a major effort to identify and cost all of the elements involved in detailing, producing, surface treating and erecting fabricated steelwork culminated in the Australian Institute of Steel Construction (AISC), now the ASI, publishing the work in the form of a detailed paper by Watson et al (1996), also referred to above. This paper proposed an improved approach to costing, known as the Rational Costing Method. It contained much detail on such items as hourly rates, estimated times (and hence costs) for different connection types and different design approaches and consequently enabled much improved accuracy of costing as well as suggesting which design elements might lead to lower costs for particular functions. It was widely disseminated by the ASI although not widely adopted. Moving on from this, further work has been done including the publication in 2004 *Economical Carparks, A Design Guide* by OneSteel. This again contains detailed design and costing information of the nature that would be included in a costing database, and this publication has been extensively used in the design and construction of fabricated steelwork-based carparks.

Currently one of the important references for quantity surveyors and others is the Australian Standard Method of Measurement of Building Works (SMM) published by the Master Builders Association in conjunction with the Australian Institute of Chartered Surveyors and last updated in 1991. A draft update of Section 9, which refers to structural steel, was produced by an industry group consisting of fabricators, quantity surveyor and steel supplier (BHP Steel at the time) and co-ordinated by the AISC. This update will be an important part of the improvement of costing as it will move the industry further away from consideration of tonnage and be more enabling of elemental costing.

In further emphasis of the importance the industry
places on improving the costing process attaching to fabricated steelwork, costing methodology is the focus of a separate project within an overall program funded by the Federal Government through ICIP to improve efficiency in the construction industry through the adoption of steel.

This project titled, The Development of Cost Models to Show the Relative Competitiveness of Building Systems, has been commissioned by the ASI, and is being undertaken by Rider Hunt, Quantity Surveyors, Sydney. The cost models developed will demonstrate the competitive position of steel versus concrete, and, critically, the process will create a database of cost factors that will become the foundation of a revitalised rational costing methodology. Part of the prescription for this work is that the database be capable of continuous updating, and modification for the different states and regions of Australia. This work will also lend itself to the updating of SMM, which we believe is an objective of the AIQS.

Looking further into the future, a most important outcome of the development of these cost models will be their application to 3D and Building Information Modelling (BIM). Arup (2006) foresee BIM having the ability to add information other than geometry to a 3D model including automated scheduling of quantities, supply chain integration (i.e. automating the procurement process and direct manufacture, e.g. CNC machining of metal components directly from the model). Given a reliable costing database, adding costing information to the automated scheduling of quantities would be a major step forward in improving the industry’s confidence when contemplating steel solutions for construction projects.

Also to come are improvements to the whole process of fabrication and erection of steelwork. It is a manufacturing process by and large, but much of the automation and other productivity enhancing developments seen elsewhere in manufacturing industry have yet to be fully adopted by this industry. The group was very interested in a workshop held jointly by the American Institute of Steel Construction and the National Institute of Standards and Technology in 2002, and involving steel producers, fabricators, designers, erectors and construction automation experts. The stated aim was to reduce the time to complete a steel frame by 25 per cent. This was seen as necessary to maintain the competitive position of steel in the US. The workshop covered design, fabrication, erection and safety (which is a major concern in the US construction industry, as it is here), and explored the way technology, especially automation, might enable the target to be reached. The outcome was an encouraging set of pointers to possible improvements, many of which would be translatable to Australian practice.

REFERENCES


3.4 TECHNOLOGY

By Sandy Longworth
For The Warren Centre

3.4.1 BUILDING CONSTRUCTION DEVELOPMENT

The construction of buildings and in particular multi-storey buildings has become far more precise and dimensionally accurate over the past century.

In Section 4.5.7 Michael Gallagher outlines this construction development in the multi-storey sector. There has been a progressive introduction of prefabrication, which was typified first by the introduction of cast iron in the mid-19th century, then wrought iron and steel in the early 20th century. The past 75 years has seen a prodigious growth in pre-cast and pre-stressed concrete in the building construction sector.

Computerisation covering a wide range of applications is now firmly established in all phases of construction. This has facilitated prefabrication, not only for steel framing but for curtain walling, pre-cast concrete, service components, modularised plant rooms, electric wiring harness and internal wall modules.

There has been a gradual reduction in skilled workers and tradespeople on site with the progressive transfer of activities to improved factory production facilities. Overall worker safety improvement has been a by-product. Product sourcing is now more widely spread geographically with many specialist products manufactured overseas. This diversified activity requires dimensional accuracy, speedy data transmission, good communications and the ability to accommodate change. Material flow logistics are becoming increasingly relevant with construction in restricted CBD locations.

Component and material handling has also progressed with improvements in crane design, incorporating greater lifting capacity, increased reach, self-raising and lowering, GPS positioning and an overall reduction in operating costs in real terms.

Today's multi-storey, steel-framed buildings with modular façades are predominantly pre-fabricated and rely for efficient and rapid delivery on the introduction of technology and changes in practice that the Steel – Framing the Future project addresses.

3.4.2 FIRE ENGINEERING

Ben Ferguson (Section 4.5.5) provides a basic introduction to fire engineering, which is an essential building block in the Steel – Framing the Future project. The Building Code of Australia has been performance based since 1996, resulting in significant benefits in the case of modern fire-engineering concepts and models applied to multi-storey, steel-framed buildings.

Code provisions now cater for a wide variety of specialist buildings and construction materials. Structural fire engineering examines analytically the behaviour of structural members under specific fire conditions. It also takes into account structural redundancies enabling certain-sized steel members to be utilised in an unprotected state. There is now an increasing number of buildings constructed with unprotected steelwork, particularly with perimeter located lift access shafts.

3.4.3 FABRICATION

In recent times significant progress has been made in the development of metal fabrication methods and technology. The majority of these advances has been made by equipment manufacturers and initially adopted by capital-intensive industries such as shipbuilding, automobile manufacture and heavy engineering plant manufacture. The building construction steel fabricating industry has been slow to capitalise on much of this technology. For those fabricators who have taken up advanced technology, the rewards have more than justified the investment.

Sandy Longworth (Sections. 4.5.6, 4.5.10) summarises the range of technologies now available to industry, which includes beam lines for both rolled and fabricated sections, high-speed drilling, high-definition plasma cutting, laser/GMAW hybrid welding for multi-positional working, full-penetration butt welding and smaller high-strength fillet welds. All of these processes are eminently suited to automated fabrication, which is in keeping with 3D computer software now increasingly adopted for engineering, detailing and CNC output.

Robots have not yet found widespread favour in structural fabricating, although they have been used for placement and welding of stiffeners for plate web girders in the UK (Fairfield, UK). It is very likely, given the degree of repetition with multi-storey beam and column fabrication that robots will be introduced in due course. They are used extensively in shipbuilding, heavy equipment component fabricating and sophisticated structural connections. The Japanese Obayashi Automated Building Construction System employs...
automated welding of beam and column connections for multi-storey construction.

While fabricated steel prices have risen along with all other building products, the real price of fabricated structural steel has fallen (Munter, S 2006). This is primarily due to increased shop-floor productivity (work hours per tonne) which is being technology driven. There is thus scope for containing and even lowering fabricated steel costs, which should more than maintain the material’s cost base against concrete.

With the growth of products from steel producers and the increasing competitiveness of overseas fabricators from China, Korea, Taiwan and India, facilitated by international detail service companies and high-speed data transfer, Australian fabricators will have to move to a higher technological level if they are to remain competitive in the medium term.

Peter Farley has contributed a very challenging paper FRAMEquick (Section 4.5.9), a world class, flexible fabricating facility with the capacity to produce beam and column units at low cost. He is proposing, in addition to fabricating long products in beam lines, the robot positioning and robot welding of fin, end, splice, base plates and miscellaneous outrigger brackets. Such a concept has the potential to impact very favourably on structural steel cost and stimulate a wider variety of composite structural design.

3.4.4 DESIGN

Emil Zyhajlo provides a ‘state of the art’ paper (Section 4.5.3), addressing multi-storey, steel metal deck and concrete construction, with reference to composite systems.

The Australian composite design code position is reviewed and, while the codes are by no means comprehensive by world standards, Zyhajlo concludes this is not inhibiting progress, principally because of the availability of manufacturers’ design aids and supporting software. In addition there are procedures for floor vibration and fire design checking. A very reasoned plea – quoting European practice – is made for more flexibility and innovation with composite design, in particular the use of prefabricated, partially encased beams and columns. These elements, which are made off site, would be composite in load carrying and meet fire-rating requirements.

Mention is made of floor systems, covering un-propped metal deck, slim deck, pre-cast pre-stressed units and proprietary ultralloor. The author also provides a cost ranking for various forms of columns and sees merit in steel erection columns for beam framing support, with composite concrete encasing.

3.4.5 3D DOCUMENTATION AND BIM

John Hainsworth and Stuart Bull, engineers well versed in state-of-the-art 3D, describe in their two papers the big gains to be made by adopting this technology.

Once the journey starts it will be an ongoing process, facilitated by interoperability and the progressive integration of the multitude of software packages that will ultimately comprise the Building Information Model (BIM). There will be a lowering of project risk and savings in time with software systems that can readily handle change.

Design, documentation, detailing and the transfer of concept to manufacturing format, in particular the software linkages between the team comprising engineer, detailer and fabricator, are keys to a successful steel-building project outcome. It is essential the fabricator be introduced into the team as early as possible.

Using 3D technology enables an initial model to be produced with general arrangement framing drawings and material lists, even though the finer details are still to come. At this point there is much to be gained by introducing the fabricator. Mr Hainsworth is advocating this approach, with the fabricator in the start-up group, even though the contract price may not have been settled. Collaboration is the key to performance. The fabricator will have early input and gain an understanding of the project, have an opportunity to introduce ideas and know from day one what is expected of him/her. He/she will have an opportunity to rationalise sections and establish the fabrication sequence and rate, thus enabling erectable packages to be set and dimensional sign-off dates established for transmission of data to the fabrication shop. This provides key project program milestones and sets the windows of opportunity for effecting design changes without incurring additional cost or program disruption.

Hainsworth’s ideas for change have been underpinned with a meaningful survey of engineers, fabricators and detailers that has confirmed the slow and widely varying proprietary nature of 3D technology take-up (Section 5.6.3). This survey shows a minority of engineers are using 3D and the majority of this minority’s software applications are not compatible with fabricators, and detailers, mainstream packages (Xsteel™, StruCad™, Prosteel™ or BoC™). Furthermore, very few engineers offer material lists at planning and estimating stage.

In a similar vein, a majority of detailers has software...
to provide NC (numerical control) output, but only 27 per cent of fabricators surveyed have the ability to process NC data. A majority of detailers and fabricators agree that access to a consultant’s model is beneficial to configuration checking.

3.4.6 DIMENSIONING

Current practice adopted by Australian engineers on steel building projects is not to provide dimensions. The fabricator/detailer has to progressively develop the information base, generating in the process requests for information and in turn time and cost. To effect a quantum change, it is suggested the engineer and detailer collaborate, or alternately the engineer assume detailing responsibility, in addition to assuming responsibility for all dimensions. This dimension discipline, along with the early appointment of the fabricator, would simplify the value chain and, when combined with JIT manufacturing and the FRAMEquick concepts of Mr Farley, would make a quantum change to the steel delivery package.

3.5 RELATIVE VALUE PROPOSITION SUMMARY

By David Ryan
Australian Steel Institute for The Warren Centre

3.5.1 OBJECTIVE

To identify the strengths and weaknesses of structural steel for use in multi-storey buildings relative to reinforced, pre-stressed or post-tensioned concrete.

3.5.2 TERMS OF REFERENCE

1. Identify perceived strengths and weaknesses of structural steel versus concrete structural solutions for multi-storey construction.
2. Test the identified perceptions with facts where possible.
3. Identify who makes the key decisions re structural form, and at what stage.
4. Identify what factors inform the decision as to structural form.
5. Identify what better information is required to better inform decision makers in future.
6. Identify the key steel solution weaknesses that can be addressed to increase the competitiveness of steel structural solutions.

3.5.3 CONCLUSIONS

The conclusions reached were as follows:

- The value proposition for steel can only be provided to the builder when a competitive design and cost is presented. The current dynamics of the industry disfavour a steel option being considered by the engineer as this represents additional cost in the process.
- Early fabricator involvement is necessary to provide a comparison cost-and-build program for steel.
- A prior fabricator relationship must be established for the builder to have confidence that the steel solution can be delivered.
- Work on the steel and fire design is necessary before the fabricator can quote as traditional engineering designs can be very conservative and not fabrication cost efficient – as a result, unnecessarily costly and non-competitive.
- Internal builders, cost figures can be significantly excessive for steel (e.g. fire spray $65/square metre ex Rawlinsons whereby a contractor was quoting $25/square metre in the Sydney market) and there needs to be a mechanism for current typical costs
to be available to builders, engineers and quantity surveyors – an ASI website is favoured.

- The decision on the framing material is made at the preliminary concept discussion time and hence the decision makers must have a representative view of cost and time for construction of the steel option at that time.
- The engineer must be convinced to have a steel option available. As this is an additional cost to his/her business there is currently little incentive for the engineer to develop a cost-effective steel alternative.
- The steel industry needs to understand and communicate where steel framing is competitive (e.g. what type of building, what span range), and define the areas of competitive advantage for steel framing.
- The building industry talks in dollars per square metre; fabricators quote dollars per tonne and do not understand what rate they need to quote to compete against concrete. The steel fabrication industry needs to understand what makes up a competitive offer and use all of the value equation aspects such as speed of construction, future proofing, lower preliminaries in setting up the value proposition to sell their offer.

3.5.4 Recommendations

1. The steel industry gears up to include and promote in its offer (as per Steel Construction New Zealand) the preliminary redesign and cost service for steel building designs in the target range. This will involve a funding of additional cost until the industry develops the necessary momentum.

2. Typical building costs are posted on the ASI website for the industry to view, plus an emailing of current costs of selected building types to structural steel decision makers, engineers, architects, quantity surveyors, estimators, builders etc.

3. The steel industry understands the value equation for steel framing and educates and informs key fabricators involved in the building market.
4.0 ISSUES GROUP REPORTS

4.1 GENERAL

This section comprises reports describing in detail the outcomes of the various issues groups’ considerations. In some cases, these are encapsulated in a single paper, in other issues groups, such as Technology, there is a suite of papers describing disparate topics under the issue. A full list of group members is included in Appendix C.

4.2 LEADERSHIP REPORT

By Reg Hobbs
Flagstaff Consulting Group Pty Ltd for The Warren Centre

4.2.1 GROUP REPORT

General

The Leadership Group held a workshop in Melbourne on ‘the realities of doing business today for the steel construction sector’. This was attended by partners of Phillips Fox and Deacons Lawyers, a director of project and infrastructure finance for the ANZ Bank, a director of the Victorian Government agency Major Projects Victoria, the Victorian Manager of ING Real Estate, a consultant from KPMG (who is also an experienced construction lawyer), the Managing Director of the Alfasi Steel Construction Group, a Leighton Contractors project and design manager, Sandy Longworth from The Warren Centre and members of the Leadership Group.

At another meeting the group was joined by two leading independent consulting engineers who specialise in the area of reviewing structural designs, developing construction or erection methodologies and designing temporary works.

One of these gentlemen, Dr Russell Keays, works closely with the steel fabrication and erection sector. The other, Emil Zyhajlo, had recently returned from a three-month assignment in the UK where he had been responsible for reviewing structural options for a major retail and commercial development. In the course of this work he had investigated a range of structural steel and composite solutions on offer from British and European suppliers.

4.2.2 TERMS OF REFERENCE

The Leadership Group concentrated on the following terms of reference:

1. Considering the industry leadership necessary to develop solutions to satisfy the realistic contractual and risk management needs of a client base that is increasingly reliant on private sector finance (banks, mezzanine financiers, equity markets and super funds dictating terms) for both private sector developments and government works (Public Private Partnerships, office leases etc).

2. Considering the industry leadership necessary to respond to increasing demand by all types of clients for ‘sustainability’ in design and materials use – noting that steel may not be currently perceived as offering the best solutions.

3. Considering whether the steel industry leadership should move to promote best use of the combined advantages of steel and concrete rather than the old steel versus concrete mindset.

4. Considering how the steel industry may foster new initiatives to enhance education of architects, engineers, para-professionals and others to gain the earliest possible familiarity and comfort with the uses, applications and technology of steel as an everyday construction material.

5. Considering whether there is a need for greater leadership in Temporary Works Design and responding to recent and future changes in OH&S legislation affecting use of steel.

4.2.3 SUMMARY OF DISCUSSIONS

Time and resources did not permit consideration of the fourth (education) issue in any detail, however it is considered to be an important matter for the steel industry to consider further and is worthy of development of long-term strategies.

The issue of ‘sustainability’ generated a significant amount of discussion. The most important task for the group was to form a view as to whether it really was
an issue that had real potential to affect the adoption of steel for building framing. The group concluded that it is a major issue and that the pace of change in adoption of the various ‘green building’ rating systems in Australia by government, property investors and commercial developers has been very significant during the past two years. Section 4.3 provides further information on the issue.

The need to focus on leveraging the best features of steel and concrete in a building design, rather than continue the eternal steel versus concrete debate, was unanimously agreed upon by the group.

The workshop on ‘realities of doing business’ produced some strident feedback to the steel sector in relation to the level of resistance to the use of steel framing expressed by a number of leading Victorian building industry executives to one of the lawyer participants during his research prior to the workshop.

The workshop also highlighted many other aspects of the decision-making process used by developers, building owners, financiers and tenants. A salient example was that a developer does not care whether a building is framed using steel or concrete; what they want is a solution that minimises construction time across all trades (not just the frame), is more economical to construct, will achieve Green Star ratings or other environmental criteria and is a flexible asset that ensures a high return on investment. The group also noted the current trends for the government sector to use outcome-based contracts to procure accommodation in buildings, under a variety of innovative procurement models, which demand high standards of functional performance, environmental sustainability and life-cycles.

The discussion of the issues involved with skill levels in temporary works design and limited discussion of aspects of engineering education and development was somewhat inconclusive. Some areas of concern were noted, however no obvious means of addressing these could be formulated in the limited time available for this study.

Some surprising outcomes of the meeting with Dr Keays and Mr Zyhajlo were the observations of the latter after his recent work assignment in the UK. He presented some very compelling views that one of the reasons the use of steel framing is more prevalent there may be because British concrete design and construction techniques are significantly less developed than in Australia and other countries. Mr Zyhajlo presented a number of specific examples of pre-stressing design issues, outdated approaches to formwork, limited use of high-performance concretes (prevalent in Australia for more than 20 years) and industry mindsets re costing, which indicated his proposition had significant merit. In many respects ‘state of the art’ concrete frame construction in the UK may be considered to be 10 or more years behind Australia.

Hence it is possible that during the next 10 years the market share of concrete in the UK may grow and the relative usage of steel framing may decline.1

The key question raised at the end of each meeting was where industry leadership will come from to address the issues that so clearly affect the use of steel in buildings. In every case the group concluded it was not reasonable to expect the major steel manufacturers to be the sole leaders or to provide increased funds for industry development and reform. Rather the leadership and change must come from all levels of the sector.

The group also discussed whether the steel sector could develop a larger market share in the low-rise and typical suburban commercial market and noted this type of structure should be ideal in steel framing, as the upper level and roof of a typical suburban office building are usually steel framed. It was noted that the engineers who typically design the structures of such buildings may have inhibitions about using steel because they do not enjoy the benefit of adequate composite design standards. Many will not be prepared to develop designs involving composite details or moment continuity where there is not an explicit standard for building regulation compliance and liability reasons.

Appendix A3 to this report presents a fairly uncompromising discussion of issues arising from the manner in which the steel construction sector presents itself to the potential specifier and client base, noting how there appears to be a significant mismatch of expectations by both.

It is considered important to put these positions, as there are no indications of the ‘take up’ of steel framing for office buildings improving, particularly in the Melbourne market.

When the Leadership Group began its deliberations there were two major steel framed buildings under construction in Melbourne, being the subject of case studies by The Warren Centre and reported as being

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1 A paper published by the Royal Institution of Chartered Surveyors ‘Concrete or Steel – The choice of frame for office buildings’ (May 2003) presents the results of research that indicates that the reported higher usage of steel in building frames in the UK needs to be considered in the context that ‘concrete frames were more likely to be used on larger buildings than smaller ones’. 

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examples of the 'state of the art'. In the following 12 months a significant number of major office buildings have started construction in Melbourne or are currently being designed. It is apparent that most of these buildings have not adopted steel framing and it is unlikely that there will be any – even those being constructed by the builder, Multiplex Constructions – who adopted steel for the buildings that were the subject of the case studies.

Ian Cairns, the ASI representative on the Leadership Group articulated some key issues for the sector:

- ‘There seems a need to embrace and invest in technology. Many steel fabrication shops have changed little in the past 25 years. There are many MRP packages used worldwide that could assist the streamlining of workflow. It is also apparent that the utilisation of computer-generated data could be used to much better effect within the steel industry chain.’

- ‘Many industries these days are looking for ‘packaged solutions’; ‘one-stop shops’. There is a need for the steel industry to pool its resources, investments and knowledge to provide more for less. An example is that of the many steel fabricators – estimated to be 500–600 nationally – there would only be 1 or 2 per cent who could handle a significant-sized job. The industry leaders within the chain need to look closely at its effectiveness.’

- ‘The industry leaders need to be continually looking at how the overall design of the frame can be done better and more efficiently. Emil Zyhajlo spoke about large steel contractors in the UK utilising heavy plate girders to speed up fabrication and reduce costs. Industry leaders need to keep abreast of trends and innovations being used around the world and where appropriate, push for their use in this market.’

- ‘There seems to be a mind-set of ‘if it’s not broken don’t change it’ – this is a dangerous attitude in any industry. The steel industry leaders need to develop a culture of challenge; innovation, research and continuous improvement in the way things are done not only within their own companies, but throughout the industry chain.’

4.2.4 SUSTAINABILITY

By Andrew Marjoribanks
Venlaw Park Pty Ltd for The Warren Centre

Companies as diverse as Bank of America, Genzyme, IBM, and Toyota are constructing or have already moved into green buildings. Green is not simply getting more respect; it is rapidly becoming a necessity as corporations as well as home builders, retailers, healthcare institutions, governments and others push green buildings fully into the mainstream over the next five to 10 years.

In fact, the owners of standard buildings face massive obsolescence. They must act now to protect their investments. ‘Building owners are starting to do reviews of their portfolios to see how green their buildings are and what they need to do to meet growing market demand,’ says Ché Wall, chair of the World Green Building Council. ‘Citigroup, for example, has already begun looking at how its 100 largest buildings stack up against accepted green standards. Based on those findings, the company will then review its worldwide real estate portfolio and create a green road map to help improve the efficiency of its buildings. Soon, financial institutions and investors will use new valuation methodologies to quantify important green building factors like productivity and long-term life-cycle costs when determining real estate values.’

The perception that steel lags in the ‘sustainability’ and ‘green building’ areas in Australia is reinforced by government publications, such as the Industrial Processes Sector Greenhouse Gas Emissions Projections 2004, published by the Department of the Environment and Heritage, Australian Greenhouse Office, which shows the concrete industry improving its position with reference to emissions, while the steel industry stays static.

It is also of note that while the Australian Cement Industry Federation (with all major cement and concrete manufacturers as members) is a member of the Australian Government’s Greenhouse Challenge Plus, BlueScope Steel and OneSteel are conspicuously absent from the list of participants.

This will be an issue of increasing importance as the Federal Government and community focus on greenhouse gas emissions, the so-called carbon footprint of industries and processes, and the inevitable debate on carbon trading, and whether it should be introduced to Australia. The steel industry has a large stake in this debate and should be readying itself accordingly.

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2 The Cbus Property development in Bourke Street, the AXA Building at Docklands, the Ericsson building at Docklands, Waterfront City Docklands (mixed use), 399 Bourke Street (mixed use) and, it appears, the very large ANZ headquarters are most likely to be concrete framed.

The Green Building Council of Australia (GBCA) has published guidelines for Green Star ratings (Green Star ratings – Materials, 3 October, 2005) which reward use of recycled materials with ratings points. The concrete industry has managed to position itself well in these ratings through the recycling of fly ash and blast furnace slags. On the other hand the recycling requirement for steel to be 90 per cent used in a building to contain 50 per cent ‘post-consumer’ scrap to obtain two Green Star points, or 60 per cent for one point virtually excludes Australian structural steel, which is made by smelting ore and has a maximum of only 25 per cent recycled content. Australia produces around 7.5 million tonnes of steel per annum and uses about 2.8 million tonnes of scrap per annum (Strezov & Scaife, 2004).

An example of how this has affected materials selection on a recent building can be studied in the research papers (Materials selection in Green Buildings and the CH2 experience) published in relation to the Melbourne City Council’s recently completed CH2 building, which achieved a ‘six-star’ GBCA rating. This report states:

The Green Star process highlighted the difficulty of obtaining necessary information when making key decisions on materials. To meet the project requirements of one particular Green Star credit point recycled steel had to be sourced. No guarantee from local steel manufacturers could be given that 30 per cent recycled content was achievable. To meet this requirement the project team had to look outside Australia. The steel for CH2 was subsequently imported from Thailand.

Since then its importance has certainly been recognised and a number of important contributions are being made to the debate.

The Steel – Framing the Future Steering Group arranged for Nigel Howard, of BRANZ to prepare a paper titled Sustainability and the Steel Industry, October 2006 – A Position Paper (Appendix A11).

It provides an excellent background to the issues of concern, and suggests the steel sector should become actively involved in supporting ‘initiatives to establish a consistent methodology for the conduct of comprehensive Life Cycle Analysis (LCA) in Australia and to promote the results in support of the use of steel for construction’.

Following from this, a meeting was held with Andrew Walker-Morison, Program Manager, Sustainable Materials, RMIT Centre for Design (www.cfd.rmit.edu.au). His group, in a Victorian initiative, is developing a Building Materials Scorecard which presents an important opportunity for steel sector involvement.

In December 2006 the Centre for Design at RMIT published a ‘state of knowledge’ report (Horne & Walker-Morison, 2006) titled The current and future opportunities for improved environmental sustainability outcomes through development and use of the building assemblies and materials scorecard. This document contains a number of interesting references to the steel industry.

The Leadership Group Chairman has also been in contact with Professor Markus Reuter, Professor of Sustainable Technology at the University of Melbourne, who has provided a number of reference papers including his presentation to the International Iron and Steel Institute (IISI) Annual Conference in Buenos Aires (October 2006). His work has centred mainly on recycling and the need to design for disassembly, and although much of his research has concentrated on the car industry, it has significant relevance for the next generation of buildings.

By contrast with the Australian position, steel is perceived as having strong sustainability credentials in the UK. Richard Elliott (2005), head of construction at British Land (a $30 billion UK property owner and developer), delivered the keynote address on steel and sustainability at the British Constructional Steel Association International Conference in London, November 2005, in which he detailed the extensive discipline adopted by British Land on sustainability matters, and listed what he regarded as steel’s strong sustainability credentials. Coincidentally, in the same month, in the context of non-financial investment risks, the UK Financial Times (17 November, 2005, Portfolio, page 7) ran an article on the environmental issues facing the construction industry, dwelling largely on concrete’s difficulties. ‘Waste concrete from demolition accounts for about 500kg of waste per person in the EU, of which only about 5 per cent is recycled,’ it said. Interestingly, the accompanying photograph was of steel beams on a construction site, although steel itself was not mentioned in the article.

Closer to home, the group was made aware of some of the work on sustainability and steel undertaken in Australia, notably the papers produced by Peter Scaife and others at the University of Newcastle. The group was also made aware of the GBCA’s misgivings about this work, and its perception that the steel industry is behind in tackling sustainability issues.

It was also noted that the International Iron and Steel Institute has done much work in this field. In
a collaborative effort involving most of the world’s major steel companies the world steel industry has developed a policy on sustainable development and determined 11 sustainability indicators against which economic environmental and social performance are to be measured. Data has been collected from member companies since 2004, with the results being communicated to stakeholders in a publicly available Sustainability Report. The current edition (2005) represents 38 per cent of world steel production and includes BlueScope Steel Limited.

The IISI also acts in a role where it institutes and co-ordinates studies and projects on sustainability issues involving the participation of member companies and the sharing of information. One such project was the ‘Ultra-Light Steel Auto Body’ (ULSAB) project, involving 33 companies and a budget of several million dollars. This ultimately developed and demonstrated technology to reduce the weight of a mid-size family car body by some 25 per cent with no increase in manufacturing cost.

Members of the Steel – Framing the Future project have now had meetings with a board member and chief executive of the GBCA. The position of the GBCA is now much better understood and there is scope for the steel industry to participate in future development of the Green Star rating documentation.

Notwithstanding this, it should be noted that it could be expected that the issue of recycling will continue to be a key consideration for the GBCA. It is unlikely that The GBCA will simply accept the proposition advanced in the Scaife paper (and other steel industry documentation) that, because a piece of ‘virgin’ steel will be recycled somewhere in the world, some time in the future, that Green Star rating points should be awarded. It is apparent that a desire to exhaust all available options for sourcing steel sections produced from recycled material may persist.

This leads to consideration of the potential for larger sections being produced in Australia using electric arc furnaces or similar technologies.

IISI statistics (2006) indicate approximately 18 per cent of Australian steel production is from electric arc furnaces, with the remaining 82 per cent being from blast furnaces. The figures for the European Union are 40.5 per cent from electric arc furnaces, with 59.5 per cent from blast furnaces, illustrating the relative abundance of scrap in Europe, and low availability in Australia.

It is of interest to compare the Australian situation with the US where the following is a direct quote from the US Government’s Department of Labor (Bureau of Labor Statistics n.d.):

The least costly method of making steel uses scrap metal as its base. Steel scrap from many sources — such as old bridges, refrigerators, and automobiles — and other additives are placed in an electric arc furnace, where the intense heat produced by carbon electrodes and chemical reactions melts the scrap, converting it into molten steel. Establishments that use this method of producing steel are called electric arc furnace (EAF) mills, or minimills. While EAFs are sometimes small, some are large enough to produce 400 tons of steel at a time. The growth of EAFs has been driven by the technology’s smaller initial capital investment and lower operating costs. Moreover, scrap metal is found in all parts of the country, so EAFs are not tied as closely to raw material deposits as are integrated mills and can be placed closer to consumers. EAFs now account for over half of American steel production and their share is expected to continue to grow in coming years.

The growth of EAFs comes partly at the expense of integrated mills. Integrated mills reduce iron ore to molten pig iron in blast furnaces. The iron is then sent to the oxygen furnace, where it is combined with scrap to make molten steel. The steel produced by integrated mills generally is considered to be of higher quality than steel from EAFs but, because the production process is more complicated and consumes more energy, it is more costly.

In the US 55 per cent of all steel production was by the electric arc furnace route, largely using recycled post-consumer scrap (IISI statistics, 2005).

The EAF process lends itself to scrap melting and is widely used for this purpose, hence ‘recycled steel’. However it can also accommodate ‘virgin feed’ in the form of hot briquetted iron (HBI), direct reduced iron (DRI), iron pellets and even iron ore. It can also be fed with pig iron. The basic oxygen steelmaking (BOS) process requires up to 25 per cent scrap in each batch to keep it cool. It can use more. Averaging Australian steel production over EAF and BOS, Australian steel is about 35 per cent recycled content with both processes using about the same annual amount of scrap.
Scrap in this case includes:

- ‘prompt scrap’ (arising in the process of manufacturing as off-cuts, rejected material etc).
- post-industrial/pre-consumer scrap (industrial scrap such as that from car body production, leftovers from cutting out circles in plate and similar sources).
- post-consumer scrap (from articles which have come to the end of their lives, such as building demolition scrap, car bodies, refrigerators, food cans etc).

The GBCA points system requires 90 per cent of the steel in a building to have a minimum of 50 per cent post-consumer scrap content to qualify for two Green Star points (or 60 per cent of the steel used to have a minimum of 50 per cent post-consumer scrap content for one point), excluding ‘prompt’ and ‘pre-consumer’ scrap from the calculations.

So EAF steel requires some virgin feed and BOS steel requires some scrap. What determines the ratios are scrap availability and quality.

The availability of scrap supply is a constant issue for EAF steelmakers, particularly in buoyant markets when the price soars. South-East Asia especially has a very high demand for scrap and imports it from the US, Europe and anywhere else it can get it.

In Australia with its relatively short industrial history and small population, scrap availability is especially tight. An Australian EAF producer, Smorgon Steel, has an initiative named The Great Scrap Round-Up focused on collection of scrap steel at market rates using the slogan, Clean Up, Cash In and Help Out. As an incentive to locate supplies of scrap the company donates $15 per tonne collected to local fire brigades.

Scrap substitutes have accordingly become popular, not least because supply and price are reasonably predictable and much scrap substitute is sold to EAF steelmakers to augment supply.

NUCOR the well-known US EAF steelmaker sank millions into a venture in Trinidad hoping to use tar waste, or similar, from the oil industry to beneficiate Brazilian ore fines to make a scrap substitute, but was not able to succeed. Again the driver was to reduce exposure to the volatility of scrap supply and price.

On the quality front, making reinforcing bar and similar products largely from post-consumer scrap is acceptable, because the demands on steel chemistry are not high, and ‘tramp elements’ like copper, tin antimony and the like can be tolerated. Once steel chemistry becomes more demanding, scrap selection becomes critical.

One solution for the EAF producers is to ‘dilute’ their scrap with virgin iron units such as DRI, pellets, pig iron or even ore, although the energy cost to break down ore is very high. This is another driver of the demand for scrap substitutes.

It is considered that notwithstanding the practical difficulties of the Australian and world situation concerning scrap availability there will be a growing desire for EAF-produced steel sections in Green Star-rated buildings. This obviously has implications for the Australian steel producers, their existing production facilities as well as importers and their sources. If international suppliers can provide such sections they may be sought by parties who are keen to use steel, but are prepared to demand EAF production as the source.

Internationally, IISI, representing virtually all of the world’s major steel producers opposes the specification of ‘recycled content’, as do national bodies such as the Steel Construction Institute in the UK. The US Steel Recycling Institute explains the steel industry view in the following statement:

Understanding the recycled content of BOS and EAF steels, one should not attempt to select one steel producer over another on the basis of a simplistic comparison of relative scrap usage or recycled content. Rather than providing an enhanced environmental benefit, such a selection could prove more costly in terms of total life-cycle assessment energy consumption or other variables. Steel does not rely on ‘recycled content’ purchasing to incorporate or drive scrap use. It already happens because of economics. Recycled content for steel is a function of the steelmaking process itself. After its useful product life, regardless of its BOS or EAF origin steel is recycled back into another steel product. Thus steel with an almost 100 per cent recycled content cannot be described as environmentally superior to steel with 30 per cent recycled content. This is not contradictory because they are both complementary parts of the total interlocking infrastructure of steelmaking, product manufacture, scrap generation and recycling. The recycled content of EAF relies on the embodied energy savings of the steel created in the BOS.

Similarly the UK Steel Construction Institute position is that, ‘a current misconception is that specifying recycled steel leads to improved sustainability. The IISI has provided guidance – recycled content has no impact
on sustainability; what is crucial is the level of recycling at the end of life.'

With this body of opinion available, the Australian steel sector needs to become involved in the debate, and fully engaged in the ongoing work of developing sustainability criteria. It would also benefit the industry to seek assistance from established experts in this field.

As previously noted, during the course of the study the work of Professor Reuter, a metallurgist, at the University of Melbourne⁴ was identified as being highly relevant to the consideration of the sustainability aspects of steel. In particular his papers advocating that the design of the recycling process and the associated metallurgical aspects should be undertaken at the time the steel product or structure is designed, has relevance to the structural steel sector in Australia.

His background in the steel industry and work with the automotive industry on including recycling strategies and metallurgical aspects in the design process offers much for the Australian steel industry to consider. The aforementioned work of Mr Howard (Appendix A11) should be considered along with this.

Although the timing of the study did not permit development of this aspect, it is recommended that the steel industry study the work of Professor Reuter and Mr Howard and involve them in ongoing development of initiatives in the sustainability area.

If nothing else the Steel – Framing the Future study has brought sustainability from a matter that was not recorded as being a ‘root cause’ in early workshops to one that will now command attention from the steel sector.

REFERENCES


Walker-Morison A & Horne, R 2006 The current and future opportunities for improved environmental sustainability outcomes through development and use of the buildings assemblies and materials scorecard, Centre for Design at RMIT.

⁴ Formerly of the Delft University of Technology (The Netherlands) and the University of Stellenbosch, South Africa.
4.3 VALUE CHAIN ISSUE GROUP

By Aruna Pavithran
Lucis Pty Ltd for The Warren Centre

Executive Summary

Steel-framed construction has a much lower share of the multi-storey construction market in Australia than it does in the US or UK. This assessment was conducted to understand steel-framed construction for medium-rise commercial buildings in Australia and where there might be opportunities to improve it. The medium-rise market was selected by the Steering Committee as a sizeable market with good potential for growth in steel usage.

A case study approach was adopted to produce an empirical and factual analysis, in the style of an internal benchmarking analysis. The small sample assessed – four steel-framed buildings and one concrete-framed building – show no systematic effect in the use of a structural steel frame on overall construction outcomes when compared with a similar concrete-framed building. The case studies show a range of steel-framed construction outcomes: some that are more cost- and time-effective relative to concrete, some that are similar and some less. The findings contradict a fundamental perception held in the market that steel framing is consistently more expensive and difficult to implement.

The analysis for the assessment was conducted in three parts:

Cost

Three of four steel-framed cases studied were less expensive per square metre of Gross Floor Area (GFA) than the concrete comparison. Where steel was less expensive, detailed cost analysis showed that structural steel added 6–13 per cent of Total Construction Cost to the relative cost of a frame, and saved 7–12 per cent of Total Construction Cost in preliminaries and wages compared to the concrete case study, summing to little or no effect on relative cost in each case. This suggests the additional costs in steel framing were saved in people-related site costs.

Time

Analysis of construction time showed no observable relationship between the use of steel or concrete framing and the time efficiency of construction. It also showed that the use of techniques such as the ‘jump-start’ do not always result in a comparatively faster time to completion. With consistent affirmation from project managers of the speed of steel-frame erection and jump-starts, this suggests that the benefits of these strategies are not fully realised in practice.

Risk

Issues considered to be common difficulties in the use of structural steel, such as long lead times, had no observed impact on the value chain. Of the realised risks observed in the case studies, the greatest source of ‘normal’ risk in the construction value chain is in the way the builder chooses to program erection. This is referred to in this report as Building Proposition risk, and encompasses builder competencies such as the sequencing of tasks, the use of process innovations and the choice of suppliers. Of the proportion of these risks attributed to the accuracy and reliability of the steel supply chain, perceived risks were much greater than actual risks realised.

As well as these findings, various characteristics contributing to the performance of the construction value chain were noted. First, not one of the cases observed was completed on the original completion date, showing a remarkable tolerance for unpredictability in timeliness in construction in Australia. This tolerance extends to variations, where steel framing is considered unviable due to its unresponsive supply chain. In fact, only ‘structural variations’, such adding a stairway, are more difficult with steel framing, whilst other variations that are unviable in concrete are achievable in steel.

The case studies also showed builders create contingencies in construction budgets by up to 5 per cent of total, to allow for possible additional or unforeseen costs that cannot be recouped under a typical fixed price contract. Any difference between these contingencies and the final cost overrun effectively constitutes a ‘builder's reward’ over and above their imputed profit margins of 4–6 per cent (in these case studies). Interfacing between steel and other construction activities arose as an area of difficulty, and estimation does not favour innovation in construction processes or materials.

The opportunities identified in the construction value chain are founded on reducing the risk burden to the builder and releasing the contingencies held in construction budgets. The first of these opportunities is repackaging the construction process into risk-minimising components. This strategy involves placing the risk where the skills exist to best handle it (e.g. making riggers/fabricators responsible for interfacing steel columns with the slab) and may not work where dramatic variations or highly aggressive timeframes will
be tolerated. Using web-enabled collaborative planning will create a more transparent information environment and aid the seamless collaboration required to reduce the builder’s risk burden. Finally, the measures currently used to gauge construction performance, e.g. floor cycle time, are not always directly related to value chain outcomes. Industry-wide measurement for performance is strongly recommended to create more visibility and focus on value chain performance.

For the steel industry, a focus on creating a highly responsive supply chain for structural steel will reduce the perceived and actual risk in steel supply. In this context, the responsiveness required is the swift delivery and installation of the correct product to site where a ‘structural variation’ is incurred. Addressing this aspect of the supply chain will improve the overall performance of steel supply in construction.

But, why change? The issues affecting value chain performance identified in this assessment are largely known and tolerated across the industry, at an estimated cost of up to 5 per cent of turnover (i.e. up to $3 billion of the $57 billion commercial construction industry). The true opportunity forgone in this status quo is effective process innovation and the opportunity to reallocate productive resources, at an incalculable cost to the Australian industry. Ultimately, it is up to the leaders of industry to decide in favour of transformational change.

A more extensive study, assessing a larger number and spread of buildings, is recommended to validate the findings in this report.

Introduction

Steel-framed buildings comprise a much smaller proportion of the construction market in Australia compared to the US and UK. A survey conducted by The Market Intelligence Co in 2005 quotes steel frame usage to be 13 per cent of commercial multi-storey construction in Australia, compared to 50 per cent in the US and 70 per cent in the UK. It was not clear, at the outset of this project, why the Australian construction industry and its decision-making developers preferred concrete to steel. Several contributing factors were nominated by experienced members of the construction industry:

- shortage of skills – both availability of skilled workers, such as architects, consulting engineers, shop detailers and steel fabricators, and quality of skill base
- more expensive when costed – i.e. that the same floor plan would be more expensive constructed in steel than concrete
- more expensive in construction – i.e. that variations and rectifications associated with steel frames were more expensive than concrete.

These issues had not been factually evaluated for their impact on the construction experience. Furthermore, there had been no assessment of other inefficiencies in the process of construction and their impact in the use of steel frames. It was the goal of this project to determine where there could be more value realised in the process of construction of steel-framed buildings, and to suggest some ways that the steel industry might help in realising that value.

It is important to note that the promotion of steel framing, or a critique of concrete framing, was not the objective of this project. Rather, a fact-based understanding of the current issues in steel-framed construction was the primary goal of this assessment.

Assessment approach

Construction is characterised by the involvement of many parties, each with a focus on a different aspect of the ultimate goal – a completed building. Indeed, the process of construction employed for any given building depends on the unique configuration of the design, site, the experience of the main parties and their choice of subcontractors to execute the work, to name but a few. Thus, the construction of a building has many hundreds of variables which may be assessed for their incremental contribution to the success of the process. For example, the choice of a jump-start, or the use of mobile vs tower cranes, each has an impact on the time and cost of the project, as well as knock-on effects to many other activities.

To simplify the task of determining the important variables in the construction process, a consultative approach was adopted. First, a Value Chain team was assembled, comprising senior and experienced members of the steel and construction industries (See Appendix C). This team confirmed the dimensions of cost, time and risk as being the most critical outcomes of the construction value chain.

The approach adopted for this assessment was designed to allow a robust factual analysis of the construction process while catering to time and resource constraints. An empirical approach was chosen, in the style of an internal benchmarking study, using the actual construction experience of five case studies: four steel-framed buildings and one concrete-framed building. Selection criteria were employed to make the cases as comparable as possible to each other.
recent, i.e. completed within the past three years
• medium rise commercial\(^5\), i.e. 5–10 storeys
• Metropolitan location
• closely connected to an initiative team member, to allow ease of data gathering.

The five buildings were chosen by the Value Chain team and are described in Appendix A: Case study descriptions. They are referred to in this report as Building W, Building X, Building Y, Building Z and Concrete comparison.

This assessment focused on the 'notable outcomes' of each case study in terms of time, cost and risk. These notable outcomes were largely identified through discussion with each building's project manager, and included major variations and rectifications, process innovations, specific delays or problems experienced on site and high-cost or unusual design items. Further notable outcomes were identified by comparing the time, cost and risk experiences of each case study, thus identifying unusual circumstances for which causes could be investigated.

The small sample size means that insights drawn from this study are unable to be extrapolated across the whole industry. Furthermore, as each building is unique, it is difficult to draw direct comparisons between their value chains, despite the efforts to select case studies as similar as possible.

The analysis and findings presented in this report allow for known differences between the buildings and their construction processes wherever possible. The caveats in the analysis methodology are also balanced in part by the contribution of the Value Chain Group. This Group assisted in the interpretation of information and analysis over several sessions during the course of this assessment. The consultative process has enabled a practical interpretation of the information gathered from the case studies and some confirmation of the findings arising from analysis of the data.

The views and findings presented in this report are solely of the author, and should be treated as indications of the value chain experience in construction in Australia. This is a useful yardstick for consideration by the leaders of industry, insofar as the results of even this small sample contradict perceptions held in both the construction and steel industries.

5 Medium rise commercial construction was chosen as a sizeable market where steel framing poses a viable alternative to concrete. ABS figures from 2003 show that office buildings were the largest source of construction turnover at 19 per cent of total. Of these, 42 per cent were for buildings less than $5 million value, and 20 per cent between $5 million and $20 million.
Findings

The findings of this assessment are presented in three parts. The first part covers the quantitative assessment of the relative impact of the use of steel frames in construction. Following this is a discussion of some key characteristics of the construction value chain as noted in the case studies. The third part outlines broad action areas that, based on the previous findings, are likely to realise significant benefits for the participants of the construction value chain.

The quantitative part of the assessment shows there is no systematic difference on total construction cost in the use of steel frames or concrete frames. The case studies showed that time in steel-framed construction could be better or worse than concrete, although there is some suggestion that the time advantages of steel were not fully exploited in the cases studied. Total risk in the value chain is also unaffected by the use of steel frames, although where there was perceived risk associated with steel, higher costs were incurred to manage them.

These findings run counter to commonly held beliefs in the construction industry. A more extensive study, covering a larger number and spread of cases, is recommended to validate the findings presented here. As the findings stand, they seem to indicate that the method of construction chosen by the builder and other participants of the value chain is the most important contributor to value-chain performance (i.e. cost- and time-effective within tolerable risk).

4.3.1 IMPACT OF FRAME MATERIAL ON THE VALUE CHAIN

Cost: No systematic cost difference between steel and concrete frames

Comparing value chain costs of the case studies yields some insight into the relative cost proposition of concrete and steel frames. In order to remove differences of building size from the data, a measure of Total Construction Cost (TCC)6 per square metre of Gross Floor Area (GFA) was used. The results show three of four steel-framed buildings are less costly than the concrete-framed comparison. This appears to contradict a common perception that steel-framed buildings are necessarily more expensive than a concrete-framed equivalent.

Further analysis, as illustrated below in Figure 3, shows that the structural steel building frames7 contributed to 21–28 per cent of TCC. The concrete-framed case study shows a structural frame cost of 15 per cent to 21–28 per cent of TCC. The concrete-framed case study shows a structural frame cost of 15 per cent to 21–28 per cent of TCC. The concrete-framed case study shows a structural frame cost of 15 per cent to 21–28 per cent of TCC.

7 “Structural frame” has been defined here as all the structural steel (which includes reinforcement) and labour, plus concrete slabs and formwork. It does not include the cost of the basement, ground floor slab or roof.
8 The other two steel-framed case studies incurred major structural rectification and planned variation costs respectively, which may explain some or all of the excess per unit costs.

Footnotes: 6 Total Construction Cost has been defined as all costs of construction as well as any rectifications and cost overruns.
The comparison of the structural frame and total costs per square metre GFA relative to concrete is summarised in Table 2.

### Table 2: Value chain cost comparison summary

<table>
<thead>
<tr>
<th>Cost relative to Concrete comparison</th>
<th>Building W</th>
<th>Building X</th>
<th>Building Y</th>
<th>Building Z</th>
<th>Concrete comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural frame as % of TCC</td>
<td>+10%</td>
<td>+6%</td>
<td>+13%</td>
<td>Insufficient data</td>
<td>-</td>
</tr>
<tr>
<td>Structural frame cost per sqm GFA</td>
<td>-24%</td>
<td>-14%</td>
<td>+113%</td>
<td>Insufficient data</td>
<td>-</td>
</tr>
<tr>
<td>Total construction cost per sqm GFA</td>
<td>-54%</td>
<td>-37%</td>
<td>+18%</td>
<td>-24%</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gross Floor Area</th>
<th>13,500</th>
<th>7,200</th>
<th>17,300</th>
<th>45,000</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building location</td>
<td>Sydney suburban</td>
<td>Adelaide CBD</td>
<td>Sydney suburban</td>
<td>Melbourne CBD</td>
<td>Sydney suburban</td>
</tr>
</tbody>
</table>

More detailed cost analysis was conducted for Building W and Building X, which both show unit costs that were significantly less expensive than the concrete comparison. The analysis focused on discovering any relationship between the costs of erection and the cost of the frame.

The erection costs for the concrete-framed building were 23% of TCC, compared with 11% for Building W and 16 per cent for Building X. This 7–12 per cent erection cost decrement compares favourably with the steel frame’s 6–13 per cent relative increment in the total cost of construction.

Erection costs per square metre GFA were also higher in the concrete-framed building at $461/sq.m GFA, compared with $106 for Building W and $207 for Building X. This is a $254-355 per square metre difference in site-related cost, in which the concrete comparison was more expensive in all categories of wages, preliminaries, site services and trade costs.

It is difficult to deduce a root cause for these differences, however, in these case studies there does appear to be a trade-off between additional costs in a structural steel frame and people-related site costs.

### Note:
The amount of steel used in Building W and Building X is comparable to that for the concrete comparison. This suggests that steel price volatility need not be a barrier to the choice of steel framing, as a concrete-framed building may be just as sensitive to the price of steel.

### Time: No relationship between frame material and construction time

It is broadly accepted that steel frames can be erected quickly, and analysis of case study data shows that the structural steel components of the frames were erected in 35 and 40 days for Building W and Building X.

Equalising these elapsed times for the Gross Floor Area of each building shows that the steel-framed buildings can be similar, better or worse than the...
No obvious relationship emerges between the use of steel framing and the speed of frame completion or the speed of overall construction.

These figures are difficult to interpret for outright time efficiency of the materials used. The average elapsed time to complete 1000 square metres GFA of the structural frame includes ‘wait time’ incurred between the completion of one floor and the next, which may be to allow for other construction activities to occur, or as a result of delays. Speed of erection seems to be more obviously correlated to the GFA of the building.

Thus, it is difficult to determine whether the materials used are a driver of time performance at all, or if other factors, such as the method of frame erection, are of greater importance. Indeed, as several project managers confirm the speed advantages of steel framing, this raises the question as to whether steel’s proposition of speedy frame erection is fully exploited in the real world.

Frame erection can be carried out in more ways than one. Three of four steel-framed case studies used a ‘jump-start’ approach, which enables work to be completed on more than one front during construction. This method is employed to gain time to building completion, although the cases studied show that, comparatively, this is not always the case.

These outcomes suggest that while the techniques exist to gain time in construction, such as the use of steel frames and jump-starts, their potential benefits may not be fully realised in practice.

### Risk: no additional risk with steel, but perceived to be high risk

Risk may be defined as the possibility of experiencing different outcomes to those expected. In this sense, risk has upside as well as downside, though downside risk is most commonly investigated and managed. Risk is realised in the construction value chain as incremental costs or as delays, which translate to additional site-related costs such as preliminaries and wages.

In this assessment, an empirical approach to assessing risk has been taken, in identifying risks by their actual realisation as significant, declared deviations from the original plan. Looking across the case studies, five risk areas have emerged, differentiated by the source of the risk experienced and the bearer of the risk.

Each of these risks has different cost and time implications for the value chain, which have been estimated and expressed for each of the case studies in Table 6 as a percentage of Total Construction Cost. Ignoring design-related risks, which are typically borne by the developer for major variations in design, and risks arising from special circumstances, the figures suggest a ‘normal’ risk level of 1.6–1.7 per cent of Total Construction Cost, borne mostly by the builder.

<table>
<thead>
<tr>
<th>Gross Floor Area (square metres)</th>
<th>Building W</th>
<th>Building X</th>
<th>Building Y</th>
<th>Building Z</th>
<th>Concrete comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,500</td>
<td>15,000</td>
<td>17,300</td>
<td>45,000</td>
<td>10,000</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: Other measures in elapsed time in construction**

<table>
<thead>
<tr>
<th>Use of jump start</th>
<th>Yes</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

**Figure 6: Elapsed time in erection of structural frame and total construction**

**Figure 7: Elapsed time per 1,000 sqm GFA**

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12 Source: interviews with project managers. May not be exhaustive.
13 Other known risks (e.g., safety) affect the value chain, but were not observed as impacting the cases studied and therefore not assessed here.
14 The Building Proposition risks in Building Y and Building Z as well as the Supply – other risks of Building X are considered to be arising from special circumstances.
The greatest source of ‘normal’ risk experienced in the value chain is in the building proposition, or, the way in which the builder chooses to erect the building. This includes the sequencing of tasks (e.g. the use of a jump start, or building on two fronts), the use of specific equipment (e.g. tower cranes vs mobile cranes) and the process used to procure materials and secure their cost.

The builder’s success in this area is based entirely on the skill and experience of their building and project managers.

Two instances of realised risks related to structural steel in the case studies. In the first instance, the builder of Building Y took on an additional risk management burden for the (perceived) likelihood of late supply of structural steel. In this case, 1.4 per cent of TCC was incurred as additional cost due to the builder’s decision to procure structural steel before the completion of engineering design. In the second instance, 0.3 per cent of TCC was incurred by the fabricator of Building X for beams fabricated without the appropriate camber.

Both these incidents highlight perceived and/or actual problems in the steel supply chain, i.e. receiving the correct product on time on site. It is pertinent to note that the perceived risk had far greater impact on total cost than the actual risk experienced. The magnitude of the actual risk (0.3 per cent) is in line with ‘normal’ aggregate risk levels of 1.6–1.7 per cent of TCC, which suggests that steel offers no additional risk above that which is usually tolerated by the participants of the value chain.

4.3.2 NOTABLE CHARACTERISTICS OF THE CONSTRUCTION VALUE CHAIN

Timeliness

None of the cases studied were completed on the original completion date. Of these, two completion dates were radically changed (one significantly forward and the other significantly backward) to fit with the demands of future tenants. The other three ran over time by 8 per cent, 17 per cent and 21 per cent respectively. This shows a remarkable tolerance for unpredictability in the timeliness of construction activities. The cost of this unpredictability is absorbed by the builder, who experiences delays in progress payments.

Variations

Of the case studies assessed, two of five experienced major structural revisions after construction had commenced. Both instances were moves by developers to customise buildings for potential tenants, exposing the developer to additional risk of up to 30 per cent of TCC. The changes involved also have the effect of amplifying any building proposition risks inherent in the program. If the results of this sample are consistent in the medium-rise market, the advent of structural variations may be considered more of a value chain reality rather than an unusual occurrence.

Examining the case studies yielded three broad categories of variations, as summarised in Figure 8.

Of these categories of changes, only structural variations are more difficult to achieve with steel frames, largely due to the lead time required to fabricate the additional material. Superficial changes or rectifications are of similar difficulty and cost to execute whether steel or concrete frames are used. Finally, variations requiring expansion or extension of floor space are not generally commercially viable in a concrete-framed building, revealing an instance of upside potential in the use of steel frames.
‘Builder’s reward’

In all these case studies, construction was executed by the builder under a fixed price contract with the developer. This strategy removes substantial financial risk from the developer and shifts it to the builder15, who is then liable for any uncertainties in construction such as the reliability of material supply and quality of subcontractors’ work. Builders often pass this risk on to their subcontractors in back-to-back contracts, thus cascading the liability for additional cost and delays. In reality, however, the final liability lies with the entity most able to absorb the magnitude of incremental costs incurred when problems emerge while still remaining in business. These case studies show that this entity tends to be the builder. This outcome is arrived at through a cost recovery process at the close of a project, and normally involves the developer, builder and key subcontractors, e.g. steel, concrete and façade suppliers.

The builder currently manages their uncertainties in the value chain by contingencies in the budget. Considering builders alone, analysis of construction costs shows specific cost categories (e.g. hydraulics or structural steel) differed from budgeted costs by up to 28 per cent16.

Analysis shows that this uncertainty in costing caused builders to inflate ‘realistic’ construction budgets by up to 5 per cent. Any difference between these contingencies and cost overruns effectively constitute an additional ‘builder’s reward’ for the risk they bear, an amount over and above fees and overheads charged. The observable builder’s reward in these case studies has been calculated as 2–5 per cent of TCC, net of declared cost overruns.

All participants in the value chain, from architects to consultants to builders and even trades, employ similar risk management tactics. As such, the construction value chain may harbour multiple, compounded contingencies because of uncertainties arising from inefficient collaboration, and inequitable distribution of financial risk.

Interfacing

Interfacing structural steel with other building components was commented on as an area of difficulty in construction. The most common problem observed was the interfacing between steel columns and the ground floor slab. The holding down bolts require a high degree of precision and co-ordination from the steel fabricators and riggers as well as the concrete formworkers employed in the project, particularly in casting-in the bolts in the slab.

Various means were employed to manage the risks associated with this issue, for example, writing in the provision of a timber template for the floor plate into the steelworker’s contract, or ensuring adequate co-ordination between the parties by the project manager. It is interesting to note that although this is a critical issue in the use of steel frames, no risks were realised as a result of failure or difficulty in this regard. This would imply that any additional cost or time required to manage interfacing issues are absorbed by the steelworkers, concrete workers and/or the builder.

Estimation

Estimation is conducted at the very beginning of the value chain, and is a crucial milestone in the planning of a building. The estimation process creates expectations amongst all the participants in the construction value chain in terms of cost, building processes and time. These expectations tend to vary little over the course of planning and execution, unless tenant demand requires changes in building design.

At its most basic, estimation can be a ‘back of the envelope’ activity; at its most sophisticated, quantity surveyors and/or financiers develop extensive models to optimise financial outcomes. Regardless of the method adopted, the quality of the information utilised is essential to the accuracy of the result. This is as much the case for the cost of construction processes (i.e. the building proposition) as it is for the cost of materials, such as structural steel.

When evaluating the use of steel or concrete frames, the estimation process may not reflect that the optimal means of erection could differ in each case, unless an experienced builder is in consultation during the preliminary design phase. While this is an appropriate time to introduce innovation in construction into budgeting and programming, ‘tried and tested’ methods are usually established into plans by default, leaving the builder to experiment with innovation at their own risk.

This does not imply that process innovation does not occur. Rather, process innovation appears to be common, and is exhibited by four of five of the cases studied. This innovation experience tends to remain with the builder, however, and does not readily filter into the market’s pool of knowledge. The result of this is multiple builders using the same or similar process.

15 The developer remains financially liable for incremental construction costs incurred from design variations to the original agreement with the builder.

16 These ‘unders’ and ‘overs’ in the actual cost of construction compared to budget aggregated to a 0–3 per cent variance from budget in the cases studied.
innovations without the benefit of shared learning. When it comes time for the preliminary design of the next building, the aggregate experience of the innovation is often discarded as each builder considers it a one-off in their own context, and estimation reverts to old processes. In this way, construction is slow to evolve.

### 4.3.3 VALUE CHAIN OPPORTUNITIES

The underlying cause of the issues raised in this assessment is imprecise collaboration between the many parties involved in construction. The resulting inefficiencies in the construction value chain are well-known and broadly accepted as a mediocre operating status quo across the industry. Instances of poor programming, design flaws, inaccurate work, incorrect materials, unreliable supply and their associated rework are largely tolerated unless they create significant delays or cost overruns. Heavy attention is given to cost recovery negotiations at the close of each project, where the claim and counter-claim process nets a result to each party that is as satisfactory as the skill of their negotiator. Any initiative to improve the construction value chain must consider this ‘uneasy equilibrium’ in which the industry and its participants operate.

The value chain participant most likely to be affected by any improvements is the builder, who bears most of the inherent risk in execution and manages over 90 per cent of the total cost of development. The cases assessed show that the builder can expect a margin of 4–6 per cent of TCC, plus a ‘builder’s reward’ of up to 5 per cent of TCC after cost overruns and underruns have been paid from built-in contingencies. These returns to the builder are, fundamentally, for their financial accountability under a fixed price contract for the co-ordination of the many parties required to produce a building.

Reducing the co-ordination burden of the builder should therefore yield a commensurate reduction or elimination of contingencies, and hence the total cost of a building. This would benefit the builder in reducing its risk burden (and hence resource usage) and the developer in the total cost of the building. The simplest way to reduce the builder’s risk burden is to remove the fixed price contract, however, this facility serves to contain the potential for ever-spiralling costs in construction, and forces the detailed planning and co-ordination that is of benefit to the many players

![Figure 8: Actual cost difference to budget](image_url)

<table>
<thead>
<tr>
<th>Table 5: Observed value chain risks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source of risk realised in the Value Chain</strong></td>
</tr>
<tr>
<td>1. Design</td>
</tr>
<tr>
<td>2. Information</td>
</tr>
<tr>
<td>3. Building Proposition</td>
</tr>
<tr>
<td>4a. Supply – steel</td>
</tr>
<tr>
<td>4b. Supply – other</td>
</tr>
</tbody>
</table>
in the construction value chain. The alternative is to rearrange the risks in construction so that they are allocated more efficiently, and reduce the overall risk in the chain.

Repackaging the construction process

In order to reduce the co-ordination burden of the builder, the construction process can be broken into logical ‘chunks’ culminating in a construction milestone (e.g. completed foundation slab, completed frame, etc.) and outsourced to specialist ‘sub-builders’. The current use of subcontractors in construction outsources specific tasks and supply, however, the builder often retains the critical risks of integration.

For example, the erection of a structural steel frame may be offered as a package including detailing, fabrication, delivery, and installation, including the requisite interfacing with the slab and the roof. Similar steel supply offers already exist, but often lack the crucial task of interfacing, which is where the builder bears significant risk. The additional effort and risk to the steel supplier is minimal, however, the effect to the builder can be a reduction in their risk equal to the proportion of construction cost tied up in the structural frame, which in these case studies is 21–29 per cent.

Similar scenarios may be mounted for fitout and façade. Placing the interfacing risk with the provider of the materials requires more active involvement of the supplier in program planning, thus increasing the need for active collaboration between parties. It also puts the onus on the supplier to create workable process innovations that deliver cost and/or time savings.

Correctly configured, this strategy can dramatically reduce the overall risk in the construction value chain, however, it may be unsuitable for projects tolerating major variations and highly aggressive timeframes. Any overlapping of ‘chunks’ would compound the building proposition risks rather than reducing them, thus annulling the benefits of the strategy.

Web-enabled collaborative planning

The use of 3D modelling products has delivered strong results overseas and has increasing exposure in Australia. Web- or intranet-hosted options would create a seamless design environment at all levels of detail. Adding a programming dimension to this tool extends the benefits to the sequencing and co-ordination of tasks in construction.

Table 8: Categories of changes during construction

<table>
<thead>
<tr>
<th>Change category</th>
<th>Examples</th>
<th>Impact on steel-framed value chain</th>
<th>Impact on concrete-framed value chain</th>
<th>Frequency of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural variations</td>
<td>Adding floor or column strength</td>
<td>Incremental cost of trades</td>
<td>Incremental cost of trades</td>
<td>4 of 5 case studies</td>
</tr>
<tr>
<td>Expansion/extension</td>
<td>Adding space to floors</td>
<td>Cantilever extra floor space with additional fabricated steel</td>
<td>Not (usually) commercially viable</td>
<td>1 of 5 case studies</td>
</tr>
</tbody>
</table>

Use of this technology reduces the co-ordination burden of the builder by making all construction information transparent and accessible. It would help enable the outsourcing of construction milestones as described in the previous paragraph. This facility holds particular promise in managing variations, and may substantially reduce the risk (and therefore cost) of executing changes to the program after the commencement of construction.

Industry-wide measurement for performance

Measures commonly used to gauge construction performance are often unrelated (or not directly related) to value chain outcomes. For example, ‘floor cycle time’ is often quoted as a measure of the time efficiency of frame erection. This measure is usually quoted as the minimum – or best – figure experienced in construction, and leaves out any waiting time between the completion of floors. In other words, a low floor cycle time may feature in a construction process that experiences a prolonged time to frame completion, if construction activities are sequenced poorly. At worst, this can create a mismatch between the performance targeted by the builder and the performance required by the developer or owner. At an industry level, this

17 Steel-framed cases only.
prevents the participants from efficiently adapting processes and innovations that truly deliver value.

A further complication is that the exchange of information in the construction industry is characterised by anecdotes and hearsay. Detailed value chain information, such as that presented in this paper, is collected within many companies, but often not utilised for learning and continuous improvement. This is particularly the case amongst the small- to medium-sized builders, where such a facility is a business luxury, or conducted case-by-case.

The collection of fact-based value chain information across the industry will assist in estimating, budgeting, and benchmarking construction performance. It will also give visibility to the measures that connect construction processes with the value chain outcomes that are of primary importance to financiers, and hence developers. A collation of process data such as innovations employed will also yield a powerful benefit in promulgating the efficacy of new processes18.

**A more responsive steel supply chain**

The steel industry can usefully contribute to the reduction of builders’ risk by improving the reliability of its product or service supply chain.

The structural steel supply chain is different to the structural concrete supply chain, as it has the additional step of fabrication and one or two additional participants, as illustrated in Figure 9. Furthermore, steel fabrication is often uniquely and precisely configured in each building, creating a higher likelihood of refabrication in the event of variations or design errors. This issue more than any other supports a continued negative perception of steel framing as being ‘more difficult’ and ‘more expensive’ than a concrete alternative.

While the steel supply chain is managed to fit with other construction activities in the original plan, it poses significant delays compared to structural concrete when variations are made. Once the original steel order has been committed to the fabrication process, any changes to the structure that are not superficial will require refabrication, which incurs a lead time and additional cost to the developer.

The steel industry can deliver tangible, attractive benefits to the construction industry by dramatically reducing the lead time to respond to structural variations. A combination of the follow strategies borrowed from the manufacturing industries may be appropriate for achieving this outcome:

- **Mass customisation** is the production of unique parts from standardised structural steel components, so that there are common ‘source’ products available for use in different buildings. This creates alternate sources of supply for the construction industry. This requires more than just the availability of standard sections, but prefabrication to standard columns and beams.

- **Manufacturing postponement** requires the customisation of products to be done as late as possible in the fabrication process, rather than each product being fabricated in one step. This allows for process efficiencies, yielding reductions in manufacturing lead times. Where possible, final detailing would ideally be done on-site, thus further reducing lead time and alleviating errors in interfacing.

A fact-based assessment of the steel supply chain is recommended to identify the actual problems experienced in the supply of steel, and the benefits to the industry in addressing them.

**Conclusion**

The small sample used for this assessment suggests that steel-framed construction offers the same value chain outcomes as concrete-framed construction. The findings presented in this report are a significant departure from commonly held perceptions of steel framing and its impact on construction. This is perhaps due to the benchmarking-like approach taken by this study, in contrast to the more common method of comparing different, theoretical models for a single building. A more extensive study, considering a larger sample size and spread of buildings, would provide a more statistically sound basis to the findings of this assessment.

But, why change? Construction today is an uneasy equilibrium between precise planning and imprecise collaboration between the many parties involved. With up to 5 per cent of total construction cost locked in contingencies, there are clearly dollar benefits to be enjoyed from removing the uncertainty from the construction value chain. The commercial construction industry in Australia experienced turnover of $57 billion in 2005-0619, of which 5 per cent represents nearly $3 billion. This value may be viewed as money spent every year by developers, and compounded in

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future years by purchasers and tenants of building assets, for unnecessary risk borne in the value chain.

The true opportunity forgone in construction, however, is in innovation and growth. Allowing more choices in materials and skills to flow into common practice will benefit the Australian economy, and a more productive use of available resources can give rise to growth through greater volume, and even possibilities in export. It is difficult or impossible to calculate the cost of forgoing this opportunity.

The opportunity for the steel industry is clear: to orient more effectively to an important customer segment, garnering greater market share in Australia and through export in construction. Steel industry players may consider an investigation of the opportunities in this report, and the incremental costs and benefits of supporting the construction industry in their execution.

The process of this assessment has shown that the characteristics of construction leading to excess cost and time are widely known amongst its participants and tolerated as ‘just the way things are’. This speaks of the need for a fundamental shift in the performance mentality of the industry, a large undertaking, with similarities to transformational change in heavyweight multinational corporations. Ultimately, it is the leaders of the construction industry who must decide: Is the status quo good enough?

In the interim, both the construction industry and steel industry may consider the findings of this report as an indication that frame material may not be a major driver of construction cost, time or risk. A steel-framed building, like a concrete-framed building, may be constructed well or constructed badly, and it is the process of construction that is the most impactful variable in value chain performance. In the interest of innovation and growth, steel-framed alternatives deserve a well-represented place at the preliminary design table.

### 4.4 COSTING IN STEEL FABRICATION FOR CONSTRUCTION

**By Andrew Marjoribanks**  
Venlaw Park Pty Ltd for The Warren Centre

#### 4.4.1 INTRODUCTION

The costing of steelwork for construction is heavily influenced by design requirements so that there can be large variations in cost between different designs for the same building, and between one building and another. Designs calling for many complicated connections, for instance, are much more expensive than those needing a minimal number of simple connections. In the current Australian construction industry environment where steelwork costing is simplistically expressed in terms of dollars per tonne, a complicated design can be as much as twice the dollar rate per tonne of a simple design, causing frustration to would-be users of steel and leading to the perception that steelwork pricing varies irrationally, and consequently the perception that using steel carries a high cost risk.

The Costing Group of the Steel – Framing the Future project therefore examined the factors involved in the process of costing fabricated steelwork for construction, and reviewed developments that will improve this process and lead to more cost-competitive designs and solutions in steel.

#### 4.4.2 THE CONCRETE FACTOR

Concrete is the dominant material in the Australian construction industry, having about 87 per cent of the market. Until two years ago it was even higher at 95 per cent (Market Intelligence Company 2005). Consequently builders, designers and quantity surveyors have great familiarity with concrete and understand its costing very well. In addition concrete designs are less sensitive to complexity in that the main variable is formwork which can be constructed to give a variety of shapes without necessarily requiring large increases in labour costs. Concrete itself and its attendant, reinforcing steel, is reasonably standard in cost and the ratio of steel to concrete well understood so that cost estimating for a project is comparatively simple. Quantity surveyors are therefore able to give reliable cost estimates at the inception of a project and even if all of the design has not been finalised, can be reasonably sure of their ground, given that whatever the final configuration happens to be, the quantity of concrete plus reinforcing is unlikely to vary
dramatically. Even if it does, estimating the cost of the final design and any variations that occur is largely a calculation based on the volume of concrete plus the reinforcing. The cubic metre cost of concrete and the per tonne rate of reinforcing steel are usually fixed and the quantities can be adjusted quite readily to suit the complexity of design, or later changes to design, and formwork is usually quoted per square metre of building, allowing considerable latitude for design evolution as the project proceeds.

4.5 TECHNOLOGY ISSUES GROUP

4.5.1 GENERAL

This section deals with one of the most pressing issues identified by the project planning phase, namely, the introduction of new technology in the design, detailing, supply, fabrication and erection of steel framing. In fact, it was found that most of the new technology exists and is proven through extensive usage overseas.

Other key issues in this area are fire protection and the need to increase the level of off-site fabrication.

Thus, the issue of technology is far reaching and covers all areas of the fabricated steel supply chain. For this reason, this section does not contain a single issues group report, rather it contains a series of papers on the pressing technological issues at the time.

The adoption of these new, though proven technologies has the potential to significantly improve steel’s competitive position compared with concrete in the key areas of cost, time, accuracy of construction and minimisation of site re-work.

4.5.2 NEW GENERATION PRACTICE IN DELIVERING STEEL-FRAMED STRUCTURES IN AUSTRALIA

By John Hainsworth and Stuart Bull
ARUP for The Warren Centre

Summary

This paper presents an idealised method of implementing the 3D technology currently available, to assist the design and delivery of a steel-framed structure, in a more efficient fashion.

Drawing on experience from a successful steelwork culture in the UK, we hope to outline that the strength of 3D technology is within the process of improved delivery. The advantages that 3D practice unlocks, as an enhanced information and data-flow mechanism, is currently under-utilised within the Australian steel industry today.

The willingness of the worldwide steel detailing communities’ continued adoption of 3D-based technology is admirable; however both the upstream and downstream ends of the supply chain in Australia have generally been slower to adopt similar practice (QISD, 2005).
Contributory advantages towards successful projects when the entire supply chain is operating within a 3D environment have been witnessed in steel (Sawyer, 2005) and concrete (Construction Project Information Committee, 2003) structures. Where structural steel solutions pose further advantage, though, is in the streamlining of an entire frame’s delivery to site as a ‘right first time product’ – this process is routinely accomplished overseas through team co-operation, established work flows, and co-operative data management and transfer.

Introduction

In comparison with overseas markets, it can be considered that, by and large, the existing processes involved in the design and delivery of a steel-framed structure in Australia are somewhat fragmented.

This paper is advocating change to the processes that contribute to the supply of a steel structure. In order to understand the processes that we might consider changing, and indeed how to implement any change, it is necessary to compare current practice with the new paradigm on offer, to identify some of the inefficiencies and problems affecting the industry today.

As part of this project a survey was devised aimed towards understanding the adoption and use of 3D technology within consultants’, detailers’ and fabricators’ organisations across NSW and the ACT. Throughout this paper the authors’ offer their own interpretation of the survey (The Warren Centre, 2006) results returned from 40 consultants, 10 detailers and 11 fabricators.

Starting with a brief introduction to the concept of BIM (Building Information Modelling) and how ‘computable data’ contained in the model contributes to the advantages of a steel-framed structure, we then outline a critical description of the current tendering process of a steel-framed structure.

While current practice may already employ 3D technology in some aspects of its delivery, we go on to explain an advantageous alternative approach, which can unlock the enormous potential of an enhanced linear flow of information. We then look at the survey to see if the industry is ready to embrace a new way of applying the technology.

We discuss concepts of ‘phasing’, ‘dimensional sign-off’ and review mechanisms that can promote a more refined, collaborative passing of information through the design process before we outline in more detail some successful applications of the technology in our local market and overseas.

Additionally, and where appropriate, we identify lines of communication and work flow that will undoubtedly challenge current contractual mechanisms and skill bases. The finer points of future training, responsibilities and liabilities are considered beyond the scope of this paper however, some arrangements already exist that can fuel the collaborative processes required to change.

Building Information Modelling (BIM)

In many aspects the software already utilised by the fabrication industry has enlightened software developers to offer similar powerful tools to the upstream design community.

For many years the fabrication industry has relied on software that operates in a 3D environment, but which is in fact more reliant on the data held by the 3D objects to drive other processes such as material ordering, drawing preparation, bolt scheduling and the like. It is only in recent years that the acronym BIM has been coined to encompass this process, and the future of design software seems almost unlimited as to how wider-ranging information relating to specification, design, construction, management and decommission of a building might be manipulated in a 3D environment.

Analytical design information from engineering packages is now able to be imported/exported through a wide range of software packages to avoid costly reworking and error in re-modelling of structural elements; currently it seems this is best kept in a one-direction transfer e.g. design-analysis to 3D CAD, then detailing to fabrication, rather than the ‘holy grail’ of bi-directional exports where revisions in the CAD model might influence the analysis model with a ‘ripple effect’ update.

Conventional design software is ever changing. However the concept of the single ‘building information model’ where the objects possess relationships and are information rich (i.e. not just geometric size, but also for example manufacturer’s details) is not yet a reality within a single software package.

Interoperability

To overcome this perceived short fall in the single building model, a vast range of software on the market aims toward some form of compatibility. Termed ‘interoperability’, the transfer of data between software packages is becoming easier, as each release of each software package seems to continually morph.
It seems the software developers recognise that their commitment to interoperability issues can contribute to an estimated 30 per cent reduction in the cost of construction spent on gathering, entering, exchanging and re-entering data and information (National Institute of Building Sciences, 2005).

Traditionally detailers and fabricators prefer the specialist steelwork detailing packages such as Xsteel®, StruCad®, Prosteel® or BoCad®. These are now able to ‘talk’ to the upstream packages used within the consultants’ offices, or to downstream ordering or process packages used in rolling mills, stockyards or on the shop floor. Collectively, file formats such as CIS/2 (CIMsteel Integration Standard), IFC (Industry Foundation Classes), NC (neutral control), SDNF (steel detailing neutral format) and others, attempt to ensure that data can be represented, shared and managed between the myriad of software applications used across the steelwork industry.

Aspects of interoperability between software, and indeed the larger particulars of BIM are beyond the scope of this paper, however the concepts presented are what is commonly referred to as ‘BIM friendly’; in this regard the passing of data (rather than re-entering data) is well practiced within the fabrication industry. Indeed the resulting fabrication models offer a superior level of ‘as built’ information for future generations that, whilst seized by the concrete industry, cannot be guaranteed by nature of the on-site activity necessary to finish the latter.

Current Practice – Tender Stage

Let us consider the ‘traditional approach’ to the stage where a consultant’s design is presented on hard copy drawings to prospective tendering fabricators.

With tender information generally presented on hard copy drawings, we see defined breaks in information flow, and repeated passing of information back and forth through the supply chain to achieve the goal of a steel frame’s delivery to site.

An idealised flow of information through a project might be considered as a linear line (refer Figure 1), with each decision or contribution made on the project complementing one another.

Within the current normal practice of steelwork tendering, and even when supplied with a bill of quantities or similar, a tenderer’s necessary task to ‘catch up’ while interpreting the information is both time consuming and error prone, and might not in fact offer a common base for each fabricator to price competitively. The information the tenderer seeks is generally not offered in a format that promotes a linear flow of communication.

Furthermore, by the time a fabricator receives the documentation to price, key decisions have already been made that might not necessarily suit their workshops’ preferred method of fabrication.

This ‘arms length’ tender process results in a reduced opportunity to influence the project through rationalised section choice or fabrication techniques, and there is clearly a break in information flow that takes time to catch up, is prone to misinterpretation, and quite often identifies shortfalls in the information, which is commonly priced by contingency.

During the selection of a fabricator and detailer, the design team is undertaking necessary work to complete ‘for construction’ documentation. Developed drawings and details are once again offered in hard copy format, and the catch-up process is repeated and magnified, often resulting in unanticipated detailing hours, or materials, or fabrication effort which may have to be re-measured.

New Generation Practice – Tender Stage

Now let us consider an alternative way to promote the linear, or complementary flow of information: by starting 3D models at the early stages in the design process.

At an early stage a 3D model can be prepared relatively quickly. Undertaken by the consultant, these models simply comprise ‘beam and stick’ elements (i.e. without connections), and while reflecting the general complexities and principles of the project at hand, they do not need to be wholly complete or fully designed.

Unconstrained by ‘finer detail’, these models are firstly prepared to convey and understand the ‘big picture’
aspects of the project; and from them benchmark material lists and ‘unformatted’ GA documentation for pricing purposes can be obtained for co-ordination and review.

By offering general arrangement framing drawings and material lists from the early consultant’s model, the input (or potentially, the selection) of the fabricator can be sought at any time during the design stage. Add to this a factor of confidence that the tendering fabricator might gain by understanding that the project is in the process of being thought through, and that they might influence some aspects of the delivery, and this should promote a fair price from them.

Of course, the process of seeking fabricators’ expertise could be considered fraught with speculation of loyalties, however if this can be overcome, their input can only be beneficial to the overall delivery of the frame.

Survey results – is the industry ready at tender stage?

According to The Warren Centre survey (2006):

- About 33 per cent of consultants surveyed are documenting their projects in 3D, and 73 per cent suggest they would be willing to pass their model to a fabricator for continued use. Interestingly, only 8 per cent report that they are using one of the mainstream software packages that could in fact be manipulated at the costing stage by fabricators, with 55 per cent of the fabricators expecting interoperability issues between software. The large discrepancy between willing consultants and their software choice may be due to an ignorance of the information that the fabricators could best use, or indeed they may have measures in place to convert the files for the fabricator.

- Only 22 per cent of consultants currently offer material lists with the tender documentation they issue. In reply to this 55 per cent of fabricators say they could use this type of information to check their offer, and in fact 36 per cent suggested this would reduce their offer.

- More than 80 per cent of the fabricators outsource their detailing and 75 per cent say they would prefer them to use 3D software. In response, 90 per cent of detailers use 3D software, and 43 per cent say their offer would be influenced if a consultant’s model were provided.

Current Practice - Design Stage

The survey results offer an interesting suggestion that detailers are already predominantly able to undertake their work in 3D, and that their fabricator clients expect this, regardless of whether the rest of the team is able to interact with them on the same technological level. It seems the current practice, albeit assuming technologically advanced and committed detailers are appointed, is to use 3D processes to fuel delivery.

Generally, within current practice, the design team is undertaking necessary work to complete ‘for construction’ documentation, during the selection process of a fabricator and detailer. However, the finalised drawings and details are routinely offered in hard copy or 2D CAD format to a successful fabricator, and so the catch-up process illustrated on Figure 1 is repeated and magnified.

Additionally, insufficient regard at an early stage to rationalisation of section sizes and connections can lead to over-complicated fabrication. A minimum weight structure might be welcome in some circumstances, but to assume that this can contribute positively to a reduced cost in all instances is misguided. With fabricators kept at arms length until the last possible moment, the cost savings of their advice with regard to the comparable pros and cons of repetitive structure and connections versus slightly increased weight, might only become apparent when its impact arises too late in the delivery process.

The detailer is charged with the task of collating all of the information presented to them in a range of formats, such as consultants’ drawings and supplementary sketches, to produce a set of 2D drawings of individual members suitable for the fabricator’s workshops personnel to understand and fabricate. These drawings, looking very similar regardless of whether they were produced using 3D technology or 2D methods, are offered to the consultant for approval in a 2D format.

Commonly, the consultant then re-addresses the information on the drawing sheets ‘in principle’ approving aspects such as member size, connection suitability, steel grade and the like. With the noted exception of some critical items such as aesthetics or structural philosophy that may bear impact on the project, issues such as erection sequence or fabrication method are not generally commented on, or indeed understood.

Furthermore, a large amount of the detailer’s time will be spent ascertaining fundamental concepts, such
as confirmation of the size of a member, or where a member should be positioned. The way this is done is most commonly through the submission of Request for Information forms (RFIs) to the design team, a fragmented 'non-linear' task that clearly takes time and which is undertaken in isolation to the upstream design.

In many cases this work is indeed necessary 'design development' or clarification of true but misguided oversight on the design team's part. Just as commonly, the design team might have already considered an issue, but has simply failed to pass the information on in a suitable fashion that cannot be misinterpreted.

With potential shortcomings in consultants' documentation, the detailer spends a disproportionate amount of time cross-referencing between various parties' drawings, raising RFIs to slowly build a concise understanding of the project that they are undertaking. Inadequate/ineffective use of technology in design and documentation (e.g. poor application of CAD techniques) is cited as one of the major contributory factors to cost over-run, re-work and applications for extension of time (Engineers Australia 2005).

In our opinion, when presented with drawings for approval, the consultant pays little regard to when or how the frame will be delivered. For example, the consultant can often not be aware of any priorities within the approval process, or the consequences that any 'tweaks' they might request on the drawing have on the overall fabrication and delivery of the frame.

Furthermore, any late but necessary changes might be agreed in isolation from the downstream detailing and fabrication parties. While it can be argued that change might be made easier prior to fabrication, it is often the disruption of the process that is not fully understood upstream of the fabrication process. An uninformed understanding of the necessary mechanism for change can result in animosity due to claims for unanticipated detailing hours, additional materials, or fabrication effort arising from those changes.

**New Generation Practice – Design Stage**

Having undertaken the 'big picture' initial 3D model and utilised it for the tender process, the consultant continues with the design in a fashion that is all encompassing of upstream and downstream needs. They consider and interpret both the client's and the design team's requirements, but just as importantly incorporate the detailer's and fabricator's needs with due consideration to the final steel erection sequence and delivery program.

Of course the undertakings of design cannot be arranged in a true linear process. Figure 2 is a far better way of describing potential advantages of inviting a fabricator's early input to the project. Drawing on fabricators' experience can contribute to an optimum design process and reduced cost, and this is best enjoyed early to maximise the effect of their advice on the project.

A consultant's upstream role is well understood; how they might balance this with their new downstream responsibilities is a challenge the fabrication industry needs to address by way of education. The recent ASI presentation outlines the concept of the effective and flexible Just In Time (JIT) fabrication process in the UK, and this should be understood as one of the keys to the future success of the industry.

Indeed, in order for the steel frame to be delivered to site in the most efficient manner, the JIT process begins in the design office, and this is facilitated by the concept of phasing.

**Phasing**

At the earliest opportunity, and with the fabricator's assistance, the design team assigns division lines running vertical (grids, or column lines) and horizontal (floors, or splices) which effectively define portions of the steel frame in erectable sequence. These portions are now considered as sacrosanct, and are the key to a smooth project delivery. The consultant's responsibility is to educate and guide the client and the remainder design team through their necessary decisions in a sequential 'phased' fashion.
Each phase can have a range of particular characteristics and influences that vary from project to project. Commonly a phase will be defined by a workshop’s weekly output, however other designations might include a difficult access location on the site, or an area of particular paint treatment, or even a known rolling date of a certain section at the steel mill. In most cases the phase has a workshop time-slot, which is linked forwards to the overall erection schedule, and linked backwards to allow sufficient detailing time.

The mainstream design process now continues with these phases in mind. At a macro level on the project, each decision, while obviously not made in complete isolation, is prioritised by the phase in which it lies, and even the design team meeting agendas might be structured in this fashion.

For the process to remain linear as possible, it is important that the design of a phase is completed to a level of detail that can be passed on to the detailing process.

At a micro level, each element of work is completed in a sequential, phase-by-phase manner. For example, the finer points of a gutter support detail on the 12th floor of a project, is of minor significance when compared with a baseplate position in the first erectable phase. Equally important to ‘ignore’ is the comparatively bigger issue of fine-tuning a column size in phase 4, at the expense of a beam connection of seemingly minor significance, but most necessary to complete phase 2.

Without exception there are issues as to how one ‘phase’ interacts with another, most commonly in the form of interconnecting members, so as to avoid the likelihood of site drilling or welding, and these common effects need resolution in a similar fashion.

This method of phasing may seem daunting and restrictive, however the UK industry continually, and routinely, operates in this fashion, both upstream and downstream of the supply chain. With continued refinement from project to project, and practised application, the argument that the process disadvantages steel in comparison to concrete frames will, over time, give way to a tendency to perceive steel’s ability to be ‘right first time’.

Notwithstanding the good intentions of phasing, there is effectively a freeze date on design information, which invariably needs a mechanism to allow change prior to fabrication. As a solution to this, there are approaches of isolating the phase or phases in which the change is impacting and removing it from the critical path of delivery. Likewise, if it is deemed unavoidable that the change will impact on the JIT, it is not uncommon in the UK for steelwork to be manufactured and erected in its original form, with altered elements then later removed or retrofitted, this approach commonly being considered more beneficial to the overall project than delaying the frame’s delivery.

**Passing of models and dimensional sign-off**

Considering now that all the information amassed and agreed upon occurs in a phased fashion, the consultant is well placed to continually transcribe the resulting decisions and information into a phased 3D model. It is not uncommon in the UK for a detailed 3D model of the entire project not to exist until the final phase is completed. In simple terms, the various phases of the model are at a percentage completed in a manner that reflects the pending issue to the detailer.

Predominantly in the UK an engineer’s documentation will include all the necessary dimensions to allow the geometry of the structure to be set out on site, and just as importantly, to be scrutinised. In Australia it is recognised that the practice is different, with the architect holding overall responsibility for dimensions. In the UK the architect will assign comparatively few dimensions, but they will check and concur with the engineer’s positioning to a level that is appropriate for their own ‘conceptual’ requirements to be met.

By nature of placing the elements in the model, an Australian consultant employing these techniques will be assigning geometrical fit to those elements, and a ‘by product’ of the model is the ability to generate all the necessary dimensions to define and place the element in an XYZ space. The generation of general arrangements drawings from the model are then automated to include dimensions on the sheet, and while responsibilities are shifted if an Australian consultant presents these in their document set, there is strong virtue in the fact that a figured dimension is at least in place and offered for scrutiny; whether the dimension is correct or not is then subject to approval, and there is a numerical figure offered for dialogue to assist the approval process.

One of the overriding advantages of modelling steelwork frames in 3D has already been seized by the detailers: if a member is deemed correct in the model, and is fabricated correctly, then the member will fit on site. In this respect the onus on the dimensions to be correct at the time of fabrication is important; but, with all necessary dimensions and their influences on other dimensions all being contained within a particular phase, there is the opportunity for a relatively easy sign-off procedure before passing on to the next stage.

The consultant’s model can include the principle connections for manipulation and copying by the detailer. In this regard, their efforts are concentrated on solving the concept of the connection with the
likely complications of incoming and influencing members being addressed. Most commonly, simple cleat connections and the like are then added by the detailer, who is best placed to apply the preferred method of connection dictated by the particular workshop that they are supplying.

With the consequent passing of the phased models, accompanied with the necessary dimensional sign-off, the detailer can concentrate on the task of supplying the fabricator with their deliverables, with minimal RFI production, and enjoying the increase in their productivity that this will bring. To continue with a spirit of co-operation, it may be beneficial to consider embedding personnel temporarily across offices. At the very least, an explanatory review meeting would assist in smooth transfer of information to the next stage in the process.

During interactive ‘fly through’ review meetings, the combined knowledge held within the team can be shared effectively. The overlaps and dependencies between disciplines become clear, and the responsibilities and interfaces well defined, the result being notable reductions in the overall construction costs (Construction Project Information Committee, 2003).

The methods for clash detection, for example between steelwork and duct elements can be automated within design review software. However, this does not alleviate the need for a systematic visual review to highlight other potential problematic aspects; for example, a column not extending to a modelled foundation is clearly not a ‘clash’ that would be identified by software automation, but obviously would be a significant issue should it be missed during review and the column is fabricated to the length modelled.

Interactive 3D models also play a key part in the necessary approval process of workshop drawings. The detailer still offers the customary 2D drawings and marking plans, but supplements the submission with a 3D model, in a read-only format that can be viewed easily. The model is used to understand the element depicted on the sheet in context to the overall frame (and vice versa), and can also be superimposed on the original consultants model to quickly identify any anomalies.

Co-ordination and approval

The development of consultants’ models can incorporate key aspects of the foundation solution, or more increasingly, architectural elements and mechanical plant and service runs – refer Figure 3.

While not so important for the downstream process, a multi-disciplinary model allows components from different design disciplines to be integrated into a 3D model environment, where the validity and compatibility with other project requirements can be tested. This can assist co-ordination in the design development, ensuring that changes are unlikely or, at least, made earlier and less expensively.

Ideally, each discipline contributes in a 3D manner, working within their particular software of choice and the models are then combined over the top of each other within readily available 3D review software.
see an early rationalisation opportunity with the model.

Of the consultants that produce and use 3D models, just over half model principal connections. Of the 29 per cent of firms who do not make the model available to the design team, 62 per cent would expect additional fees for such a service.

Some 67 per cent of detailers advise that it would help their work if principal connections were included in the consultant’s model.

Of the consultants who already undertake 3D models in the design phase, around 40 per cent maintain the model through to construction completion, while 75 per cent would consider passing their model to the fabricator. That same percentage also see the value in being given a fabricator’s 3D model to assist with the approval process; 95 per cent anticipate their usefulness in the aspects of geometry and sizing approval, 52 per cent anticipate a reduction in RFI documentation, and 33 per cent see the value in early standardisation from the model.

3D technology driving JIT fabrication and erection

Increasingly popular in the UK is the Just In Time practice where the material lists from the 3D models are used to establish the necessary information to batch material ordering processes across projects. This has two advantages. Firstly the fabricator can take advantage of bulk delivery or particular rolling dates coinciding at the mill. Secondly, it culminates in the receipt of that material as close as possible to coinciding with the detail drawings to the workshop.

Further skills of the detailers using 3D technology include the ability to nest plates in efficient stock sizes, and to match available stock lengths of sections to the required end use element, hence minimising the amount of waste material.

Detailers supply information to the fabricators to enable the division of the phases into ‘lots’, where each lot represents a transportable, sequenced and erectable portion of the structure, fundamental to the order in which it is processed in the workshop. Stockholding costs can be minimised, and the building can be delivered on a succession of trucks in erectable sequences that will be of huge benefit to contractors operating on confined sites. Some UK fabricators even utilise the software’s ability to produce ‘point to point’ bolt lists, which give the erection team a detailed breakdown of exactly which bolts are necessary to connect one part to another, for each and every member on the project.

The way 3D technology assists with JIT is well advanced with NC file output from 3D models facilitating the rapid transfer of information to workshop cutting and drilling machinery. The welding of end plates, fin plates stiffeners and the like to the cut sections is currently undertaken ‘manually’ but in a rapid production line environment.

One notable point of the process is the very infrequent use of on-site welding in the UK. This reflects the confidence the UK industry has in 3D modelling and the assurance that once manufactured correctly, the final frame will be a direct real-life representation of its virtual counterpart.

Survey results – is the industry ready at fabrication stage?

The survey shows 80 per cent of detailers routinely get asked to supply NC files from their models, and 90 per cent of detailers are asked to supply material lists and bolt lists. By contrast, a recent Australian Institute fabricators forum identified that despite distributors and rollformers’ ability to deal with electronic data, fabricators do not generally include this data in their demands from detailers. This is supported by the fact that only 27 per cent of fabricators state their workshops have the ability to process NC data.

Project examples

Examples of high-speed design, fabrication and erection as well as collaboration and co-ordination of the many parties overseas are demonstrated by buildings such as Terminal 5 at Heathrow Airport and the new Emirates Stadium in the UK – refer Figure 5.
The construction of the Emirates Stadium roof trusses features here as an example of a rapid fabrication to delivery time: triangular trusses some 205m long x 15m deep and weighing 700 tonnes with the primary trusses being fully site welded due to transportation restrictions. The primary truss supports a series of secondary girders, which in turn span onto a doubly curved perimeter truss. The roof geometry is therefore very complicated, but with a consultant 3D model then being used as a background for a fabrication 3D model in turn with direct steel CAD/CAM fabrication.

A local project which has taken tentative steps towards a consultant/detailer/fabricator collaboration has been the façade support steelwork to a shopping centre in Parramatta, NSW – ref Figure 6.

This project allowed the consultant and detailer to co-ordinate, fabricate and erect the secondary steel frame with increased confidence. With additional complications of a bolted glass façade being fabricated overseas, the setting out of the secondary steel was critical. The margin for error was small with tight deadlines and a restrictive site boundary. The successful delivery and installation of this façade can be in part attributed to the way the process was rehearsed in a collaborative virtual construction environment.

Another project that has demonstrated collaboration of BIM on a large scale is the Khalifa Stadium redevelopment in Doha, Qatar – refer Figure 7. This project enabled engineers, detailers, fabricators and contractors in several countries around the world to design, fabricate and erect a highly complicated structure with minimal RFIs and constructional errors.

For this international, integrated design team approach to succeed a new work flow would have to be introduced, and re-organisation of the way steel contractors are appointed would be required.

**Beyond fabrication**

Interoperability and collaboration go hand in hand and it potentially falls to the client, or the main contractor in a Design and Construct environment, to insist the team works this way. In Finland for example, interoperable BIMs are already a central part of construction practice and future strategy, to the extent that Skanska, a very large European project manager, will only accept input to their projects from designers who can deliver 3D models.

This initial step into a BIM environment then leads into 4D and 5D construction planning.

Planning in 4D is the ability to link a project programme with 3D CAD data to create a real-time graphical simulation of the planned works, effectively 3D plus time.

The British Airports Authority Terminal 5 team used the 4D process to reduce construction costs by 10 per cent (Figure 8) (Navisworks 2006a).
An example of a local project applying this technology is the Lane Cove tunnel project in Sydney, where Thiess John Holland JV used Navisworks ™ and Navisworks Timeliner ™ to assist in risk management and communication (Navisworks 2006b).

Adding a fifth dimension offers the determination of cost through direct interpretation of quantities from the 3D model. Termed 5D, this approach removes the need for manual quantity take-offs with its inherent potential for error, and speeds up the process for evaluating the relative merits and costs of competing options.

Concluding remarks

3D technology is widely accepted as contributing to the continued market share of steel within the UK construction market.

This paper has offered discussion as to how data might be passed in a more linear controlled fashion between like-minded, technologically aligned parties. Which disciplines these parties should represent, and at which stage they each might work or take responsibility for the information which needs to go into the 3D model environment (as well as out of the model) has an impact on the success of the technology.

The required change to current practice suggests that existing contractual arrangements and methods of procurement should be scrutinised to maximise the impact of the linear design process that 3D technology enables.

Phasing

To optimise the delivery of steelwork through a ‘production environment’ needs careful education of the client and the design team to the extent that the whole effort is a process. There are many opportunities for design change during the process, but there is also phased information freezes on which the downstream processes depend.

The mentality of phasing needs explaining to clients/tenants and consultants, such that it is not a concept to be afraid of, but rather a way of ensuring that best value can be obtained by off-site manufacture: the work is done up front to ensure a quality product arrives on site error free.

Virtual Construction

The compatibility of separate architect’s model, MEP model, structural model and fabricator’s model etc can be overlaid in interactive review meetings to understand phasing, clashing and compatibility with each other’s area of specialisation.

Virtual construction techniques are geared towards the prototyping or trial construction of projects and this vastly reduces the need for RFIs downstream in the supply chain, saving downtime in the drawing office and its knock-on effects.

Reduced Program

One aspect of construction programming that can often be improved through the uptake of 3D technology, is the traditional lengthy ‘lead-in time’ for steelwork deliveries.

Where a fabricator is appointed under the traditional route, there is a question as to whether the industry is making the best use of the information that the design team has amassed in the efficient development of the design.

Those who embrace the new technology can have their consultant work early with a fabricator on a model that will produce documentation and calculations at the early stages. This model can then be passed on to the fabricator to prepare fabrication drawings, and sometimes even place material orders and commence fabrication, ahead of, or coincident with, preparing the site and the foundations for delivery.

Just in Time Approach

A common use of the 3D technology has the larger UK fabricators effectively streamlining their material purchasing and fabrication processes, and ultimately batching their steel in erectable lots that fit on delivery trucks for sequential rapid delivery to site. The application of the JIT concept using 3D technology within the consultant’s design process will effectively streamline this process, and concentrate the effort of design in a contributory fashion.

In many respects, the current process of designing and supplying a steel frame is undertaken in a fashion that suits the economies and practices undertaken by each individual participant in the supply chain. The sum of these economies is however disproportionate to those on offer if a more collaborative method of enabling the 3D technology was adopted through the whole of the design and fabrication process.

By embracing 3D technology, the building industry can reap the benefits of a more streamlined, right-first-time approach to construction.
4.5.3 Design and Construction of Steel-Concrete Composite Building Structures: Australian Practice

By Emil Zyhajlo
For The Warren Centre

The selection of a building structural frame may be based on a cost-comparative preliminary design study, or it may be the result of judgement based on previous experiences. The building size, shape, location and occupancy type may favour or require a particular structure. Building elements cost relativity at the time of design, and the supply capacities of sub-trades and fabricated components (whether factual or perceived), underlie decisions on the structure selected. Designer bias and designer level of familiarity in alternative materials design methods and in the codes, particularly from smaller design offices, is a factor of design outcome. Office design procedures depend on having relevant design guides, codes and software to output cost-effective and constructible structures. Steel fabricators may need to adapt to producing hybrid steel-concrete prefabricated structural members.

Introduction

The current suitability and competitiveness of structural steel in buildings is represented by the different structures that are common to building occupancy types of residential, office, retail, and car parking. Architecture and occupancy determines the services and fire protection requirements and floor to ceiling heights, and usually the columns grids. The structure is then selected to satisfy the building function and the relevant serviceability performance parameters expected for that building. In high-rise buildings the steel structure versus concrete structure has different competitiveness and preferences outcomes to that same comparison for low-rise, multi-span construction.

The issues reflecting the total construction cost of a structure include engineered input, contractual agreements, reliability, construction method skills, logistics, construction environment and safety protection requirements. Only engineered input as applied to composite construction is considered in this discussion.

In Australia, building structure design typically assigns lateral load and stability strength to stairwells and service cores. This is particularly so in the case of multi-storey buildings; low rise may have diagonally braced frames. Moment (sway) resisting frames are not used therefore in steel-frame structures – the steel beams and steel columns basically support gravity loads.
Beams need to support floor slabs. Floor slab types that are currently used may be in situ concrete cast on strippable formwork, or cast on profiled metal decking which becomes composite acting with the concrete, or as a concrete topping cast on precast planks to form a composite concrete floor slab. Each of the available slab methods has differing suitability and is keenly cost competitive. Making the steel beams act compositely with the slab introduces direct economies in the floor costs. Design of the beams needs to further address services reticulation in the ceiling plenum space, fabrication costs, and beam connections to facilitate erection. Fire protection cost of beams and on-site installation is a fundamental issue.

In column-beam structures steel columns are rarely used without steel beam floor frames and similarly steel beams are rarely used without steel columns. They are complementary. A downside or unsuitability of one can render the total steel frame unsuitable or uncompetitive.

The cost of bare steel section structural columns is high, up to three to four times that of reinforced concrete columns in multi-storey buildings. To design a competitive steel frame using bare steel columns would require a steel-favourable structure grid or loading conditions or erection times considered to be faster than in concrete.

Codes for composite construction

A summary of coverage of composite design by Australian Codes as compared with European and American practice is as follows:

- There is no Australian Standard Code for the design of composite concrete slabs with profiled steel decking.
- There is an Australian Standard Code AS2327.1 (www.standards.org.au) for the design of simply supported beams composite with solid concrete in situ slabs (without a haunch) cast on formwork or on steel decking of re-entrant ribs profile. For the design of composite beams with negative moment actions AS2327 defers to British Standard BS5950.3 (www.bsi-global.com).
- The Australian Bridge Design Code (Austroads in collaboration with Standards Australia) Section 6 deals with composite beams and box girders for simply supported or continuous actions. The slabs must be solid concrete (haunch included), not cast on profiled steel decking.
- There is no Australian Standard Code (buildings) for the design of composite steel-concrete columns.

The Australian Bridge Code Section 6 does cover the design of composite compression members using concrete-filled circular and rectangular hollow steel sections only. Section 6 is a condensed version of the Eurocode and BS Standards (that also include compression members of fully concrete encased steel sections and partially concrete encased steel sections).

• The American Institute of Steel Construction’s Manual for Load and Resistance Factor Design Specification for Steel Buildings (www.aisc.org) includes the design of composite compression members using concrete-filled circular and rectangular hollow steel sections and fully concrete-encased steel sections and the design of simply supported or continuous beams composite with a slab or concrete encased.

Design of floor slabs

The design of composite slabs is being done using manufacturers’ design guides that also include computer design software. The design method intent in each of these guides is to conform to AS3600 Concrete Structures Code. The emphasis is on capacity tables for the design of decking to support concrete in a plastic state and in the composite state on formats that relate loads, slab and decking thicknesses, and number of spans. The Design of Composite Slabs for Strength booklet (BHP, 1998) provides the most comprehensive Australian publication on strength design using decking that conforms to AS2327 Composite Beams Code. Longitudinal shear connection between deck and concrete has been rationalised for different decks and as vertical shear design at simply supported ends. The booklet introduces partial shear connection for different concrete strengths into flexural strength design. Design for other limit states and design conditions such as deflection, cracking control, fire, continuity design over internal supports, and lateral distribution to concentrated loads are not covered. These other conditions are treated separately and at times differently by each decking manufacturer. It is up to the designer to assess each situation individually.

For straightforward uniformly distributed load conditions onto composite slabs in steel structures, design information is adequate. There is some inconsistency of design output between designers, however that is usually within the varying bounds of designer approach.

Composite slabs on steel decking are frequently used to span between concrete, masonry or steel supports. Other forms of floor slabs using pre-cast concrete are
also used, more so in smaller, low-rise buildings. Refer to later discussion.

**Design of simply supported beams**

The design of simply supported composite beams is well covered by the AS Code. OneSteel computer software enables easy design using standard rolled and welded sections and alternatively proportioned sections (the most materially efficient composite beam uses a smaller, top flange section). Floor vibration characteristics can be calculated using the latest updated method and the effect of web penetrations on shear and flexural strengths and on deflections of the composite beam is also available on OneSteel computer software. Fire design guides are available; however, except for low fire resistance periods, as in carparks, fire design consultants need to be consulted if variation from normal protection (Building Code of Australia requirements) to beams is sought. Further work needs to be done on end connections of simply supported composite beams where the slab is continuous at ends; at present end connections of composite beams are determined as for bare steel beams.

Design of composite, simply supported beams with slabs complying with AS2327.1 can be designed very efficiently and accurately.

**Precast floors to composite beams**

The standard composite beam floor comprises beams spacing set to satisfy the capacity (mostly deflection under wet concrete) of un-propped continuous steel decking. Propping is usually uneconomical. Shear connectors are applied on site to erected steel beams after decking is installed. Steel decking is not always preferred. In floors exposed to severe corrosive environments (greater than B1 as per AS3600), such as carpark structures near coastline, steel decking requires additional protection. In floors supporting high, superimposed dead loads additional slab reinforcement is required for fire resistance.

In small structures and particularly with non-symmetric or non-repetitive floor arrangements where formworking is difficult, pre-cast/prefabricated floors are often preferred. Currently such floors are typically designed to be supported on walls or on conservatively designed beams. The procedure of installing decking and welding studs on site to steel beams and then fixing reinforcement is often not favoured by small builders. Constructing slabs on pre-cast panels or slabs on concrete ribs supported on pre-studded steel beams can provide economic composite action and if required increase the spacing of the steel beams.

The use of in situ concrete cast on pre-cast panels is common for bridge decks composite with steel girders. Slabs are cast on reinforced ‘Transfloor’ pre-cast panels, a proprietary system that allows for block-outs or continuous openings in the panels to coincide with pre-studded beams underneath. The panels are usually 2.4m wide and of practical lengths up to about 10m. This method is not used in buildings.

‘Ultra-floor’ is a proprietary system using pre-tensioned, pre-cast concrete ribs that support concrete topping cast on ‘lost’ form planks spanning between the ribs or on metal deck spanning between ribs. The ribs span simply between beams or walls (similar to timber floor planks on joists spanning onto bearers). If steel beams are used to support the floor system, shear studs are typically pre-welded on beams before delivery and erection. Composite action can then be achieved with the concrete topping via a formed concrete haunch along the beam. However haunched slabs are not part of the AS Code and not included in OneSteel software. Designers use studs or similar to provide beam top flange lateral restraint. This system (proprietary name ‘Interspan’) is commonly used in New Zealand multi-storey construction.

Hollow core pre-cast planks have an established usage for providing floor slabs spanning between walls and between pre-cast concrete beams. The planks are typically 1.2m wide and economically span between supports at typical floor grids of 8m to 10m. The use of hollow core planks spanning between steel-framed structures would reduce the number of steel beams to be erected and can allow for better services reticulation. The method is in use in the UK and in NZ in competition with slab on steel decking. Also in NZ, ‘Unispan’ pre-cast solid panels and pre-cast ‘Double-Tee’ panels are used, supported by steel beams.

Designers in Australia using any of the above construction methods need to rely on research literature, or overseas codes or structural basics presumably with conservatism built in. The main design issues in using pre-cast component floors are effective compression flange and longitudinal shear connection design. Without authoritative (or manufacturer’s testing) design backing the pre-cast floor composite methods are not likely to be considered in general situations.

‘Slimdeck’ and similar floors

‘Slimdeck’ refers to floors that comprise wide flange steel column type sections used as floor beams to support the floor slab off the bottom flange. The floor
slab can be of concrete cast on deep profiled (sheet pile type) steel decking or on hollow core planks or ‘Transfloor’ planks. The bottom flange is exposed and maybe covered with fire cladding; otherwise a heavier section is used and then the bottom flange is considered not effective in fire load conditions. The top flange is typically located 50mm below the top of the concrete slab. The grid of beams can be one way, which may require propping for slab construction, or a grid of primary and secondary beams to eliminate propping for slab construction. Slimdeck is probably more expensive than ‘standard’ composite beam floors, but the shallow result facilitates services reticulation without extra storey height to floors.

**Partially encased beams**

Partially encased beams are prefabricated steel universal beam sections concrete encased between flanges each side of the web. Steel bar reinforcement is cast into the concrete. The edges and underside of the bottom flange are exposed. The beam section is designed as fully effective to act compositely with a concrete floor slab for dead and live loads. In the fire condition loads (reduced) the bottom flange is ineffective, the cast in reinforcement replaces the bottom flange in providing the tensile strength. Shear studs are welded on in fabrication. The beam has improved lateral stability in the construction stage. Therefore deeper (larger simply spanning) metal decking can quickly be installed between beams. The method is in use in parts of Europe in steel frames to provide quick construction. The beams are often finished exposed below the ceiling. Cost competitiveness depends on the total package, not just the floor cost. This method is not in use in Australia.

**Continuous composite beams**

The OneSteel booklet (2001), *Design of Continuous Composite Beams with Rigid Connections* provides a detailed explanation of the design of continuous beams, and presents design charts and tables of typical spans and slab reinforcement ratios. Smaller steel sections and smaller deflections result from continuity without detriment to vibration performance. Connections required are more expensive than the web-plate connection typical for simply supported designed beams (in Australia). Probably a combination of continuous beams and simply supported beams in a floor frame would optimise the method. Secondary beams acting semi-continuous with end-plate connections into primary beams reduces beam depths. End-plate connections are commonly used in the UK. The method of construction has not been fully tried in Australia, so total costs have not been established, and without a nominated Code method of design, it is unlikely that continuity design has been fully considered.

**Composite columns**

Multi-storey carparks, open or closed, with sprinklers that are constructed with a steel frame, typically have bare steel columns. The structure beams and columns satisfy fire limit state by meeting minimum exposed surface area to mass ratios. That requirement can be satisfied in most cases by the beam and column sizes as designed for load and serviceability limit states. For small buildings or other occupancy classifications when fire limit states permit, bare steel columns are used, otherwise steel columns are fire clad or sprayed or concrete or masonry encased for fire resistance. For columns in multi-storey buildings, columns typically require 120 minutes or more fire-resistance levels. That becomes expensive fire protection if it is not structural.

In Australia concrete-encased steel columns are usually pseudo-composite columns, the section is sized for action initially for ‘temporary erection’ of the frame construction, then the column is fully reinforced and concreted. The design is along reinforced concrete column principles. Often for exterior grid columns the steel section is not located at the centre of the concreted column. A composite concrete-encased column refers to full action of a steel section or even a steel billet with only minimum reinforcement added to provide concrete surface durability.

Concrete-filled hollow section columns have been used for the past decade on a number of large buildings in Australia. Designers have referred to overseas codes for guidance. Recent OneSteel notes (2002) on load capacity of concrete-filled hollow sections for the fire state give better guidance for reinforced and for not-reinforced columns.

The cost hierarchy of structural column types compared with a standard, reinforced concrete column, is 15 per cent extra cost for a reinforced concrete column using a steel erection section, 20 per cent extra for a composite tube-filled reinforced column, 100 per cent extra for a composite concrete-encased column, and 250 per cent extra for a bare steel section with fire spray or cladding. The ratios are approximate and vary according to final architectural finish, and differing load combinations as for low-rise structures compared with high-rise structures.

The above summary is for concrete cast in situ columns, where the concrete and reinforcement is made
continuous through the floors in the same manner as for normal reinforced concrete columns.

Prefabricated composite columns of partially encased steel sections or concrete-filled sections are available in Europe. Partially encased column sections are similar to partially encased composite beams. The columns have end/base plates for end bearing and bolted connection, and the reinforcement is terminated welded to the end plates. Both the partially encased or concrete-filled methods use designs that do not require additional fire protection; exposed steel is considered not effective. The design is optimised with the amount of exposed steel providing the extra strength difference between full-load combinations and the fire condition loads. Erection is therefore as in bare steel mode. There are variations devised to suit architectural treatments of such columns.

High-rise buildings

High-rise buildings, particularly for office occupancy, have the typical vertical structure that comprises a service core located (near) centrally of the building floor and an exterior frame. The floor surrounds the core with primary beams spanning between the core and exterior frame. The beams are generally designed as simply supported. To provide beam fixity at the core, end-heavy embedments or couplers or extra reinforcing in the supporting concrete core wall would be necessary to resist end fixity of a beam. That would interfere with expedient core construction. Providing fixity at the exterior frame end is similarly detail complex. Continuity for exterior frame columns may be viable if columns are large and/or all columns coincide with beam spacing; otherwise floor beams connecting into spandrels need simple support to minimise torsion to the spandrel. Often the beams have the soffit notched at ends for services; that depletes beam-end fixity strength.

The requirements described are common to steel beam or concrete beam floors. Both need to be designed as simply supported for strength and serviceability. A typical 13m floor span, between core and façade, designed using composite steel beams would require 120mm slab on steel beams of 460UB or 530UB at 2.8m or 3.2m spacing respectively. The overall depth of slab and beams and fire protection is about 600mm and 700mm respectively. The same all-concrete floor of 120mm reinforced concrete slab would require 500mm overall depth post-tensioned concrete beams. That maximum difference of 200mm in floor depth does not necessarily favour either floor. About the same storey height eventuates. End notching fabrication to steel beams can be minimised.

Larger spans in composite steel beams can probably be achieved more economically than in post-tensioned concrete for simply supported floors. However floor vibration with steel beams and ‘excessive’ pre-cambering requirements for long steel beams results in similar limits as for PT concrete in situ beams.

Constructing composite steel beam floors is competitive with all concrete floors using post-tensioned beams in the simply supported condition. Erection of steel beam floors over two floors sequenced into quadrant areas is efficient and often ‘quicker’ than a post-tensioned floor sequenced into two pour areas.

The type of beams and columns used in the exterior frame is significant in the overall structure cost comparison with concrete. The steel erection section in a reinforced concrete column is usual practice. Reinforcement fixing around the erection section and then formwork to the column height is messy but ‘works’ in exterior frame columns. The spandrel beam is usually in steel and fire sprayed. Partially concrete encased sections may economically eliminate the formwork exercise and provide fire protection, as will also the use of tubes filled in situ, in the case of columns.

Building services cores are constructed in reinforced concrete. That is currently the best method.

Low multi-bay buildings

Low-rise building structures are typically multiple floor bays on a grid of columns in two directions. Current practice for a composite steel beam design is to design the floor structure with simply supported primary and secondary beams and in situ composite concrete slab on steel decking. The alternative in situ concrete floor structure is designed for continuity over the supports. For a straightforward orthogonal column grid the concrete option has an inherent material efficiency advantage due to continuous action. An alternative based on pre-cast concrete elements is usually designed for semi-continuous actions. Continuous design of a composite steel beam floor may minimise the material cost disadvantages.

Non-repetitive and non-symmetrical column grids advantage steel beam floors. In a column grid of changing successive spans in one direction, simply supported steel beams are efficiently designed according to each bay span. Continuous concrete beam design efficiency drops for the beam spanning over the smaller spans. Changing the concrete beam depths per span adds formwork cost. In non-orthogonal column grids, or curvilinear grids, formwork concrete floors and the
standard post-tensioning method and reinforcement length changes complicate the floor construction. Steel beam floors fit. Steel beams with web cleat connections don’t need to connect at right angles.

Composite columns construction presents other issues. For the standard in situ concrete structure the sequence is column then floor (although pouring columns down at the same time as the floor pour is done). Concrete structures of pre-cast columns only and full pre-cast concrete structures are constructed in a similar sequence to the in situ concrete method. In steel beam floor frames, steel columns are erected in two- or three-storey heights for the sequencing requirements of the floor construction activities. Full bare steel columns would provide the simplest construction, but after fire protection and architectural cladding are the most expensive columns. Steel erection sections in reinforced concrete columns are the cheapest columns. Construction can be messy for such internal columns; most of the work needs to be done in the lower levels. Reinforcing vertical rebars and ligatures are as for reinforced concrete, columns but fixed around the steel erection section, and the formwork is installed and removed between steel frame floors. Concrete-filled tubes or partially encased columns provide a better overall solution for internal columns notwithstanding architectural and cost considerations.

Low-rise buildings are often built using mobile cranes. Steel erection needs full-floor area reach, which is not always available for mobile cranes. The use of mobile cranes needs erection planning to avoid jib-bound conditions.

Building structures by building occupancy

A brief of some of the defining characteristics of building structures of differing occupancies:

- The multi-storey carpark can be competitively constructed in composite steel or concrete frame. The fireproofing cost difference is minimal.
- High-rise residential buildings are designed to maximise the number of storeys and, because there is low need for services reticulation to each apartment, flat soffit floors are preferred favouring post-tensioned floors. In NZ the apartments are constructed with steel beams and pre-cast type floors. The steel beams are located to coincide with apartment walls, possibly with some restriction to apartment layouts.
- Offices, requirements are as discussed in the previous high- and low-rise structures.
- Hospitals, demand is high for services and slab set-downs for wet areas, requiring more careful design for a steel floor beam structure.
- Shopping mall structures are typically constructed in post-tensioned concrete; the large spans required make simply supported steel beams costly.

Concluding remarks

The Australian Standards Code for composite structures covers only the most basic element of the simply supported floor beam composite with an in situ concrete slab. Other parts are not yet available. Steel beams are being used to support differing types of slabs particularly when slab costs dictate, and for other isolated situations. Columns of steel beam floors largely remain the erection column type cast in a reinforced concrete column. The full potential of steel composite construction in Australia is not known.

Construction costs fluctuate with time, not all well-designed structures are built with efficiency and although structural knowledge of construction costs of comparative structures is not perfect, structural frames are still chosen on cost comparisons or assumptions.

Direct comparisons with economy of construction in other countries cannot be made. Key parameters are often vastly different: there may be materials cost relativity differences or industry skills or environment loading differences or different heating/cooling requirements (affecting floor structure).

Innovative design of steel structures used in buildings in other countries is not going to advance in Australia, particularly not from small consultants’ offices, without expanded design standards or design guides and software and training. Consultants need backup to sign off on their designs.

Standard codes take time to write. Current expectations are for changes to be made soon. The quickest way may be for the Australian Standards to refer to a relevant overseas code or codes. That may still require some instruction on ensuring all relevant clauses in the Code are complied with and still comply with the Australian loading codes and the other limit states. Australian Standards may lift out from another code and issue interim condensed sections. The ASI may initiate Codes of Practice to cover composite design methods not in AS Code.

Additional composite steel construction methods will find relevance if competitive on cost. The steel structures industry needs to continue to put forward solutions for designers. Design rules for the composite column types, differing floor types acting compositely
with steel beams, connections for composite beams and continuity design of beams can all be presented.

Finally, steel fabricators would need to produce composite steel-concrete prefabricated sections if such construction can be less costly than the full concrete alternative. In low-rise construction, prefabricated composite sections may be quicker to erect and efficient in fire design.

4.5.4 FIRE AND STEEL REGULATIONS

By Ian D Bennetts  
Noel Arnold & Associates for The Warren Centre

Introduction

For many years, BHP and more recently OneSteel, have funded research aimed at reversing the perception that the fire protection of structural steel buildings will add significantly to the costs (and uncertainty) of construction. There is no question that if significant fire protection is required, there will be additional costs but the perception in the market place is that the costs are much greater than simply the cost of applying the material on site.

In the 1970s and 80s, delays were caused by in-fighting between fire protection companies and local regulators who were constantly arguing about whether the thickness of fire protection applied was correct. This issue was resolved by the steel industry, which engaged BHP Research to produce a set of rules for analysing the fire test data and determining the required thickness, for all available materials. This early document (Bennetts, Proe & Thomas, 1987) was published by the Australian Institute of Steel Construction (AISC) and was followed up by a handbook giving thicknesses for proprietary materials for the range of steel member sizes to achieve given levels of fire resistance (Proe, Bennetts & Thomas, 1990). The 1987 guidelines formed the basis for the requirements given later in both AS4100 and AS2327. The adoption of rules to which everyone had to adhere removed the delays associated with using protected structural steelwork.

Another reason often cited by builders is that the introduction of wet fire protection methods such as fire spray to a building site will result in significant additional site allowances due to the perception that it is a harmful trade creating increased air contamination and mess. To overcome this issue on a major city building in the later 1980s, sprayed fire protection was applied off site, with it being accepted that a certain degree of ‘touch-up’ would be required. This approach obviously puts limits on handling of the structural steelwork, but on that project was considered to be reasonably successful. The author is unaware if this approach has been used on other projects where wet fire spray has been used.

Strategies adopted by the steel industry

At this point, two strategies were considered by the steel industry via BHP Research. The first was to find ways of reducing and possibly eliminating the need for
OneSteel strategy for addressing the ‘fire problem’. In detail since this has been central to the BHP/Thomas 1992) where it was found that wrapping a steel member in Al foil and then cladding with steel sheet could allow typical practical steel members to get between 35–50 minutes of fire resistance compared with 15–25 in their unprotected state. These levels of fire resistance fall well below those required by current regulations. BHP Research also worked with Boral Australian Gypsum in attempting to develop a low-cost column protection system whereby boards were positioned around a column using stainless wire as opposed to the complicated and labour intensive use of furring channels. This approach was used on several projects but was not promoted by Boral. Other innovations were noted, such as the possible use of attaching boards around columns using staples (an approach that was being pioneered by British Gypsum), but this was not considered further.

In hindsight, a third strategy should have been adopted in addition to the above strategies and that was to work with industry to develop adequate and cost-effective application procedures for wet fire spray so as to overcome the negative site perceptions associated with the application of this material. We will come back to this strategy later.

**Consideration of first strategy**

The first strategy of reducing or eliminating the need for fire protection of structural steelwork is now considered in detail since this has been central to the BHP/OneSteel strategy for addressing the ‘fire problem’.

In considering this issue, BHP Research identified that it would be necessary to bring about regulatory change. At this point, the BCA was fully prescriptive in that there was no allowance for the development of ‘Alternative Solutions’ 20. Thus it was necessary to bring about change to the deemed-to-satisfy (DTS) provisions.

Regulatory change was achieved as the result of full-scale testing and involvement of key regulatory personnel (Bennetts et al 1985) (Bennetts et al 1989) (Thomas, Bennetts et al, 1989) (Thomas, Almand et al 1989) in relation to open-deck carparks, closed carparks and carparks under other buildings (support-of-another part). The findings from this work brought about regulatory change, which resulted in the construction of many steel carparks – and in structural steel being seen in a more positive light than previously. It needs to be noted however, that the fire load in carparks is not highly variable and that few people occupy these buildings. Gaining regulatory acceptance was relatively easy compared with that which would have been required if changes has been proposed for other classes of building.

BHP Research next conducted research into office buildings to see if something similar could be achieved. The refurbishment project at 140 William St provided a real-life project that enabled some innovative testing and analysis (Dayawansa et al 1994; Thomas et al 1992a) (Thomas et al 1992b). This was 1993 and predated the introduction of the performance-based version of the BCA (1996). This was an extremely successful project and, following a presentation to the full board of the referees in Melbourne, was approved. This resulted in the first high-rise building in the world utilising unprotected structural steel beams. In many ways, this building was unique – a central core, large amount of external glazing, relatively short distances to the external façade and a very robust structure. This result could not be generally applied to other office buildings without undertaking further evaluation specific to these other buildings. However, this project highlighted the fact that fire-engineering concepts could be applied to other building and that reduction in the level of fire protection was certainly possible. Unlike carparks, office buildings are quite variable. Eccentric cores, relatively light columns and deep floors – all make it much more difficult to achieve the same outcome as for 140 William St. The 140 William

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20 This occurred in 1996 when the BCA was modified to allow a ‘performance approach’ to design. Of course, in most states (Qld, Vic, SA) variations to the DTS provisions for particular projects were permitted by presenting the proposed variations to a panel of referees.
St project caused great interest in the UK and British Steel funded a series of fire tests at Cardington. These tests provided the basis for a renewed academic interest in the behaviour of steel frames in fire, especially in the UK. A recent overview of these developments is given in the work of Bennetts and Thomas (2002).

In May 1994, the Fire Code Reform Centre (FCRC) was launched in Australia. This followed an earlier project of The Warren Centre (1989) on fire engineering. The FCRC was a combination of the Australian Building Codes Board and industry partners and was aimed at evaluating aspects of the deemed-to-satisfy provisions of the BCA. One of the most important projects was Project Three, which was aimed at evaluating the Fire Resistance Levels in the DTS provisions of the BCA. Given that UK and Europe have typically lesser requirements (e.g. the UK has 60 minutes FRL for office buildings up to 30m), it was hoped that this project would bring about a similar result. The project considered the full range of building geometries and concluded that no clear case could be made to reduce the current requirements since the DTS provisions are meant to cover all situations. Certainly, it was found that some circumstances would result in significantly lesser requirement for FRL, but at the time, it was not considered that this should be further pursued. It is noted that this project did not consider whether the buildings had sprinklers or not.

The FCRC’s Project 6 looked at sprinklered shopping centres and was funded jointly by the Building Control Commission of Victoria (now the Building Commission) and BHP. This project enabled a realistic understanding of the fire safety issues in modern shopping centres and was able to demonstrate that the fire resistance of the building structure is not the controlling factor in achieving a building with sufficient fire safety. It argued that bare steel floor construction could be used in many situations. The ABCB was unable to see how this work could be incorporated into the DTS provisions but considered that the information was more appropriate for engineers undertaking performance designs. This project was completed in 1996 and this coincided with the release of the performance-based BCA.

In recent years, OneSteel (via CESARE at Victoria University, Melbourne) has funded a project aimed at achieving changes to the DTS provisions of the BCA in respect office buildings of up to four storeys. A submission has been made to argue for permitting unprotected structural steel given that sprinklers are voluntarily provided. This is still being considered by the ABCB and progress is very slow. Other submissions are possible beyond this that could enable the use of lower FRLs than currently expected for office buildings. A OneSteel paper (2001), based on work done at CESARE, draws attention to the fact that the current DTS provisions would appear to be excessive for buildings of up to four storeys. The problem is that getting changes to the DTS provisions is a very time-consuming exercise since a wide range of people and organisations must consider any proposal. This is likely to lead to delays and dilution of the desired outcomes. Although there is some scope for further changes to the DTS provisions of the BCA, such changes are limited and will be seen by many as reducing current safety levels. Nevertheless, it is important to attempt to bring about changes to the DTS provisions.

Since it is unlikely that smaller projects will utilise a fire engineer to develop an alternative solution, it is difficult to see how the fire and steel issues can be resolved unless there are corresponding changes to the DTS provisions.

It is noted that recent changes to the DTS provisions have mostly resulted in the addition of other fire safety systems (usually with no justification other than perception) and associated Australian Standards are modified to incorporate any improvements to current systems that have often been prompted through the application of fire-safety engineering to real projects. Thus it would appear that the DTS provisions in combination with the nominated Australian Standards are fast developing into a ‘Rolls Royce’ design against which it is becoming increasingly difficult to develop an Alternative Solution capable of matching the level of safety associated with the DTS provisions.

An approach currently being developed at CESARE and funded jointly by OneSteel, BlueScope and an ARC grant is the development of a comprehensive risk assessment model to better enable the justification of Alternative Solutions for high-rise office buildings. This model is seeking to incorporate all aspects of the fire safety system including stair and smoke pressurisation, sprinklers, the behaviour of the steel structures, etc.

**Consideration of strategies 2 and 3**

The outcome of many fire-engineering submissions undertaken for major projects is that some fire protection will be needed on some members. The development of a range of cost-effective fire protection measures ranging from 60 to 120 minutes is therefore important, as is the development of low impact, cost-effective measures for applying these materials on and off site. Sprayed fire protection for 120 minutes
(putting aside any associated site allowances should these come into play) would still appear to be more cost competitive than thin-film intumescent coatings. There is a role for both types of material. The cost of off- or on-site application of intumescent materials will reduce if the market size increases, but some effort needs to be made to improve the cost effectiveness and the marketing of these materials.

Similarly, an increased effort is required to advance Strategy 3 in achieving builder acceptance of sprayed fire protection.

References


Thomas IR, Bennetts, ID Lewins, RR & Proe DJ 1989a, ‘Fire and Unprotected Steel in Closed Carparks’, BHP Melbourne Research Laboratories Report No MRL/Ps69/89/006, August.


4.5.5 FIRE ENGINEERING

By Ben Ferguson
For The Warren Centre

Summary

Generic building codes may not provide the most suitable solution for today’s steel buildings. Fire engineering can be used to ensure the structural solution is developed with respect to each particular building’s characteristics, resulting in efficiencies of design, cost, aesthetics and program.

Through the use of fire-engineering technology, ‘Alternative Solutions’ can be developed to reflect specific developments where generic codes cannot be applied or are inappropriate. The Building Code of Australia (BCA) has been a performance-based document since 1996, which supports such Alternative Solutions as a means of designing buildings that are fit for purpose, efficient and robust.

Some examples of how fire engineering, undertaken by a qualified fire engineer with specialist structural fire engineering knowledge and experience, can benefit steel buildings are:

- reduction or deletion of fire-rating requirements to specific structural elements, including beams, columns, walls etc. For example, modern open-plan offices with full height, glazed curtain walls are often suitable without full protection to steel beams. The use of bare steel secondary beams is becoming common in many such buildings and there are recent examples of buildings with all steel beams unprotected
- use of unprotected structure supporting external elements of a building, such as a balcony/walkway.
- use of external stairways, constructed of unprotected steel and glazing
- use of alternative fire protection methods
- use of steel cores in some circumstances (i.e. low-rise buildings)
- use of lightweight construction.

This paper provides a summary of fire engineering to assist developers, designers and authorities to understand the methodologies used to assess steel buildings and the benefits of fire engineering.

What is fire engineering?

Fire engineering is based on knowledge of fire science and chemistry, physics, mathematics, building services engineering, structural engineering, materials science,
architecture and psychology. These elements are used to assess and determine fire-safety solutions for new developments and redevelopments of existing buildings.

The primary aims of fire safety in the built environment are:

- ensuring the safety and safe escape of building occupants in the event of fire
- protection of adjoining buildings
- protection of fire fighters
- minimising property damage or loss due to fire.

These are the key objectives of the BCA. Figure 1 shows the structure of the BCA.

At the compliance level of the diagram, the Performance Requirements are the absolute requirements that must be satisfied to ensure the design of a building complies with the BCA. There are two ways of meeting the Performance Requirements, namely: Deemed-to-satisfy (DTS) provisions (i.e. follow the ‘cookbook’ type approach); or develop an Alternative Solution.

Fire engineering is concerned with the second of the two, ‘Alternative Solutions – Performance-Based Solutions’, which are developed as part of the overall fire-safety design when the DTS provisions cannot be applied or are inappropriate. This may be due to the generic DTS provisions being:

- excessively conservative for a specific building
- inflexible and restrictive
- inappropriate for complex architecture, structure or services design
- unsuitable for heritage/refurbishment projects.

Fire-engineering techniques are used to measure the level of fire safety and risk in a building and establish an acceptable fire-safety design. Some of the areas fire engineering can be applied in buildings are:

- alternative smoke hazard management strategies
- rationalisation of materials for construction
- assessment of fire and smoke spread
- rationalised structural fire protection
- increased fire and smoke compartment areas
- computer modelling of fire and smoke development
- assessment of fire authority requirements
- access and egress of emergency personnel
- fire fighting facilities.

Fire engineering and steel structures

There are a small number of qualified fire engineers in Australia who have a detailed understanding of a sub-category of fire engineering, known in the UK as ‘structural fire engineering’. Fire engineers with this specialist knowledge offer significant advantages on a steel-framed building project, including time savings, cost reduction and design flexibility/freedom.

Traditionally, the design of steel structures to withstand fire has been based on a series of tests conducted for isolated steel members. The load characteristics of each section type and size are well known, as is the effect of high temperatures on steel.

To enable a reasonably simple set of reference tables, the tests were limited by the following parameters:

- A ‘standard’ heating regime was used (i.e. AS1530.4 in Australia). The structural member was placed in a furnace that has a temperature controlled in accordance with a specific rate over time.
- The heating regime used in the tests does not represent all types of fire scenario, however is designed to be applicable to all types of fire to ensure the structure retains its integrity during a total burnout of a particular compartment. It is therefore logical to suggest that such a generic application may create cases where the structure and/or its protection is over-designed.

From these tests, the behaviour of the steel when heated was determined and the amount of protection required to maintain the structural integrity of the steel element was derived.

A single member of each section type and size was tested.

Research undertaken in recent years (British Steel 1999, Thomas 1992a 1992b) has demonstrated that a structural system will behave more favourably in a fire than a single element, due to the transfer of load from a weakened element to other structural members.

Figure 1: Structure of the BCA
and the concrete floor slab. This further highlights the suggestion that the tests are a conservative representation of most real situations.

Therefore, the fire resistance level (FRL) of a steel section has inherent redundancies 'built-in' in many cases. Often, when structural steel is used in an outdoor/external area or within a 'sterile' space containing little fire load, applying the generic fire-protection measures may be unduly onerous. For example, the BCA requires a café structure to have the same FRL as a newsagent (three hours) as they can both be classified as 'retail' use. Obviously, a newsagent would generally have a much higher fire load than a café. There are many such examples.

The application of fire engineering would be beneficial in such cases. The fire engineer will undertake the following steps to develop the optimum solution for a specific case:

- review the type, amount, orientation and characteristics of materials located in the compartment/building
- review the building fabric materials
- review the building ventilation characteristics
- identify fire hazards
- develop possible 'worst-credible' fire scenarios
- review the structural elements, loads, failure mechanisms and consequence (with structural engineer)
- undertake analyses to determine the affect of the fire scenarios on the structure
- determine if the design provides a reasonable level of safety and if not, recommend modifications
- ensure that the outcome of the assessment will be a structural solution that is optimised for the specific development.

Examples of the types of development where fire engineering has been applied to develop a structural solution, are:

- high-rise office buildings (Latitude Tower, Sydney; 50 Lonsdale Street, Melbourne)
- medium-rise office buildings (particularly buildings less than 25m that contain a sprinkler system)
- residential developments (balconies, external structure)
- retail shopping centres
- hospitals
- atria, open foyers etc.
- open deck carparks
- large floor plate low-rise buildings
- sports stadia
- exhibition centres
- extensions and redevelopments.

Fire engineering methodology

A number of methodologies can be used to determine the conditions that a severe building fire could be reasonably expected to create. Calculations are carried out using methods developed throughout the world and compared, providing cross-validation and enabling a reasonable worst-case scenario to be determined.

a. Equivalent fire severity calculations are initially used to give a general idea of the range of fire severity expected. Whilst these calculations are useful for small compartments, they have limitations in large spaces and are not strictly applicable for open-plan floors. Therefore, caution should be used and the results considered as support to a more detailed analyses.

b. An assessment can be carried out using a two-layer zone model. Based on different 'compartment' sizes (areas of the floor burning), the expected fire load and ventilation conditions, a 'credible worst-case' fire is developed from calculation of the burning rate, compartment temperatures and fire duration.

An analysis of the effect of the compartment temperatures on the steel structure is undertaken to justify the design fire rating (FRL) of the structure, such as exposed beams.

Full-scale fire tests carried out in the 1990s by BRE at Cardington, UK (British Steel 1999), comprised six scenarios. The Cardington test comprised an eight-level steel tower furnished to represent a severe office-type fire. The results of these tests, including compartment temperatures and duration of burning and their relevance can be applied to many Australian buildings.

Acceptance criteria

The use of unprotected or reduced fire rating to steel is considered to be reasonable if it can be shown that its use will not impact on life safety of the occupants or life safety of fire brigade personnel or cause damage to adjacent property.

Research and analysis of the effects of high temperatures upon the strength and load-bearing characteristics of steel are used to consider the adequacy of the structural system to ensure the structural system does not fail resulting in catastrophic collapse.
The results of a deterministic study are used to assess the adequacy of a steel solution. Where issues are identified during the study, recommendations are suggested to increase the level of redundancy in the building.

The key acceptance criteria for the Alternative Solution were:

- columns to remain stable through the fire-affected floor
- fire-affected floor may deflect, but not fail causing catastrophic/progressive collapse.

The above terms are defined for the purposes of this report as follows:

- ‘Deflect’ – the structure (beams and floor) may move and ‘sag’ when heated.
- ‘Catastrophic collapse’ – the floor structure fails such that it rests on the level below.
- ‘Progressive collapse’ – catastrophic collapse of one floor causes catastrophic collapse of one or more other floors.

The ISO834 standard fire curve is the internationally accepted heating regime used for the testing of steel members. This is equivalent to the Australian AS1530.4 curve. The standard fire curve is shown in the figure 2.

![Chart showing the approximate standard fire curve ISO834/AS1530.4](Source: Standards Australia)

**Figure 2: Standard Fire Curve**

The standard curve is defined by the temperature-time variation of gasses within a large furnace. Normally, the fire resistance of a steel member is characterised by the time to failure in the standard fire test.

However, the exposure of a steel element can be significantly different from that experienced in an actual fire. The tightly controlled conditions of the standard fire are unlikely to be emulated in an actual fire.

### Compartment fire scenario

A fire is more likely to occur during normal working hours (i.e. offices) than after hours. However, statistics show (Bennetts et al 2000) that the likelihood of a large fire occurring during normal working hours is considerably less than at other times. This is due mostly to the presence and actions of occupants.

The office levels will be occupied during normal working hours and will contain no sleeping accommodation. During the day, the fire is likely to be sighted and the alarm raised very quickly. A fire is typically expected to be extinguished whilst still in its early stages.

It is therefore expected that most fires during times of occupation will be minor and a large fire out of hours will affect few, if any, building occupants.

If a fire does grow without manual intervention, it is expected that a reliable and well-maintained, automatic fire sprinkler system will activate where provided, controlling the fire such that the structure is not affected to the degree where it may deflect.

At night, or in plant areas that may not be occupied, a fire may not be discovered immediately and an extended alarm activation time may occur. However, the fire brigade will be alerted automatically by the detection systems and occupants are expected to be very few and will have sufficient provision for egress.

To consider the worst credible case, the primary design fire for the assessment of the structure is typically a non-sprinklered, fully developed fire.

Approximately 70 per cent of fires do not spread beyond the item of origin (Thomas 1996). Furthermore, for a fully developed fire to occur, it would mean that the sprinklers within the compartment have failed to operate. Australian fire incident statistics (Australasian Fire Authorities Council 1989/90-94) and work carried out by Marryatt (1988) show that the reliability of automatic sprinkler installations can be estimated at 95–99 per cent. The enhanced building fire sprinkler system shall typically incorporate monitored isolation valves on every level which, when backed by an effective management strategy, will provide a greater level of redundancy by enhancing fire sprinkler system reliability. The AS1121.8.1 sprinkler system should be enhanced to incorporate the following:

- A connection to allow the testing of the presence of water in the sprinkler system on each floor at one of the most remote sprinkler branches. The presence
of water should be tested upon the completion of any alteration to the sprinkler system.

- On each level may incorporate Two interconnected sprinkler system tappings. Each tapping should incorporate a monitored subsidiary valve and flow switch.

In the event that a fire can grow without manual intervention or effective sprinkler activation, a severe fire may occur.

Figure 3 (Drysdale 1998) below shows a representative growth curve of a cellulosic compartment fire if left to burn without intervention. The dotted line shows a fire that is suppressed by automatic fire sprinklers or manual suppression.

Figure 3: Cellulosic compartment fire growth

A fire will normally begin with some degree of growth depending mainly on the amount and type of fuel available. As the fire develops within a compartment, given the right conditions, the compartment may ‘flashover’. Flashover occurs when the room temperature is high enough (approximately 600°C) (ABCB, 2005) to cause most of the combustible items in the room to produce enough volatile gases to cause them to ignite.

When this occurs the temperature within the compartment rapidly increases. It is the period after flashover where the structure is subjected to temperatures that could cause it to fail after prolonged exposure. Therefore, this is the time we study to determine fire protection requirements.

Flashover conditions would normally be untenable for occupants and it is therefore important that appropriate safety provisions are provided to ensure early detection and rapid evacuation.

In a building protected effectively by sprinklers, the compartment would not reach flashover temperatures and hence would not reach temperatures that could affect the steel structure.

**Fires in large open-plan areas**

In a building with large open-plan office areas, a fire would not be expected to fully involve all areas simultaneously. As a large fire requires a significant amount of oxygen, a fire would be expected to spread from its point of origin towards a source of ventilation. Early in the fire, sufficient oxygen will be obtained from the general floor area, however as the fire grows in intensity its oxygen requirements will increase.

In a compartment that is effectively sealed such that the fire could not receive sufficient oxygen to support combustion, the growth of the fire would be limited. However, the hot gases from an unsprinklered fire would be expected to cause failure of curtain wall glass on the external façade, thus providing ventilation. The main fire would immediately move from the item or area of origin to the new source of ventilation, initially having little affect on the combustibles it passes to get there.

The fire would then burn in a localised area near the ventilation, denying sufficient oxygen for free burning of other combustibles. As the burning combustibles are consumed and the adjacent combustible items are preheated, the fire will gradually burn back away from the broken window into the building. As other windows are broken, the fire would be expected to spread to the new sources of oxygen.

Once most of the combustible items in a localised area of the floor have been burnt, the fire severity in that area would reduce. Therefore, the fire event may last for a significant time but the fire duration in any local area would be expected to be considerably less.

The duration for which a defined amount of combustible items could burn is a function of the burning rate of the fire. The burning rate of a fire is directly proportional to the amount of available ventilation.

Typically, a fire with an unlimited amount of ventilation will be short and severe. A fire limited by ventilation would be expected to be less severe and would burn for longer. If the sprinklers were ineffective during a fire, a significant amount of the external glass would be expected to fail, allowing oxygen to the fire.
Therefore, the fire is expected to burn quickly in any localised area and, in this case, unprotected steel beams would experience high temperatures for a time less than the duration of the overall fire event.

**Application of the design fire to the steel structure**

The behaviour of the steel in a severe design fire must be thoroughly investigated. The time that unprotected beams may reach their design limiting temperature and possibly deflect can be estimated. Such deflection should not cause catastrophic collapse. The time to beam deflection is not necessarily reflective of a real scenario as:

- the tests carried out to obtain a fire-resistance level assume beams to be simply supported, individual members. However each member is part of a structural system. The frame configuration provides support for elements in the event of large deformations and/or loss of strength from heat by allowing some of the load to be transferred to less-affected areas of the structure. This will in general, improve the fire resistance of the members.
- concrete floors lying above unprotected beams act as a heat sink when the beams are heated and extend the fire resistance of the beam. This transfer of heat is not considered in fire tests.
- beams will often be protected by ceiling tiles, which are expected to provide an additional level of protection in the critical early stages of a fire. The ceilings must be constructed to ensure they remain in place during the early stages of a fire to maximise the protection of the beams. Tests performed by BHP (140 William Street tests) to observe the development and effect of fires in a typical office found that non-combustible barriers, such as plasterboard ceilings, can significantly delay the spread of fire and heat from a burning compartment to the structure above, in the order of 10 minutes (Thomas 1990).

**Conclusion**

The Building Code of Australia encourages the use of performance-based methods to design buildings that are innovative, cost effective and customised.

Fire engineering uses the BCA performance requirements to permit designers the necessary freedom to achieve these goals. The use of steel as the structural solution for a building can greatly benefit from having a suitably qualified fire engineer working with the structural engineer and design team early in the project.

The use of fire engineering will assist to increase the cost-effectiveness, design flexibility and bring significant value to a steel-framed building.

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4.5.6 IMPACT OF EMERGING TECHNOLOGIES ON STEEL FABRICATION FOR THE CONSTRUCTION INDUSTRY

By Sandy Longworth
For The Warren Centre

Introduction

The use of steel in high-rise building construction in Australia is low compared with some other developed markets, such as the UK. This paper examines the fabricating processes used in building construction, particularly new and emerging technologies. Its aim is to promote awareness of the potential economic benefits from adopting new technologies and to identify some of the barriers in realising these benefits.

STEEL FABRICATING PROCESSES FOR BUILDING CONSTRUCTION

The major processes are:

- **cleaning**: typically by some form of blasting, which may be done before or after most of the other processes depending on the extent of work being done on that component.
- **cutting and profiling**: sawing is the most commonly used method for cut-to-length beams and columns. Oxy cutting and plasma cutting are both widely used for cutting plates for welded beam webs and flanges, and profiling the end of beams (also known as coping).
- **bending/forming**: bending presses to produce a camber are sometimes incorporated into beam lines. Roll forming is also commonly used for lighter sections.
- **drilling/punching**: holes for bolted connections are usually made by drilling, but occasionally punching is found to be more efficient.
- **welding**: fully automated welding is used for the production of beams and columns fabricated from three plates, usually with the submerged arc welding process. Most other welding is done with hand-held, semi-automatic gas metal arc welding (GMAW).
- **machining**: load-bearing end faces of columns are often machined by milling to achieve the desired tolerances.
- **Protecting**: steelwork is spray-painted or metal-sprayed for corrosion, and usually with intumescent paint for fire protection.
- **Handling**: although this is a non-value-adding process, the awkwardness of handling large steel components and the importance of timely supply to site demand that close attention be paid at the time of design to component or module size, erection handling and sequence.

Existing commonly used technology

Beam lines are designed for processing columns and beams. In Australia there are an estimated 40 beam lines, with 14 on order. The vast majority of beam lines have a saw for cut-to-length, including a mitre capability, and hole drilling or punching capability. It is common to have dedicated in-line blasting facilities for cleaning of regular shapes, while cleaning of irregular shapes and coating are manual operations.
Several beam lines include oxy or plasma cutting for coping (profiling) the ends of the beams.

Markings are also mechanically engraved on the beams for identification and traceability.

Whilst the majority of these beam lines do have CNC capability, the machine controls do not generally provide for download of data from steel design packages at present.

There are at least three beam lines in Australia for production of beams by welding three plates. One of these, at BlueScope Steel in Unanderra, welds one side of the web to both flanges using two tandem submerged arc heads at one station. The web is in the flat position. The beams are then turned over, and the other side of the web-to-flange joins are made in a second identical station. While very productive, this configuration is not set up for the production of asymmetrical beams.

The other two beam lines make both fillet welds between one flange and the web in one pass. The second flange is welded in another pass, and it is therefore relatively easy to make an asymmetric section in these lines.

The welded beam lines are typically partial penetration welds. That is, the fillet welds on either side do not penetrate the full thickness of the web, leaving the surface between the web and the flange unwelded at the centre of the web.

The major market for all this equipment in Australia has been for infrastructure projects rather than building construction. Innovative building design incorporating slim-floor construction, chilled beams and large spans could change this.

Virtually all other components, such as cleats and stiffeners, are welded with hand-held, semi-automatic GMAW processes.

The majority of beam lines are with fabricators, but some steel distributors have also installed beam lines to provide partial pre-fabrication.

**Emerging technologies**

**Hole-drilling**

New designs of low-vibration machine tools and advancement in drill design have resulted in major reductions in drilling time, to the point where a 26mm diameter hole can be drilled in 12mm plate literally in seconds. As a result, CNC single tool drilling stations...
are replacing gang drilling in some applications because of the greater flexibility offered.

New welding power source inverter

Inverter technology development has reached the point where high power (1000amp+) welding power sources are now readily commercially available. As well as much more efficient transformation of high voltage mains supply to low voltage welding current, with more than 95 per cent power factor, these new inverters allow much greater flexibility in the welding current waveform. Until now, submerged arc welding processes commonly used tandem arc for greater welding speeds. The lead wire was supplied with DC power, while the trailing wire was AC to avoid electrical interference between the two arcs. Additional wires can be fed into the weld pool but it is difficult to achieve stable conditions.

With the advent of new waveform control, new configurations are possible which may allow full penetration welds to be achieved in welded beam fabrication, and require smaller external fillets with proportional increases in welding speeds. The result should be higher quality welded beams at lower cost due to less wire being used and lower power consumption.

Laser and high-definition plasma cutting

Laser technology continues to advance rapidly, but is a major capital expense. The energy conversion is also quite poor. Despite these disadvantages, laser cutting is finding more and more application in metal fabrication due to the very rapid and precise parallel-sided cut that can be achieved with very high surface finish.

In the automotive industry, laser cutting has displaced press trimming and punching in many applications due to the flexibility with which shapes can be produced. Could there be similar potential for building construction?

Due to the energy demand, most applications have been for light gauge metals, but laser cutting is now being used in shipbuilding in Europe for cutting steel up to 20mm thick.

Plasma cutting, where an arc is used to remove metal rather than weld it, has been a popular alternative to the more traditional oxy-cutting process. But like oxy cutting, plasma cutting has had the disadvantage of producing a wedge-shaped cut, and a surface finish similar to oxy cutting.

High-definition plasma cutting, where the two cut surfaces are much closer to parallel, improves the precision of the cut and the surface quality. Although still not as precise as laser cutting, it is a much more economical process and arguably superior to oxy cutting at higher speeds.

Laser/laser hybrid welding

Laser welding allows deep penetration and very precise welds, and the heat source can be directed into tight area locations. These advantages have allowed joint configurations not possible before. However, a weld requiring 4kW requires an input power of approximately 340kW with a Nd:YAG laser, compared with approximately 4.2kW with arc welding. Laser welding also requires very precise fit-up as no filler material is added and the weld pool is small.

Laser hybrid welding, where a laser is used in conjunction with an arc weld, overcomes some of these
disadvantages. It is being used increasingly in the automotive and shipbuilding industries.

Both laser and laser/GMAW hybrid welding in conjunction with robots can be used for welding in all positions. It is possible to weld connections to large components that are difficult to move with this process.

Robotics

According to the Robotic Industry Association, there are an estimated 158,000 robots in use in manufacturing in the US alone. The number of robots in use in Japan is believed to be even higher. The major industry use is automotive, where small components and high repetition are ideally suited to robotic production. The Japanese construction company, Obayashi has, however, applied the system to the automated butt-welding of beams and columns in its automated building control and big structure. (Source: Bowerman H 2002)

Robots are ideally suited to cutting and welding of complex three-dimensional shapes where there are a large number of identical parts to be processed. Robots also have application in cleaning, painting and handling. The greatest limitation has been the size of the working envelope, but recent innovations are changing this.

The need for greater efficiency as a matter of survival has seen greater use of robots in the shipbuilding industry, particularly in Europe. This has driven the development of large manipulators and gantry mounting of robots to access large components, as shown in Figure 9.

More recently there has been progressive introduction of gantry fabrication in Europe in the construction fabricating field. Figure 10 illustrates the use of gantry robot plant for construction steelwork fabrication.

In Australia automated fabrication, excluding the application of beam lines, but utilising gantry robots has yet to be adopted for construction steelwork fabrication. The technology is however being applied very effectively by Austin Engineering Limited in the fabrication of complex heavy mining buckets and associated components as well as large off-highway dump truck trays. Austin states in its 2006 annual report, ‘The introduction of the robotic welding system has been of great assistance in counteracting the critical skill shortage in Western Australia’.

Automation with robots generally offers better quality for operations such as welding since the parameters are more precisely maintained than can be achieved with manual welding. Higher welding speeds and greater
duty cycles ensure a dramatic increase in productivity, typically of the order of 300 per cent.

Apart from the capital cost, the major disadvantage is that the robotic operations require much more precise jigging and tighter part tolerances than manual operations, since correction for these errors is much more difficult. However, this in turn leads to better quality.

Typically, in the automotive industry the welding sequence is taught to the robot controller by manually driving the robot arm through the cycle and saving various program points. As this can be a time-consuming exercise, it tends to limit the use of robots to relatively long runs.

Recent improvements to some robot controller software have made the programs much more intuitive and easier to learn and use, thereby making shorter production runs more attractive. This is a development likely to have appeal to the building fabricating industry.

Software also exists that allows the robot to be programmed off-line in the convenience of the office using the design drawing data. This has the potential to make the changeover for short runs even easier. However, from the author’s observation this technology is not yet being widely used although it would seem to have great potential.

An example of one company taking full advantage of robot technology in building construction is ConXtech in the US. It has designed a system that allows virtually all welding to be done at its fabricating plant, allowing self-locating slots to locate the beams onto the columns on site, before the beams are bolted together to produce a moment connection suitable for use in areas with high probability of seismic activity. Design data is directly converted into manufacturing data with proprietary software for CNC cutting and drilling. In addition to using CNC milling and drilling to produce the end plates, and a CNC-controlled beam line to cut the columns and beams to length, robots are used to weld the connections to the beams. More than 10,000 of these connections have been used in construction (The Fabricator 2005).

Robots for building maintenance, condition monitoring and security are being developed or are under consideration (Spencer 2004) (Weston & Burdekin 2000) and are already in use for façade cleaning on at least one high-rise building in Europe (Elkmann et al 2006) and building construction in Japan (Taylor et al 2003).

Figure 11: Full moment connection with no on-site welding. End plates welded by robots (Image courtesy The Fabricator March 2005)

Friction stir welding

Friction stir welding (FSW) was developed in the early 1990s by TWI in the UK and has been widely used to join aluminium and other non-ferrous alloys. The technology uses mechanical forces to create a plastic state in which the surfaces of the parts to be joined can be mixed together without reaching a liquid state. This has significant advantages for welding alloys that are too volatile for arc welding.

The process produces high-integrity joins at high speed with little residual thermal stress. The process does not require welding consumables or join preparation, and cost savings of a factor of three or more are claimed in comparison with arc welding process, ignoring establishment cost (Taylor et al 2003). The main disadvantage is the high capital cost of the equipment.
No commercial systems for production of welds in steel have yet been produced. One of the key issues is tool life. However, research continues and the use of double-sided contra flow tools is showing potential (Thomas et al 1999).

Information technology

The introduction of computer 3D modelling for building construction has been widely discussed in Section 4.5.2 (Hainsworth).

The potential to integrate the design model with the CNC commands for beam lines and robotic welding, cutting, cleaning and painting offers an exciting opportunity to improve the efficiency of steel fabrication. Software already exists that translates design data into a format that can be used directly by CNC beam lines, CNC cutting machines and robots, and this technology is finding wider appeal.

The opportunity to create new connections and component design that is conducive to fully automated, high-volume production, as per ConXtech's innovation, also has significant implications for the construction industry. Automation on the shop floor with electronic linkage to design and detail sources has the potential to catalyse innovative construction ideas and slash production cycle time.

The challenge now is how to take full advantage of these innovations.

Cost comparison and implications of emerging technologies

The real cost of fabricated steel in the UK has effectively fallen by nearly 50 per cent over the past 25 years to around £1500/tonne or A$3750/tonne (Thomas et al 1999). This has given steel structures a significant price advantage in the UK as shown in Figure 13. Unfortunately a similar comparison for Australian conditions is not available.

Australia has not benefited from improvements in efficiency and fabricating to the same degree as the UK, where designers have more flexibility, particularly in section selection.

It would be fair to say that Australia’s concrete industry is more efficient than the UK’s. Notwithstanding this, for similar grid layouts and building types, it has been established that steel composite construction in metropolitan areas is marginally (10 per cent) cheaper than post-tensioned concrete (Marjoribanks 2006)

Arguably, for steel fabrication to gain significant market share from a highly competitive concrete industry, fabrication costs will need to be more competitive relative to the UK despite the market size being smaller. To achieve this, the industry must take full advantage of the technologies available. The authors believe this is achievable within the steel value chain and will result in some rationalisation and consolidation within the industry

Conclusion

If steel is to make significant inroads into areas of the construction market currently met by concrete, it must be able to offer greater economic benefit. Whilst there may be other design and timing advantages to steel, cost will remain an important factor. Given that industry practices for concrete construction are more efficient in Australia than in the UK, and given the more favourable taxation treatment of concrete in Australia, it is reasonable to assume that despite the smaller volumes, steel fabrication costs will have to be lower in Australia to be competitive in the construction market. This will require adoption of world’s best practice and the latest technology.

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4.5.7  HISTORY OF OFF-SITE MODULAR CONSTRUCTION TRENDS

By Michael Gallagher
For The Warren Centre

Introduction

The hypothesis for this paper is:

- Major buildings are being constructed with an increasing percentage of prefabricated components.
- Steel framing by its nature is and has been a ‘prefabricated’ element of the building.
- Thus steel framing of the structure is compatible with building trends and as such is naturally disposed to benefit.

The new technologies support and drive this trend. Computer-aided design assists co-ordination of the various components of the design – architecture, structure, engineering services and finishes. The internet has generated the communication tool for the design, co-ordination and fabrication of the building elements in diverse locations – a 21st century building could easily comprise prefabricated elements from around the globe.

History

Buildings are an assembly, on a site, of materials that are produced off site. The essence of the art of building is the materials handling. Thus the off-site fabrication needs to be tuned to the on-site handling of materials.

The industrialisation of the 19th century saw the advent of industrially produced building materials. Bricks were made in kilns; nails, cast iron pipes and even the Twyford ceramic toilets and baths were mass-produced. Historically, the majority of materials produced for buildings were sized and packaged to be carried and placed manually. Thus bricks, bags of cement, marble tiles, earthenware pipes etc were sized and shaped to be handled by workers on site. Materials were standard sizes, which were then cut, shaped and assembled on site.

The second industrial age saw the advent of steel. The Eiffel Tower, completed in 1889, heralded a new form of construction. The Home Insurance Building in Chicago – often cited as the first high-rise building – was a 10-storey building with cast-iron columns, rolled steel beams with the structure encased with bricks and tiles. The second industrial age also saw the advent of mechanical lifting, with larger materials capable of being lifted. Steel framing became a possibility,
and to a large extent dominated the larger building structures around the world. However the remainder of the buildings elements continued as before – on-site assembly of standard elements.

Although steel dominated tall building structures, the industrial production of Portland cement (from 1824) plus the capacity to lift, saw the advent of concrete-framed buildings. The 16-storey Ingalls building, built in Cincinnati in 1903, was the world's first reinforced concrete skyscraper. Concrete structures were basically on-site construction with formwork and reinforcement in sizes capable of human handling. The concrete itself was batched on site.

The design of the building accompanied the industrial age. Thomas Young published the Modulus of Elasticity in 1807 – and the advent of structural engineering followed. The designer, supported by a league of draftsmen, produced ink drawings on linen. Copy draftsmen produced copies of drawings. Thus copies of drawings were expensive and time consuming to produce. As hard copy, engineering consultants needed to trace and superimpose. All of this may sound like ancient history, but then my cousin started work at Sydney architects Peddle Thorp & Walker as a copy draftsman in 1960, printing processes were limited to ‘blue prints’.

With this sort of design capability, the trades, services and finishes were extensively co-ordinated on site. Many trades and finishes would 'site measure' from the structure to produce the windows, engineering services and the like. The opportunity for extensive pre-fabrication was limited. The 'bricks and mortar' era was one of dimensional tolerances, mouldings and fitments at joints to accommodate the dimensional tolerances associated with the predominance of the site works. Thus in this environment, a steel structure (if used) was one of the few pre-fabricated components of the building.

Off-site works posed a number of contractual issues for builders – particularly for payments for off-site works prior to delivery to site. Although large manufacturers of equipment could accommodate the payment regime, the arrangement of payment only when items were on site posed difficulties for smaller off-site fabricators – such as suppliers of steel structures.

Nonetheless, the advent of tall buildings did see the start of prefabricated façade elements (pre-cast spandrels and prefabricated window units). Engineering services (apart from items of plant) remained as site measure and install with limited pre-fabrication in the real sense.

Craneage was also improving – Favco tower cranes were invented in Australia in the 1950s. The capacity to self-lift and the luffing mechanism made these cranes suitable for high-rise construction on congested city locations. Concrete could be pumped – but was limited to small vertical lifts with higher lifts completed by combinations of craneage and pumping.

However, just as the industrial revolution impacted on the traditional, conservative, local building industry, the technology revolution is making significant changes to the building industry. There is little doubt that technology is leading to more prefabrication across the whole building industry.

**Observations – design**

The design phase of any building project is critical. However, if any project is to incorporate prefabrication at a range of off-site locations, then the design, design co-ordination and information transfer between parties becomes more critical. Thus the following observations are made:

- Prefabricated elements require design – to enable manufacture/assembly off site prior to delivery to site.
- Most significantly prefabricated elements require design co-ordination to incorporate services and connection details with other components of the building.
- The advent of computers, particularly 3D design facilitates the inclusion of prefabricated elements.
- The widespread use of computers and the increasing ‘computer literate’ workforce makes this introduction possible.
- The cost of computers and computer software has assisted.
- The advent of internet communications (say between designer, fabricator, project manager/constructor and architect) significantly improves
the opportunity for utilisation of prefabricated elements where different suppliers (prefabricators) are remotely located.

- The advent of computer technology and the internet expedites the marking of shop drawings, tracking changes and thus overcomes the time and co-ordination issues associated with prefabrication.

The advent of prefabricated elements and rooms is now a reality, and modern technology facilitates the introduction.

**Observations – lifting**

Crane technology improves over time. Technology and electrical control systems have made dramatic changes to controls and equipment levels on all major equipment. Technology and electronics allow accurate positioning (GPS) levels and other support for placement of loads. The modern crane is not recognisable from the Favco of the 1960s, complete with a dogman to ride the load, whose signal and whistle to the crane driver was the only form of communication. The technology has reduced manning and improved safety for crane operations. Thus the following observations are made:

- Prefabricated elements predominantly require mechanical lifting – cranage.
- The acceptance of prefabricated elements for buildings has partially been assisted by more competitive cranage – partially due to changing workplace arrangements. More particularly the acceptance has been assisted by the ready availability of cranes and crane contractors.
- Crane capacities and reach have improved and therefore larger loads at remote corners of the site are possible.
- As well as fixed building cranes (used on high-rise city buildings), the availability, capacity and cost of mobile cranes is allowing the introduction of prefabricated building elements across the whole spectrum of building types from cottages to high rise. With the diversity of applications, the use of prefabricated elements becomes more entrenched throughout the industry.

**Observations – facades**

One hundred years ago, the only prefabricated elements of a façade were the window units (and even these were assemblies of sub-elements with frames, sub-frames, sashes etc). Windows were essentially single units (occasionally double units) and represented a small percentage of the façade (less than 25 per cent).

The windows were ‘built into’ the façade with masonry elements built up to the window frame and tolerances accommodated through external mouldings and internal joinery. Although the façade was substantially made off site, the façade construction required considerable on-site works in the cutting, fitting and assembly of the modular units. Building tolerances were accommodated on site.

Fifty years ago, facades started to be assemblies of prefabricated elements. This heralded the advent of the curtain wall (The ICI building in Melbourne, see Figure 2, was designed by Melbourne architects Bates, Smart and McCutcheon).

![Figure 1: The MLC Building in Martin Place, Sydney, completed in 1938 (Photo courtesy Sydney Architecture Images)](image1)

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![Figure 2: Former ICI Building Melbourne 1961: an early curtain wall building in Australia (Image courtesy Heritage Council of Australia)](image2)

Figure 2: Former ICI Building Melbourne 1961: an early curtain wall building in Australia (Image courtesy Heritage Council of Australia)
In that era, some facades retained substantial areas of masonry. Window units became pre-assembled, double-glazed and vacuum sealed. Spandrels and column cladding were often pre-cast concrete units for fire reasons. The detailing of facades posed problems. The waterproofing of the joints of elements from different suppliers posed problems. The pre-cast concrete elements were prone to concrete cancer. The detailing of facades required methods of accommodating the building structure tolerances.

Over the past 20 years, lightweight curtain wall facades have predominated, particularly for commercial buildings. Advances in technology allowed use of different materials in the spandrel to achieve different architectural effects. Sydney-based examples of spandrel infills can be glass (the all-glass buildings – Maritime Services building in Kent St), granite panels/masonry panels (Governor Phillip Tower) or metal/aluminium (Darling Park).

The units are accurately made and incorporate waterproofing in accordance with established principles (drained joint principle – CSIRO). Three-dimensional, computer-aided drawing has facilitated production of more complex shapes.

Facades on commercial buildings are now prefabricated curtain-wall elements. Facades of residential buildings are substantially prefabricated window and door units.

Observations – services

The trend to prefabrication is extending across the whole building industry and some examples of prefabrication for services are cited below.

- **Air conditioning**: International companies are marketing modularised, prefabricated plant rooms, as seen in Figure 3. Ductwork is essentially prefabricated – but still predominantly in pieces capable of handling. Computer-aided, 3D design has made co-ordination significantly easier and allows computer-aided cutting and forming of the assemblies.
- **Electrical and Telecommunication Cabling** is becoming more prefabricated with factory assembled ‘harness’. The images in Figure 4 from the Toyokuni web page depict innovations in modern cabling techniques. 3D allows prefabrication of less flexible elements.
- **Fire protection** in the form of sprinkler systems appears to be less advanced. Fire protection in the form of early warning devices is increasingly integrated into the access control, security and other telecommunications wiring as described above.
- **Hydraulics**: Services are still predominantly ‘on-site’ assembly of standard units. However for hotels, the prefabricated bathroom module is occurring. The internet advertises companies from China and elsewhere offering prefabricated modules for kitchens, bathrooms etc for incorporation into high-rise buildings, particularly apartments.
Observations – ceilings

Ceilings are one of the more labour-intensive parts of a building. In some countries, the practice is to produce office buildings as shell and core. Although ceiling tiles, light fixtures and other ceiling fitments (sprinklers, speakers, and smoke detectors) are integrated into modular/standard panel units, the installation of ceilings remains labour intensive for installation. The labour-intensive parts involve the drilling of fixing points on the structure for suspension of the ceiling grid.

With technology, it may be possible in the future to provide for these fixing points on any prefabricated structure and formwork.

Observations – internal walls

Internal walls and partitioning, either as heavy masonry or lightweight, are becoming more prevalent. The off-site, prefabricated walls integrate services reticulation and distribution. Increasingly, the wall modules are prefabricated to a design with simple on-site assembly with minimal cutting and on-site works.

Observations – fixtures and fittings

To some extent fixtures and fittings, commercial kitchens, bar units, and joinery have been substantially prefabricated with minimal on-site reassembly. Increasingly services (wiring and plumbing) are integrated into the prefabricated units.

Conclusion

Buildings are a combination of many elements and trades from structure to finishes and fittings. Technology is impacting on the manufacture of all parts of the building. Increasingly, more of a building is being prefabricated off site.

Computer technology assists the trend – allowing co-ordination of design and fabrication at diverse locations – reducing the extent of on-site works and co-ordination. The internet allows the rapid transmission of digital information in the drawings and specification material.

Steel by its nature is the prefabricated structural form. Thus the trend to wider use of prefabricated building elements could assist increasing use of steel structures in building form. The competitor for steel – concrete – is already seeing wider use of prefabricated building elements both in structure and finishes.

4.5.8 A GLIMPSE TO THE FUTURE – BIM – THE NEW BUILDING INFORMATION MODEL PARADIGM

By John Hainsworth
ARUP for The Warren Centre

Introduction

There is a revolution facing the architectural, engineering construction (AEC) industry. Those aligning themselves now with 3D CAD-based practices, are driving this revolution, and will be best placed to contribute to, and also interrogate, the new Building Information Model paradigm that will emerge.

What follows can only be introduced as a somewhat blinkered peer into the future which will provoke discussion, possibly argument, and only time will tell whether it is valid or not.

What is BIM?

Building Information Modelling (BIM) is a descriptive term for technologically advanced processes contributing to building design, construction, operation and ultimately, decommission. BIM is characterised by the creation and use of geometrically co-ordinated 3D ‘objects’, which are enhanced by associated computable data. This data is attached to the objects within the model, which can then be manipulated to describe a building project in many, many ways – too many ways, possibly, to be described by one single acronym.

Does BIM mean 3D?

This is a very good question, and the short answer is, no. As a more lengthy explanation of why it is not, we have to think back to the decades when the industry transitioned from manual drafting processes to 2D CAD drawing production. At this time, the industry grappled with the need for, and the methods of, simply producing the same representation of a drawing using electronic lines. On closer interrogation of the lines in these 2D CAD files, we captured little information except for length, display thickness, and the like.

Presently, the industry at large is facing similar disruption in a shift towards 3D CAD. To produce 2D documentation Arup now routinely models in 3D CAD, to streamline the production of our deliverables as 2D drawings from the model. As the drawings are a reflection of the model, they are fully co-coordinated with one another and do not present ambiguous information. Arup has already amassed significant experience in the successful production of
co-ordinated documentation sets, interactive virtual construction methods, material scheduling, and the innovative procurement methods that this 3D CAD technology offers.

Closer interrogation of the geometry produced by many 3D CAD applications can yield little more data than their 2D ancestors. Rest assured Arup is pushing the boundaries as to what we can do with the data we can enter, recapture and manipulate, but the trick lies in having this data ‘computable’.

This last aspect is where the BIM acronym might become confused with 3D CAD. Within a future BIM environment the interrogation of an object could yield limitless properties – in other words, the 3D view is just a graphical representation of the data it represents, and that data can be manipulated by many disciplines because it is in a format that can be cross linked, i.e. with dependencies on each other – or in other words the data which the object represents is ‘computable’.

BIM in the future

As an ‘idealised’ futuristic example, let us consider that a structural engineer proposes a new beam in a building, and its required depth is seen to have an impact on the ceiling height. Because there is a relationship defined in the model between the ‘engineer’s beam object’ and the ‘architect’s ceiling object’, the architect is prompted to see that a decision is necessary to either accept the proposal of a deeper beam or not.

On accepting the proposal, the architect’s model is automatically altered – but then the further impacts, such as the necessary bulkhead relationships, ripple through the model, managed by a controlled ‘accept or not’ interface. In parallel to this, because the cubic volume of the space bounded by the ceiling is now altered, the cost plan is updated to reflect the change in paint area required to the walls. Furthermore, the ‘mechanical engineer’s duct object’ alters in size in order to service the room, the energy analysis is updated with instantaneous results, and the fabricator’s order and erection sequence changes.

Interestingly, on completion of the physical construction, everything that comprises the BIM is then available to be exploited by the building owner through the management of their asset’s complete lifecycle and its final demolition.

Just as a spreadsheet is a tool for thinking about numbers, a BIM-enabled project will be a tool for thinking about the building. When a change is made in a spreadsheet, its effects are expected to update everywhere, and you can choose whether to accept the results or not. Is it not beyond the imagination to see technology advancing to offer a similar approach to the way a team might interact when we plan to build something?

Current BIM within Arup

Back in the real, but information hungry world, it is fair to say ‘we always want more’ – and so Arup’s move from 3D CAD towards the BIM paradigm has already begun. For example, when we add costing information to the 3D objects, the model can now be scheduled to assist with budget comparisons, adding a dimension of cost to the model, and hence the term ‘4D model’. Similarly, our 5D models are so-called by further adding time, date and sequencing information to the objects, to link them to project management software. Through data translation methods such as the IFC protocol, we already enjoy exploiting the current levels of interoperability between the massive range of software that we use within our own practice, and within the teams we join.

A significant shift in workflows, relationships, liabilities – and opportunities

The industry’s challenge is to embrace and accept the BIM-enabled technology on offer now, to produce a more streamlined, right-first-time approach to construction. As with all ‘revolutions’, external influences aplenty will attempt to quash the adoption of BIM and advancement of a new approach, but Arup is proud, and committed, to be leading the charge.

Forward-thinking clients already tend towards an expectation of 3D CAD-based design. As technology advances these are the clients who will expect the model’s object content to be packed with any conceivable aspect of data that can give them a future business advantage. The resulting BIM models will open far-reaching opportunities within the future management and business operations related to the building, and we see Arup contributing to this process as a key part of its multi-disciplinary teams’ offerings.
Executive summary

A number of advances in technology are coming together in a way that could revolutionise construction of steel buildings at a scale and price that is affordable to a typical Australian fabrication shop. This paper explores the possibilities of a flexible beam and column fabrication facility that will produce precision-made structural members tailored to suit any building. The system is designed to deliver members on demand so that deliveries to site are in the exact erection order and the manufacturing time is so short that floorspace requirements at the fabricator are halved and raw material stock and work in process could be measured in days.

Adoption of this system and complementary systems by industry could increase the turnover of the fabricating industry by a factor of two-three and result in massive savings for the Australian economy.

From the architectural and design point of view, FRAMEquick gives great freedom of design with spans up to 25m and curved, haunched or asymmetric beams being as easy to supply as straight sections. Structural members can be individually designed to allow penetrations for air-conditioning and other services through the beam to minimise floor heights and optimise material use. At the same time fire ratings and vibration standards are confirmed.

While fabricated sections are notionally more expensive than rolled sections, in many cases, because of the ability to optimise the material usage (e.g. make a 650mm deep beam rather than have to go up to a standard 700WB) and to make beams with narrow top flanges for composite decks, the fabricated structures are lighter, thus offsetting higher labour cost.

As the members are supplied complete with fin plates, base plates, splice plates and facia outriggers etc, on-site drilling and welding can be almost eliminated. Where site work is required, the positions of attachments can be marked out on the metal so that site cost and erection time are absolutely minimised. This concept has already been proved with highway bridges with spans to 25m and accuracies better than 1mm. Due to the high level of automation, delivered cost to site of completely detailed and painted structural members would average around $2300–$2500 per tonne and erection cost would be lower than industry standards because of the minimal field work and assembly accuracy.

FRAMEquick

Framequick is a concept for a flexible automated system using current generation software, machine tools and robotics to fabricate beams and columns for commercial, institutional and residential buildings. It is not a total building system like the Japanese systems, but a scalable small system that could easily be employed by quite a number of existing Australian fabricators. It does require a tighter level of integration between the engineer and fabricator but offers lower cost, shorter lead times and greater design flexibility.

Framequick is scalable so that a minimal system can produce about 1 tonne per hour of completely detailed beams; i.e. all the ‘jewellery’, bolt holes and end preparation, is included. This system will employ from none to seven shop floor staff and two to three engineers/programmers. In the early stages there can be a mix of robotic and manual welding so there is a smooth introduction of the technology. As demand increases production can be scaled up to 2000–3000 tonnes per month by replicating some components and increasing the size and sophistication of others. As production scales up, more sophisticated software packages reduce data preparation and programming time so that labour and capital costs do not rise proportionately.

The key factory components are robot welding cells and a high-performance cutting and drilling machine. The key software is a suite of structurally oriented CAD/CAM systems.

The system can be used with fabricated plate girders and columns, hot rolled structural sections and round or rectangular hollow sections. It can also be mixed with other beam fabrication systems such as the Zeman corrugated web construction.

It is dependant on a combination of current technologies:

CAD/CAM software
- structural design software such as Strucad, X-steel etc.
- beam/fire design software such as Fabsec
- offline robot programming
- offline cutting and nesting software.
- High output cutting and drilling systems with marking and bevelling options
- Magnet beam crane(s) with rotation and tilt
- Multi-axis programmable assembly fixture
- Gantry-supported welding and handling robots
- High-performance MIG welding such as twin wire systems from Fronius, SAF and others or the Australian MIGfast system
- In higher volume situations the system would be complimented by a conventional beam line with marking and optional coping attachments.

**FRAMEquick: the process**

Design data is forwarded from an engineering design system such as Strucad, Xsteel etc to the fabricator. Here a program such as Fabsec is used to perform detailed analysis of the structure and fire protection. Depending on customer requirements, parameters such as fire rating, natural frequency, paint versus metal trade-offs and penetration, calculations can all be altered to suit the particular building. The whole building can be processed in one pass, area by area or even member by member if required.

If the fabricator has in-house engineering expertise then many design improvements are often proposed to improve performance or reduce costs. These changes will depend on the fabricator’s logistics, current prices for plate versus rolled sections and the available manufacturing technology. Because the system is still based on 3D geometry it is easy to pass the proposed design changes back to the consultant for discussion/approval. Experience at Barrett and Severfield Reeve in the UK shows such optimisation can reduce steel usage by up to 20 per cent.

Following approval of the design, the building is broken down section by section into manufacturing details. These are split into four groups: parts from section, plate webs and flanges, small plate parts and purchased parts. All components are fed into an ERP system but also the plate components are sent to a CAM system for generating part programs and nests and all the plate components. These programs include not just profiling but line marking, identification marking, fabrication marking, hole drilling (tapping, countersinking etc) and even, if required, weld preparation.

Small parts are marked with ID numbers as they are cut and the machine operator sorts them on to pallets one beam/column to a pallet. Multi-component fittings are sent to a separate manual or robotic welding cell for fabrication. Components that are directly welded to the beam/column are delivered direct to the welding stations.
Parts that are made from rolled or hollow sections are segregated and NC program are generated for beam lines. Modern beam lines have marking and coping facilities so the beam can be completely detailed.

Plate components are delivered to a welding jig where they are clamped and then welded. Cutting and welding precision is so high beams usually come out straight and accurate within 1-2mm. UK and US bridge builders have been making welded bridge beams up to 25m by 4m for years where all the holes are predrilled in the flat, the girders welded, painted and shipped to site without the traditional trial erection.

Up to this stage all these technologies already exist and have done for at least five years in a number of structural fabrication shops around the world. Bridge builders have taken the process one step further in that the attachments are now robot welded rather than manually welded. In many ways this is a much more demanding task than for building frames because modern bridges have very few similar components – as almost every beam in a bridge is different so there is very little repetition – yet robotic welding has proved very effective for at least 15 years.

FRAMEquick relies on three recent technology improvements to make the process even more flexible than current generation systems. These techniques are not so much new as newly applied to the structural industry.

One is that, instead of using conventional moving beam fixed station sub arc welding systems, it uses robot-mounted, high deposition MIG welding mounted on a gantry moving over a fixed programmable jig. This allows much more freedom in beam configuration and more precise positioning of parts.

The second change is using one robot to pick up and position the accessories while a second robot tack them into position. This technology has been well established within the automotive industry where often three or four robots are accessing a part at the same time and 16–20 are in a single cell handling and welding a single fabrication. On a larger scale, multi-unit robot welding is now being applied to ship modules in Europe and has been applied to structural columns and beams in Japan for many years.

In this case the application is facilitated by a vision system on the robot that locates the parts on a pallet, reads the ID number and then picks up the part with a magnetic gripper and holds it in position while a second robot tack welds the part. Depending on the amount of welding required both robots could travel along
the beam placing and tacking the parts and then the handling robot could do a tool change and put down its gripper and pick up a welding torch and then both robots would traverse back down the beam completing the welding. If there is not so much welding the welding robot completes the weld while the handling robot is finding and positioning the next component.

Once one side of the beam is welded it is picked up with a crane and a magnet beam and turned over so the reverse side can be welded on a second but simpler jig. Rotation is assisted by a turnover machine such as the Stierli Rotator.

Following final welding it can be straightened if necessary and then blasted/painted to suit customer requirements. Blasting is sometimes done before cutting or after cutting but before welding.

From the start of cutting to the end of painting should be around 48 hours on average but could be as short as eight to 10 hours depending on the paint drying time. With good co-ordination it is quite possible for a cellular beam ordered by lunchtime to be on site the following morning.

Is it practical?

There are obviously complications in this concept that could not have been addressed either practically or economically even a few years ago.

The first improvement is cutting precision. While bridge beams have been drilled and plasma cut in the flat for at least 15 years there were still variations in the fit-up of parts such as web stiffeners.

Modern high-precision plasmas such as Hypertherm HyPerformance and Komatsu Razor plasma give a smaller, more consistent cut angle and combined with a high-precision profiling system can maintain part accuracies better than 0.5mm. This means parts can be placed in position to be tacked without the manual jigging and filling that used to be needed. Weld gaps are much more consistent so that distortion is usually of little concern which in turn means subsequent operations proceed with little manual intervention. Further, higher speeds, cutting ranges over 40mm and longer consumable life have reduced the cutting cost per metre by about half over the past six to seven years.

The second and most dramatic change is in robot programming software. Five to 10 years ago the easiest way to program a robot was to teach it what you wanted it to do. Offline programming systems existed, but they were very expensive and hard to learn. In those days there used to be a rule of thumb of 100 minutes of teaching or programming for one minute of welding. The situation has turned around so much now that some users are reporting less than one hour of programming for 10 hours of welding. Given that for heavy duty applications a robot can lay down up to three times as much metal per day as a person, it could be said that one programmer with 10 robots can keep up with 30 welders (in theory).

Another recent technology is high-deposition MIG welding. Up to now the most advanced plants have used sub arc for the longitudinal welds and robots for component welding. That meant two large welding stations and limited flexibility in beam design. Replacing the sub arc station with a combined use robot station improves the economics and simplifies placement of components while allowing a much more flexible design. The reduction in investment, floor space, labour and handling can result in a cost saving of $60–$100/tonne. Also 10mm leg fillet welds can be laid down as fast as 1.2m/min with twin-wire systems from Fronius, SKS and SAF among others. The Australian MIGfast System can reach 750mm/min with much simpler welding equipment.

The fourth improvement is the reduction in cost of automation generally. This system relies on a programmable jig so that changeover time from one beam to the next is one to two minutes, so little time is lost making one-off components. The other benefit is that the components are positioned within 0.5mm so welding is quicker and distortion lowered. Building such a jig even five years ago would have required $300,000–$400,000 in automation components let alone structural components, labour etc. Now, the automation components using networked actuators probably cost $100,000–130,000 and wiring time and set-up would be reduced by a factor of four. In real terms compared with the annual cost of a welder the jig is probably 30–40 per cent of what it cost even five years ago.

Similarly, vision systems and automatic part recognition have been around for many years, but it is only in the past two to three years where the technology has become reliable enough and the cost low enough to be used in an application like this.

While it is not likely that robotic painting will be used initially, even here the robots are much more usable and inexpensive than they once were; so it can be expected that, once the first FRAMEquick installation has been running a couple of years, automating the painting will be the next step.
The main constraint on the viability of this system is the current industry structure with its convoluted supply chain and non-standardised, uni-directional information flow. It is much easier for a company like Barrett to make such a system work where it controls the whole process. On the other hand, Severfield-Reeve Structures and Watson Steel usually take designs from consultants and architects, but they have enough engineering and technical skill within the company to refine the design with the customers and manage the information and automation.

In Australia this is still not common, with the work being split between engineers, builders, detailers, steel service centres and fabricators. It is difficult to transmit changes back up the system quickly and the number of organisations required to agree to changes makes lowest common denominator practices the order of the day.

Hence, for the average Australian fabricator, 10 or 15 per cent of the labour saving on the shop floor will be replaced by engineers and technicians to make the system work. However labour saving is only part of the story. Quicker turnaround, reduced working capital, more design options for the client and faster erection are together much more important.

Is it economically viable?

The current rule of thumb is that erected steel framing is $4000–$5000 per tonne.

The cost breakdown shown in Figure 7 is what can be expected from a 3500tpa FRAMEquick system. The variable costs are direct costs of materials, labour and consumables only. Overheads are placed in the fixed costs.

### Figure 7: Estimated cost breakdown of automated steel fabrication

<table>
<thead>
<tr>
<th>Stage</th>
<th>Cost/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design/detailing</td>
<td>$80</td>
</tr>
<tr>
<td>Part programming data clean-up</td>
<td>$25</td>
</tr>
<tr>
<td>Steel</td>
<td>$1,000</td>
</tr>
<tr>
<td>Cutting/marketing drilling cost</td>
<td>$80</td>
</tr>
<tr>
<td>Handling plate/cut parts</td>
<td>$30</td>
</tr>
<tr>
<td>Fabricating components</td>
<td>$30</td>
</tr>
<tr>
<td>Purchased components</td>
<td>$50</td>
</tr>
<tr>
<td>Beam welding</td>
<td>$40</td>
</tr>
<tr>
<td>Component welding</td>
<td>$50</td>
</tr>
<tr>
<td>Blasting</td>
<td>$10</td>
</tr>
<tr>
<td>In shop handling</td>
<td>$20</td>
</tr>
<tr>
<td>Painting</td>
<td>$80</td>
</tr>
<tr>
<td>Transport</td>
<td>$50</td>
</tr>
<tr>
<td>Erection</td>
<td>$250</td>
</tr>
<tr>
<td>Total</td>
<td>$1,820</td>
</tr>
<tr>
<td>Fixed Costs</td>
<td></td>
</tr>
<tr>
<td>Rent/light etc</td>
<td>$150,000</td>
</tr>
<tr>
<td>Maintenance and upgrades</td>
<td>$100,000</td>
</tr>
<tr>
<td>Equipment lease costs</td>
<td>$900,000</td>
</tr>
<tr>
<td>Management sales and admin</td>
<td>$650,000</td>
</tr>
<tr>
<td></td>
<td>$1,800,000</td>
</tr>
<tr>
<td>Overheads per tonne</td>
<td>$520</td>
</tr>
<tr>
<td>Cost per tonne installed</td>
<td>$2,320</td>
</tr>
<tr>
<td>Profit</td>
<td>$420–640</td>
</tr>
<tr>
<td>Selling</td>
<td>$2,750–3,000</td>
</tr>
</tbody>
</table>

### Conclusions

If Australian fabricators and engineers work together they can reduce the cost of steel framing to the point where it can triple the market share it now has in multi-storey buildings.

The technology is available, affordable and applicable to Australian scale operations.

With this technology, repetition is not important. Modern automation is about making one-off parts as efficiently as thousands, so there is no need to say we need to standardise the design. On the contrary, using this technology we can offer the customer unprecedented design choice and that in itself will win markets.

The gains to the industry and the economy will be in the order of hundreds of millions of dollars every year.

The sticking point is not money or even market size, it is the will to lead the game and provide the skills and communication environment to make it happen.
4.5.10 WHAT DOES THE FUTURE HOLD

By John Hainsworth, Peter Farley and Sandy Longworth
For The Warren Centre

Introduction

The key facts emerging from the Technology Issues Group the views expressed on ‘what the future holds’ were:

- The take-up of digital information documentation and transfer of technology by the Australian steel construction sector is low compared with other industries undertaking similar process operations and is waiting to be utilised.
- There is an abundance of automated fabrication technology, some already in use, which can transform the industry.
- Once introduced, the progressive improvement of existing technologies and introduction of new techniques will establish and maintain the competitiveness of structural steel.

Project resources did not permit an exhaustive analysis of all technologies, the priorities addressed being:

- design, detailing and information flow
- fabrication and erection.

Design detailing and information flow

Increased take-up of 3D technology

The Technology Group concluded that, given the practice of fabrication of steel off site under factory conditions and the increase in dimensional accuracy now governing the construction industry, the benefits to be gained in the foreseeable future from 3D documentation and electronic information flow, in combination with progressive automation of fabrication, will be more beneficial to steel construction than concrete. This applies particularly to the greater accuracy and quality control of the steel product and the lesser site construction activities. While this is a given, 3D technology and information flow is equally applicable to the concrete sector, particularly with respect to automated scheduling and bending of reinforcement. There will also be a greater prefabricated component finding favour with concrete construction with the adoption of pre-cast elements such as columns and formwork profiles for hybrid composite construction. The aspect of ‘design freeze’ will therefore tend to apply equally to both the steel and concrete sectors.

Progressive development and uptake of BIM for larger projects

Software for Building Information Modelling (BIM) has developed rapidly over recent years, and is being energetically promoted by its vendors. While BIM definitions vary, the concept of data flow, data manipulation and what-if scenarios is becoming more commonplace in construction globally. Climate change will influence the market place and concepts such as carbon footprint data will become a more dominant driver of change. Increasing pressure is now being placed on UK steelwork contractors to furnish planning authorities with this carbon footprint data. Through BIM practices, the future planning of buildings will progressively translate the data held by the model’s objects in all permutations of analysis, leading to comparable results of design options. These will be scrutinised as more emphasis is placed on sustainable design and construction. The steelwork industry will focus on sustainability and the product will become more cost effective over the lifecycle of the building, addressing, ease and safety of erection, adaptability, recyclability, serviceability and asset value. The larger clients will become increasingly focused not just on today’s cost, but also life-cycle costs and quite possibly how an impact on their branding/image might be affected if they choose inappropriate materials and services.

Continuing pressure on interoperability of software with cost reductions throughout the value chain

Uniform standards for interoperability are being promoted by the Australian Co-operative Research Centre for Construction Innovation, The International Alliance for Interoperability and others, and various government and industry reports (EngAust, NIST, CSIRO) have highlighted the potential cost savings to building owners and other participants in the construction supply chain. From a ‘steelwork’ perspective, interoperability of software through SDNF (steel detailing neutral format) and CIS/2 (CIMsteel Integration Standards) especially, as well as VRML (Virtual Reality Model Language,) X3D (Extensible 3D Graphics) are already well established and serve the industry well. With the next generation of BIM applications aimed upstream of the supply chain, what seems most encouraging is that these protocols are already taking hold in the vast range of software, and so the future passing and translation of data that the supply chain needs will only get better over the next five years.
Engineer, detailer and fabricator linkages

It is not foreseen that great changes will occur in this link of the steel value chain. The project has shown that detailers have been more pro-active in taking up technology and establishing overseas markets. While closer relationships and mergers between engineers and detailers would seem likely, engineers’ perception of risk exposure and management of the detailing discipline would tend to work against possible marriages. Furthermore, detailing business drivers are very much production focused compared with engineering, which is project and concept focused.

The detailer’s scope of services will become progressively larger with the increase in fabrication automation and associated CNC input. Detailers will become more familiar with the fabricator’s technology. There will also be a trend back to some in-house detailing capability based on workshop equipment exposure for the reasons mentioned later under the fabrication and erection section of this report.

Fabricators’ input to design team

The project has confirmed that in general fabricators’ expertise is not being sought at project inception. It is projected that, with those fabricators taking up the Design and Construct (D&C) route as well as new entrants, the fabricators’ status will be redeemed. Sales and business promotion will be essential for the D&C contractor requiring experienced representation, thus enabling fabricators to recover their seat at project inception. UK experience has shown that the D&C procurement route has aided the advancement of the fabricator’s role from that of a mere supplier role, to an innovative, solution-based steelwork contractor. In order for Australian fabricators to advance in this way, it seems logical to have them court the larger contractors, engineers and architects, by offering advice and up-to-date experience as well as costing and rationalisation knowledge. From this, trusting relationships will be nurtured with repeat business coming, with a will to deliver a steel-framed solution time and time again. Equally, this will bring fabricators into contact with people they may need to employ to develop their business.

Progressive integration of digital flow of information from engineer to workshop floor

With current practice and the existing value chain, the likelihood of rapid take-up of 3D software and associated digital information data transfer with other than selected organisations is not thought to be likely. There will be document exchange and transfer of material data for tendering and pre-ordering but it is difficult to see a versatile system developing rapidly that can envelop all of the roles traditionally undertaken by each party. On the other hand, with the D&C steelwork contractor, the change will be rapid, with take-up depending on the degree of investment in technology already readily available for a ‘one-stop shop solution’.

Adaptability of systems to handle change

The advent of D&C provided by steelwork contractors will bring with it more programmed discipline in the phasing of the project. Change will be possible, at little or no extra cost within the phasing windows. This will be a direct benefit of the enhanced information flow system. This will be little different to a concrete project, except that changes in formwork profile and reinforcement can be accommodated more rapidly, provided the concrete has not been poured. With the advent of pre-cast components and more hybrid type concrete, composite deck buildings, change irrespective of the building system, will pose equal challenges.

Pricing benchmarks, material lists and budget pricing

It is likely in the next five years with the progressive use of the Building Information Model, to envisage pricing benchmarks and budget pricing being linked to price indices. In the meantime, material lists will continue to be routinely issued with tender documentation to assist the pricing process. Where there could be change to assist in project estimating may be with the introduction, on a regular quarterly basis, of the reporting of the finished erected cost of steelwork on a unit area basis for various types of building. The reporting entity could also maintain a database of steel statistics for recently completed buildings of given types. These statistics would be available in weights per unit area for given elements, in addition to a general description of the structure but without name disclosure.

Fabrication and erection

It is foreseeable that in three years, world’s best practice will produce painted fabrications for multi-storey buildings with less than three hours per tonne labour content. That is about four to seven times faster than the current Australian average. The introduction of technology throughout the steel value chain will be the best insurance available to counter imported fabricated product in the large project end of the market.

The key to this revolution will be more streamlined digital information flow from engineer, through
detailing to modern, high-performance, structural machinery and automated welding. Software systems have reached a level of performance where virtual modelling for manufacture and construction will become commonplace. The completion of the integrated design, data and material flows has already been shown to produce rapid turnaround of two to three days and even less in the best case.

The current industry structure, in the commercial multi-storey building sector makes achievement of this very difficult, due to the number of parties in the value chain and the distribution of risk and reward.

The resolution of this problem in other countries, in particular the UK, has resulted in the increasing popularity of D&C with the formation of steelwork contractors who are assuming an increasing share of the engineering, fabrication and erection responsibility for complete building framing. This not only concentrates and enables better management of risk but enhances design optimisation and compatibility with the fabri cator’s methods, thus enabling hands-on control of scheduling, erection sequences etc. From the customer’s point of view there is a single point of responsibility leading to shorter construction time, and better cost, quality and risk control.

In the current environment, technology uptake, whether it be associated with information flow or fabrication, will be influenced by skills shortage throughout the value chain.

While there have not been significant breakthroughs in erection techniques, there has been marked improvements in crane costs, including erection and dismantling times, capital and operating costs, capac ities and operational flexibility. More detailed attention will be paid to pre-assembly and phased erection. The erection of steel composite structures, with the use of cherry pickers for securing connections, is now very much safer.

Information flow to workshop floor – CAM systems

How is it envisaged that future change will emerge? There will be changes to the business models and structures adopted by the various players. This subject has been touched on in other sections of this report, here we focus on the technology at the shop-floor end.

As mentioned in the design and documentation introduction to this section of the report, digital flow of information is an essential link. Detailing must therefore be produced on a recognised detailing package such as Xsteel, StruCad, Prosteel etc so that dimensions are precise and details exactly specified. The detailing system should include sufficient information that every attachment to the structure and its position is included, not just the major components. For example if there are five purlin cleats it is not sufficient to have a note saying five cleats @ 1200 spacing. The CAD data must include the detail of the cleat and the exact position of each one on the frame. Under the current business model many of the detailing systems are external to the fabricator, being provided by specialist detailers. This practice will continue even though there will be fabricators bringing detailing back in-house. The fabricators will specify data requirements specific to their capabilities rather than generic drawings.

A key consideration currently, is that, the information provided is a combination of drawings and instructions. For the digital fabricating shop of the future all the information needs to be on the ‘disc’ or in the computer.

There will be increasing application of CAM systems that translates the geometry data into commands for machine tools and eventually robots. For example, CAD data might include a 22mm hole, in which case the CAM data tells the machine tool which drill to select and what spindle speed, feed rate and stroke to use to make the hole. Depending on the fabricator, the output from the CAM system from the same input data can be quite different as each machine has its own capabilities and dialect of machine commands. The CAM system is a production function of the fabricator’s equipment.

Marking, labour input and skills

Today most of the medium to large fabricators already have computerised or CNC machines for cutting, drilling and punching flat details or in the form of beamlines for processing sections, so they have some familiarity with the technology. However many of these systems have limited or no marking capability. In this case the part comes off the machine and cleat positions etc are still measured and marked by hand. There will be increasing refinement of this operation.

With reference to existing skills levels, operating and programming these CNC cutting, drilling and punching machines, even the more sophisticated ones are usually within the capabilities of a traditional boilermaker/ welder with perhaps a post-apprenticeship certificate in NC technology. There is therefore no immediate need to change the training system. In fact it could be argued that these systems require less highly skilled labour, possibly level-headed, IT-proficient, young workers.
To reduce production labour input, increase productivity and accuracy, it will be necessary to introduce modern machines, capable of marking, not only the item number on each part, but the precise location and item number of any parts to be attached. To achieve short lead times, and low error rates, there will be need for the introduction of marking technology which is essential and, as pointed out above, will require increased input from the detailers.

This will demand more manufacturing knowledge from the detailers but not necessarily a higher level of academic training.

Fabricator-detailed relationships

While detailing will still be outsourced, for fabricators accepting the technological challenge, there will be advantages to be gained by bringing some detailing back in-house. This will facilitate vertical integration, enabling the setting up of standard procedures for comprehensive detailing information to suit marking conventions and CAM methods. Once the standards are established, then work may be outsourced but only according to the fabricator’s standards rather than those of the detailer or consulting engineer. This is the start of the fabricator’s uniqueness and their brand.

The next aspect of automation is the scheduling of the project. For major projects, this is done first, working from customers’ project timelines to establish and link the detailing and scheduling systems together to ensure that the workflow through the shop can be optimised and delivery dates and sequences met. It is at this point, depending upon the fabricator’s commitments, that decisions may be made to outsource sectors of the project: outsourcing or collaborating with competitors who have compatible operations and in whom the Fabricato has confidence. This will in due course develop specialist fabrication clusters, resulting in greater industry flexibility and reliability of supply.

The progressive development of fabrication shop automation and scheduling will lead to its linkage through an MRP system to ensure that materials and supplies are managed and provided as required. With D&C operations, this is an appropriate stage for the introduction of just-in-time (JIT) working. Given that the actual time in processing for most components is less than 48 hours, there are significant economies in stock holding, floor space requirements and work-in-process provisions to be gained by automated scheduling and management of incoming material and finished product.

Digital information flow in the future, particularly with D&C projects, will include data collection for progress tracking and scheduling, thus enhancing quality standards which are projected to increase commensurate with technology input.

Fabricator–engineer relationships – business models

The progressive introduction of increased automation will bring with it the need for closer alignment of engineers, detailers and fabricators. This development will occur in many ways, ranging from collaboration between compatible parties, to the progressive assumption of increased in-house engineering responsibilities assumed by the fabricator. Where the focus is on D&C, the benefits to be gained from in-house detailing and engineering will be very compelling. The scope for design and fabrication versatility and innovation is very great indeed. There is a multitude of design options available, quite apart from framing concepts, comprising member sections, profiles and connection details. Flexibility in material specification and sourcing will become increasingly important in the next five years. The range of unwrought products available from both local and imported manufacturers will be a strong driver for innovation by the collaborative and alliance teams as well as the all-embracing D&C operators.

It is also possible that D&C steelwork contractors will emerge during the next five years, with no fabrication facilities or construction equipment. Such organisations will have strong engineering and marketing skills, supported by appropriate financial resources. They will be well-equipped with appropriate software, some possibly of a proprietary nature, adequately financed, prepared to accept and manage risk and will support their organisations, either through alliances, collaboration or more formal agreements with selected fabricators and erectors. In a sense they will be virtual operations. These organisations may emerge from fabricators, builders, contractors, manufacturers, engineering firms, project managers or simply entrepreneurs. They will be characterised by strong innovative leadership.

The frame, which represents only a minor portion of the total building cost, is the most permanent portion of the building and will have the longest life. Facades, services and finishes, like Davy Crockett’s axe, can be renewed many times. Frame selection, and in particular ‘The Relative Value Proposition’ impacting material selection will focus more on aspects of ease and safety of erection, serviceability, adaptability, sustainability and asset value. The weight of steel in a structure will be of less significance.
Painting, fire protection

Surface treatment today is becoming more sophisticated and varied. It invariably requires blast cleaning followed by specified painting or intumescent passive fire protection. Currently, in Australia intumescent painting is significantly more expensive than in the UK, resulting in the use of cheaper vermiculite fire spray where steelwork is not exposed. There has been a significant reduction in intumescent painting costs in the UK, over the past three years, primarily due to increased competition from suppliers. This trend is likely to follow in Australia, should usage increase and paint products be manufactured locally.

It is projected that the more progressive fabricating facilities will bring surface treatment and painting in-house, thus reducing the logistical cost of sending work out and enabling better control of material. Blasting will preferably be done before fabrication, which will improve cutting and welding efficiency and allow the use of smaller, lower-cost blasting machines.

Fabricated beams

While there will not be an immediate move to manufacture custom-designed, welded beams and columns, the closer relationships between engineering, detailing and fabrication, be it through collaboration, alliances or integrated D&C, will introduce the competitive advantages of this process, as mentioned above.

Along with custom beam manufacture will be the introduction of proprietary design software, such as Cellbeam or Fabsec and no doubt others to be developed. This will enable replacement of standard sections with more efficient sections, possibly asymmetrical and or tapered, resulting in design and cost optimisation.

Communication

As mentioned in the introduction to this section, there will be a need for progressive flow of information in a standardised format that can be read by all parties. In some cases a standardised neutral format such as DXF, DSTV, SDNF or STEP will be acceptable. For major projects, there will be a progressive introduction, by the prime contractor, of a BIM system with which the steelwork data will have to be compatible. This aspect of data transmission is likely to be the biggest inhibitor to the progress of change within the industry and will work to the advantage of the integrated D&C operator.

Robotic positioning and welding

While there may be a general feeling that it will be quite some time before robotic processes enter the building fabrication sector, a comparison of similar industries, the threat of imports and the skills shortage will stimulate the more adventurous operators to progressively introduce these systems, initially alongside traditional manual systems.

In most industries, systems efficiency drives the introduction of automation, leading to cost and workforce reduction. In the fabricating industry, it would appear that the major driver for introduction of robotic processes will be the skills shortage. If there is no skills shortage, change will be slow.

It is more likely that the robotic welding of connections, splice and base plates will be introduced progressively to new beam fabrication lines rather than to existing rolled section processing installations. Beam fabrication lines will probably use sub-arc or perhaps mechanised MIG welding for the main welds and initially connection details, stiffeners etc, will be attached by manual welding. It is logical at this point to install a parallel robot welding station, which welds parts that have been manually tacked to the beam. This type of system has been well proven overseas in the bridge-building industry for some 15 years. Once established it will be a relatively simple exercise to extend the process to detailing standard rolled sections.

The key development that will drive introduction of this technology is the maturity of robot programming software and the progressive reduction in the total cost of robot installations. Vision systems have also improved in performance and are becoming cheaper. This improvement combined with software is enhancing the capability and flexibility of robotic cutting, welding and handling.

When first introduced, robotic operations consumed 100 hours of programming time for one hour of arc time. Today systems are now running at one hour of programming time for 10 hours of welding time, thus demonstrating worthwhile savings and payback. A limitation to the more rapid adoption of robotics is the proliferation of communication protocols such as Arclink, Profibus, Canbus and others. This has led to difficulties in the integration of welding machines with robots, resulting in alliances between robot manufacturers and welding machine suppliers. While this limitation will be progressively overcome, there is a need for expert advice on equipment selection and compatibility in the planning of robot installations.
There is emerging an increasing requirement for robotic programming skills, which is mentioned in the skills section (1.3) of this report. While some introductory training will be necessary, employees with the basic IT skills background necessary to perform these programming tasks will be more readily sourced than experienced welder trades persons.

Once the initial robotic connection welding operations are introduced, the next step will be to have robots scan and identify parts, position these and hold them in place while a second robot performs the welding. This has been happening for years in the automotive and ship-building industries and, with advances in cost/performance of robots and particularly the software, it is projected that it will be introduced into the Australian fabrication industry in the next five years. Key issues to be resolved by individual operators will be the handling of parts to service robots, the automatic turning of beams, columns, cutting square and straightening. All these operations have been demonstrated by overseas operators.

Robot painting has been established in the automotive industry for many years. It is now spreading to ship building and is readily applicable to the structural steel industry. As mentioned above, the rotating of the components to ensure all faces are coated without damaging the fresh paint, poses a relatively straightforward material handling challenge.

Capital and operating costs

All these changes seem like a lot of work and extra responsibility for the fabricator who has to be convinced that it is worth the extra cost. A 5000 tonne per year operation with typical Australian technology would have a labour and overhead cost of about $3.5–$4 million per year. Without including painting or welded beam manufacture, those costs would fall to about $1.5 million. The in-house engineering cost, based on UK practice, would be around $500,000–$600,000 per year and capital and maintenance costs of additional equipment would be in the order of $600,000–$700,000. Assuming a 5 per cent reduction in material usage through design optimisation, this gives a further saving of $250,000–$300,000 in material, transport and erection costs.

Overall there is a contribution to the bottom line of the order of $1 million-plus per year just by improving manufacturing efficiency.

However, the purpose of this system is not only to make money as we have shown, but also to improve the fabricators, competitive position versus PSC and imports by offering a better, faster service to the customer. The system outlined gives shorter, more accurate deliveries, fewer site preliminaries and a quicker return on investment.

Adding in-house painting and welded beam fabrication can both add to the profits and the value offered to the customer, but these functions are not necessary to justify modernising manufacture. However there are synergistic benefits in having these processes as part of the offering. Welded beams might only be a small fraction of the total tonnage but they are sometimes critical to making a complete offer.

It is likely that, once the step is taken to introduce beam fabrication and robotic welding, progressive integration of the entire process will follow relatively quickly. It will most likely be initiated by D&C operators because of their control of the total process. Operations will be introduced progressively, reducing the fabricator’s performance risk and spreading capital outlay, but once introduced, will be driven by cost savings, product quality and predictable output. With a committed staff and capital systems outlined, the systems could be operating in the next five years. For straightforward ‘stick and column’ structures, average time from design and detail approval to first steel on the job would be approximately a week with labour costs in the order of two hours per tonne.
4.6  RELATIVE VALUE PROPOSITION

4.6.1 GROUP REPORT

By Brian Mahony
The Warren Centre

Executive summary

This paper discusses in detail the findings of the Relative Values Issues Group, which focused on the relative values, monetary and otherwise, of the use of steel and concrete as framing materials for commercial buildings.

The group found that at present concrete is a more attractive framing material. However, while raw material for concrete is likely to increase in the near future, there is a substantial opportunity for steel to reduce its costs in the future. This will be achieved by the adoption, by all participants in the steel value chain – such as engineers, drafters, fabricators and material suppliers – of new technologies that allow seamless interoperability between these participants.

The relative values of steel and concrete are summarised in Table 1, which compares the two materials with the prevailing low-tech and the new steel delivery methodologies.

General

The value proposition is what the customer (or decision maker) sees or perceives is being offered and delivered into the marketplace. The relative value proposition compares the important attributes of steel and concrete to enable decision makers to decide to choose either a steel or a concrete frame for the building in question.

This section discusses the merits of each of the attributes listed below for both steel and concrete frames.

The commercial building industry environment

The commercial building industry comprises a disparate group of developers, owners, architects and project managers who have the responsibility for delivering a wide range of commercial building types to the owners/occupiers. Buildings under consideration in this project include low-high rise offices, shopping centres, hospitals and government buildings.

The commencement of any development project starts with the purchase of the land. A concept study is then undertaken to determine the most economic outcome for the development, taking into account planning regulations, likely rental returns, and the net lettable area of the building. These commercial decisions are then reflected in the maximum capital cost of the building as dictated by the rental revenue stream. This capital limitation then impacts on the building in terms of finishes, services, façade etc. At approximately 25 per cent of the building cost, the frame impacts on the management of capital costs.

Table 1: Assessments of Relative Values – Present and New Steel Technology

<table>
<thead>
<tr>
<th>Item</th>
<th>Superior material – present steel practice</th>
<th>Superior material – new steel practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Both approx the same</td>
<td>Steel</td>
</tr>
<tr>
<td>Time</td>
<td>Steel may be quicker</td>
<td>Steel</td>
</tr>
<tr>
<td>Safety</td>
<td>Steel and Concrete Equal</td>
<td>Equal using hi-tech steel</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Concrete deemed better at this time – steel industry to seek new rating</td>
<td>Steel – if re-rated by GBCA</td>
</tr>
<tr>
<td>Fire engineering</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>Risk</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>Design process</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>Design change and re-work</td>
<td>Concrete</td>
<td>Steel</td>
</tr>
<tr>
<td>Technical Issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- TI.1 - Accuracy of construction</td>
<td>Equal</td>
<td>Steel</td>
</tr>
<tr>
<td>- TI.2 Services interface</td>
<td>Equal</td>
<td>Steel</td>
</tr>
<tr>
<td>- TL.3 Façade interface</td>
<td>Equal</td>
<td>Steel</td>
</tr>
<tr>
<td>- TI.4 Floors and roof</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>- TI.5 Core design</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td>- TI 6 Floor vibration/deflection</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>- TI 7 Craneage issues</td>
<td>Concrete</td>
<td>Steel</td>
</tr>
<tr>
<td>- TI 8 Building geometry</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
<tr>
<td>- TI 9 Durability and maintainability</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td>- TI 10 Footings and foundations</td>
<td>Equal</td>
<td>Steel</td>
</tr>
<tr>
<td>Delivery structure</td>
<td>Concrete</td>
<td>Equal</td>
</tr>
</tbody>
</table>
It is at this concept design stage that the decision on framing material is taken. In general, the engineering design with respect to structure and services is limited in detail, except for site-specific issues. For major works, it would be expected at this stage that the preliminary framing would be developed in 3D format for both steel and concrete solutions. A services engineering consultant should be engaged at this stage to advise on duct sizes and location, with this information being incorporated into the 3D model.

At this stage there is generally a reduction in design effort until a ‘keystone’ tenant is confirmed, at which time, the design program and construction period becomes critical due to the commercial conditions of the tenancy. This invariably means that some re-design of the building is required to meet the specific needs of major tenants. The availability of the 3D model at this time is essential in handling change with the development of detailed design.

At present, and in particular for large, high-rise, commercial projects on the eastern seaboard, concrete is often the automatic choice for the framing system due to the following:

- Concrete is about the same cost as steel
- Change can be accommodated more readily with concrete.
- The concrete industry is well organised with reliable supply.
- The pre-stressed concrete industry is very attuned to meeting the needs of the building industry with design and construct offers.
- Concrete is assumed to have a higher sustainability rating.
- Concrete is assumed to have superior fire resistance.
- Concrete pump technology ensures minimum craneage for frame construction.
- Concrete is more accommodating for services installation, ceiling treatment and floor to floor heights.

**The new steel paradigm**

Unlike other industries, the Australian steel fabricating industry has been slow to take up much of the existing computer-driven technology, which has made steel framing so competitive and so successful in Europe and the UK.

The Warren Centre survey conducted by the Technology Group (see Section. 5.6.3) indicated poor take-up of 3D documentation technology by fabricators and slow adoption of NC driven fabricating equipment e.g. cutting, drilling, marking. Architects and engineers, other than those from the very progressive firms have been slow to adopt 3D technology. On the other hand detailers as a group have shown the most enterprise, possibly because their survival depends upon high productivity.

This technology revolves around the use of 3D design tools, which are initially used to design the building and to form the database starting point for the building information model (BIM). As described by Barrett, (Section 1.4) the digital outcomes of the 3D structural model are then used as inputs to programs for:

- detailing each member
- automatic CNC cutting, drilling and welding machines (beam lines)
- the manufacture of weldments associated with each member
- material take-offs and procurement of the steel.
  These MTO’s are then sorted into sections, cutting lengths to minimise scrap, drilling, marking and nesting programs
- the design of the floors and the procurement of metal decking for these floors
- the marking-off and identification of every steel member in terms of member number, mass, truck delivery and section.

The paper by Farley (Section 4.5.9) discusses the fabrication part of this technology in more detail. The new low-cost fabrication approach allows the alternative production of more efficient fabricated plate sections (compared with rolled sections) which can be tailored to accommodate services.

The net result of the application of the new steel technology to serve the building industry would be a reduction in the delivered price of steel framing of about 20 per cent (Farley Section 4.5.9) or about $100/sq m in a typical non-CBD, medium-rise building.

Japan has pioneered automated, self-climbing, canopy-style erection methodologies (Taylor et al 2003) that:

- allow all-weather construction
- allow 24/7 construction
- minimise large craneage use
- improves on-site safety.

However, it is doubtful if the size of the Australian market could justify introduction of this technology at present.

There is also the potential in the use of quick erection techniques to replace the alignment and bolting time of the connecting members (Munter 2006).
It would appear that there is great scope for the introduction of automation in the fabricating of steelwork to reduce building costs in the near future, while concrete construction, particularly on the eastern seaboard has a lesser opportunity to do so, given the expected increases in raw material and labour costs.

The Relative Values

General

The attributes listed below have been identified as the main factors in the decision-making process between concrete and steel. In order of precedence, they are:

- cost
- time
- risk
- safety
- ease of construction
- sustainability
- the design process
- technical issues
- adaptability.

Floor to floor height may be critical but in most cases the so-called battle zone (i.e. the space between ceiling and floor above) is marginally different for steel and concrete. It can be accommodated, however, by using clever steel design, albeit integrated with services. Steel has countering advantages, e.g. span flexibility and smaller columns.

Most of these issues have been thoroughly canvassed in the other issues group reports described elsewhere in this report (Section 4). The leading factors pertaining to each issue are briefly discussed below.

Cost issues

The costing issues associated with steel fabrication for the building industry are discussed in Section 4.4. Unlike the UK fabricators that serve a market so large that they can specialise in market sectors (Section 1.4), many Australian building structural steel fabricators serve a number of sectors including the resources industry. For this reason, fabricated steel pricing is opportunistic and tends to follow the overall Australian economy, and not just the commercial building industry. This means that a long-term stable pricing regime rarely exists and leads to uncertainty in the estimating/budget process; compare the concrete industry, whose supply pricing is relatively stable.

On the other hand, raw material costs for concrete are expected to rise significantly as the easily won alluvial sand and gravel deposits are worked out and replaced by distant hard rock quarries.

The progressive introduction of new fabricating facilities, employing proven new technology and targeting the building industry, has the ability, through early participation in the design process, to provide accurate competitive pricing based on cost of production rather than the present opportunistic-pricing regime.

It is of interest to note the potential savings offered by the adoption of the new technology discussed in this report. In his paper Farley (Section 4.5.9) suggests a fabricated cost of $2500/tonne fabricated, while case study 1 (Appendix B1) indicates present steel prices in the range of $3500–4000/tonne.

Time for construction

The Value Chain Study (Section 4.3) showed little difference in the time for construction between a sample of four steel-framed and one concrete-framed buildings.

The adoption of the new technology, which enables the precise order of erection and hence fabrication to be planned, significantly reduces erection times with many frames erected in two to three weeks from arrival at site (Barrett, Section 1.6). This gives a significant saving in overall construction time, provided the frame lies on the critical path. (In some cases the façade supply/install contract lies in the critical path.)

In any case, the fast steel-frame erection, followed by composite floor construction utilising unpropped metal decking, allows a safe work platform to be achieved in quick time, thus allowing an early start on the installation of services.

Fire engineering

General

A common perception in the construction industry is that fire ratings are intrinsically assured by concrete structures, while steel structures require expensive treatment to achieve the equivalent rating. In the UK, fire protection is applied on a ‘deemed to comply’ basis, while Australian practice is subject to the BCA regulatory regime. UK fire ratings of approximately 60 minutes are significantly more liberal than those in Australia (120 minutes).

Nevertheless, Barrett asserts that there has been a progressive reduction in fire protection coatings costs in
the UK and this needs to be addressed in Australia. Fire spray is much cheaper in Australia than intumescent paint. There is a challenge for the fire spray contractors to address efficient application of spray on site after steel-frame erection (see Section 4.5.4). Like corrosion, fire protection is a serious issue to be addressed by the ASI. The advent of cost-effective, intumescent paint systems for fireproofing steel and the near-ubiquitous installation of sprinkler systems to protect building content as well as life, removes fire ratings as an impediment choosing steel. There is need for increased competition in the fire protection trades which, given UK performance, is achievable. In some cases, steel can achieve the rating by the addition of extra thickness of material, or by filling hollow column sections with concrete.

Bennetts (Section 4.4.2) has written a very interesting paper outlining the recent history of fire-rating regulation and suggests strategies for the fire protection of steel. He recommends the use of fire engineering for those projects able to absorb the additional costs and makes reference to the potential for acceptance of non-fire protected steelwork in four-storey buildings fitted with sprinklers, albeit with additional fire insurance premiums.

**Approach to fire engineering**

Ferguson (Section 4.4.3) has stated that the primary objectives on the BCA fire code for safety in the built environment are:

- ensuring the safety and safe escape of building occupants in the event of fire
- protection of adjoining buildings
- protection of fire fighters
- minimising property damage or loss due to fire.

The performance requirements of the Code are the absolute requirements that must be satisfied to ensure the design of a building complies. There are two ways of meeting the performance requirements, namely:

- by satisfying the deemed-to-satisfy (DTS) provisions (i.e. follow the ‘cookbook’ type approach)
- by developing an Alternative Solution.

Fire engineering is concerned with the ‘Alternative Solution’, i.e. performance-based solution, which is developed as part of the overall fire safety design where the DTS provisions cannot be applied or are inappropriate. This may be due to the generic DTS provisions being:

- excessively conservative for a specific building
- inflexible and restrictive
- inappropriate for complex architecture, structure or services design
- unsuitable for heritage/refurbishment projects

**Conclusion**

There is today an improved recognition of fire protection in steel buildings, which enable the frame to meet fire ratings in a cost-effective way. Barrett (Section 1.4) indicates the cost of fire protection for steel lies between 5-10 per cent of total frame costs.

**Risk**

There is a perceived risk among builders that steel fabricators are unreliable and that the delivery of steel framing sections is subject to delay, one stated reason being the non-availability of sections. The ASI regularly monitors distribution centre stocks and reports good availability for popular sections.

While there are documented cases of poor performance of steel fabricators, poor steel contract management experience on the part of a contractor would account for some of these cases and, where a D&C contractor is used, delivery risk is minimised.

In summary, the delivery risk is the same as encountered by the resources industry (where it is not a perceived problem) and is manageable.

In the case of concrete, the supply in most urban areas is timely and quality assured, the main risk being weather related.

**Site safety**

The work in assembling a steel frame comprises mainly off-site work with about 20 per cent of the accrued value being expended on a short-term erection phase. (For concrete these values are reversed, with about 80 per cent of the value being site works).

Given that all major contractors are now heavily focused on site safety, it cannot be unequivocally stated that the use of one material is safer than the use of the other. However, given the degree of off-site work in a steel frame, the short erection time utilising fewer workers on site, the prevailing safety culture of major constructors and revised statutory regulations covering steel erection, it can be expected that site safety will not be compromised when compared with concrete and could be expected to improve. Long-term statistics comparing the two alternatives are not yet available, though at least one contractor has started compiling them.
**Sustainability**

One of the findings of the project is the emergence of sustainability as a major issue. This is driven by tenancy preferences, particularly in buildings where the major tenants are statutory bodies.

At present, the Australian Green Buildings Council rates concrete ahead of steel in establishing a Sustainability Scorecard under present building rating systems. This view is disputed by UK fabricators such as Visiting Fellow Richard Barrett and other experts (M Reuter, see Appendices A10, A11).

The ASI and the steelmakers (BlueScope, OneSteel) have established a Sustainability in Steel Committee to have steel positively re-rated for use in buildings, based mainly upon the multiple re-use of steel through repeated recycling. The findings of this committee are awaited.

**The design process**

As mentioned earlier (Section 4.5.2), the 3D design/modelling process is the key to modern steel fabricating practice. It must be said however that similar 3D design technologies also exist for concrete designers.

The fundamental difference between the two designs lies in their downstream use. The 3D software, with compatible interoperability, can be used to seamlessly program digital flows of information terminating in CNC outputs for steel fabrication processes. With concrete, 3D software can generate re-bar processing and prefabrication but there still remains the labour intensive on-site activities such as form working, re-bar placing and pouring concrete.

**Design changes and rework**

Concrete framing has traditionally delivered more flexibility to the builder for site changes and rework, provided that the concrete has not yet been placed, while changes in steelwork have to be redesigned and re-detailed before the revised drawings reach the shop for fabrication.

The use of the 3D software greatly facilitates change and enables work to proceed in a timely fashion. In a sense, this is because one of the outcomes of automated fabrication, feeding off a 3D model, is speed of change and greater accuracy of fabrication resulting in a reduction in on-site rework due to errors in detailing and faster erection.

**Technical Issues**

**General**

This section discusses the performance of steel in meeting the engineering framing requirements.

**Accuracy of construction**

The experience of UK steel contractors using the new technology is that the completed frame is erected with greatly improved accuracy of construction, with 2–3mm tolerances being achieved compared with achieved tolerances of about 20mm using concrete.

**Services interface**

The interface between steel framing for air and electrical services is intrinsically easier with steel beams, given the relative ease in designing penetrations in beam webs. The adoption of the new technology in steel design, with its ability to produce efficient sections using for example, FabSec asymmetrical haunched beams, can provide an efficient platform for carrying services ducting without increasing floor to floor height.

The most effective approach is to engage services engineers to work alongside the structural engineer in the preliminary concept design stage to nominate ductwork sizes and locations and to incorporate these design matters into the 3D model.

**Façade interface**

It is considered that many activities associated with the completion of the building after erection of the frame can be accelerated by new work practices enabled by the accuracy of the construction. A good example of this is the erection of the façade, which can be supported by purpose-type fittings attached to precision-erected perimeter beams, providing a dimensionally accurate platform for the façade.

**Floors and roof – composite construction**

There are two competing floor systems that follow the construction of the frame (a) pre-cast flooring units or planks and (b) composite concrete/metal decking slabs. In the absence of a design code, Emile Zyhajlo, (Section 4.5.3) has written a position paper on the design of composite construction as an aid to structural designers. His paper should bring about a more uniform approach and potential saving in floor construction.
Core design

In Australia, the building core is invariably built of concrete, as this medium provides good fire resistance and shear strength against horizontal loads. There is no reason why the core cannot be of steel construction. Although this would require additional fire protection, it would also provide more accurate shafts for the elevators.

Acceptable floor vibration/deflection characteristics

There is some perceived user resistance to the use of steel in buildings where a vibration-free zone is required (e.g. hospital operating theatres). The elimination of vibration is a matter of careful design to ensure forcing frequencies (or harmonics) do not match the natural frequency of frame members. The use of composite floor construction provides some additional damping.

Floor flatness is an important issue in accommodating some of the new European office fit-out modules. Nevertheless, this has not been an issue in the steel-framed UK buildings employing this fit-out technology.

Deflections in steel beams are usually minimised by the use of camber. At present, the design camber in rolled sections is achieved by running the beam through a set of adjustable rolls, which is a time consuming and imprecise process.

The new technology utilising fabricated beams is able to precisely replicate the desired camber by cutting the top and bottom edges of the web to the design camber curve and then fitting the flanges to the curved edges. Thus camber is achieved in FabSec beams at no extra cost or re-handling. Steel may well be superior to concrete in terms of flatness, where the initially true concrete floors are subject to long-term creep.

Cranage issues

In concrete frames, the columns and beams are poured using concrete pumps which eliminates the use of cranes for this task. Cranes are still required for the heavy pre-cast floor sections. Cranage to erect the steel frame and decking is required on a full-time basis for a shorter period, as is concrete pumping for composite steel deck infill and ancillary works.

Building geometry

Traditionally, the extra depth of rolled sections meant that floor-to-floor spacing was greater than for concrete beams. This meant that a steel building was taller for the same net lettable area. The extra flexibility afforded by custom-designed FabSec beams allows steel to provide lower floor-to-floor spacings than concrete.

Similarly, UK practice has shown that custom-designed beams provide cost-effective, long-span elements that are competitive with concrete beams of the same span.

Footings and foundations

A typical steel frame in a medium-rise commercial building will have about 1500 tonnes of steel (+ composite floor concrete 150mm thick. Published costing information similar to concrete buildings, when converted to concrete volumes, indicates a concrete frame mass of about 12,000 tonnes). This reduction in dead load and cost can be significant where foundation conditions are poor.

Demolition issues

Concrete buildings, particularly post-stressed structures are difficult to demolish. The residual concrete is generally reduced to a road-base type material that is energy intensive to produce and costly to transport. On the other hand, the steel structure can be salvaged for re-use as a structural member or as recycled steel having been used as either blast furnace or electric arc furnace feed.

Delivery Structure

Present delivery structure

Concrete

For a concrete frame, the site works remain under the control of the building contractor who is responsible for the site preliminaries and the construction of footings and foundations.

This work entails:

- supply of concrete
- supply of re-bar
- supply of scaffolding, formwork and formwork support structures
- supply of embedded fittings
- installation of formwork
- re-bar fixing
- installing embedments required for other services
- pumping and placing and finishing of concrete
- stripping of formwork.

All the above is co-ordinated and managed by the builder, and requires project resources from the builder’s team.
Steel

For the steel frame, the builder, on receipt of the engineer's structural steel drawings, calls tenders for the supply and erection. The steel fabricator using advice, where appropriate from the sub-contractor then prices the frame for items detailed below.

- detailers
- suppliers of steel and fasteners
- supply of metal deck
- stud welding of shear connectors
- crane and truck hire
- painting for corrosion protection
- intumescent painting or fire spray
- erection (if not done by the fabricator)
- touch-up of paint and on-site fire protection.

On letting the contract, the builder is responsible for:

- use of site crane for erection (if required)
- co-ordination with building services
- overall site safety.

In essence, the builder turns the site over to the steelwork contractor for the time during which the frame and metal deck is erected. The steelwork contractor supervises and co-ordinates all sub-contractors as listed above.

New steel delivery structure

To service the construction industry, steel industry participants, i.e. steel contractors, can offer a Design & Construct package involving a single point of responsibility. The trades covered by the D&C contract will be agreed between builder/developer and steelwork contractor. The steelwork contractor will co-ordinate subcontractors, some of whom, such as an engineer or project manager, may work in some form of alliance. While D&C has not been readily available for multi-storey, steel building structures, this situation is changing. It is therefore likely that some D&C contractors will develop their own in-house design. Whether design is in-house or provided by a third-party engineer, the D&C contractor will be responsible for the completed structure and as such will require acceptable insurance cover for design and performance.

An owner may choose to engage an independent design-engineering auditor, which will depend very much on the standing and track record of the D&C contractor.

The scope of work provided by the D&C contractor may comprise some or all of the following:

- design detail, supply of fabricate, painting and erecting all steelwork
- steel passive fire protection
- service core, and access stairs
- stud welding to composite beams
- supply and erection of metal floor decking
- mesh and bar supply and placement
- associated concrete formwork
- supply, placement and finishing of floor and associated concrete works.

Conclusion

The objective of this paper was to examine in detail the Relative Value Proposition (RVP) between the use of either steel or concrete as a framing material in significant buildings.

The paper confirms the existing RVP which indicates that concrete is, for the moment, more attractive than steel. It also confirms that if the steel fabrication industry was to wholeheartedly embrace new, proven technologies, it would be very competitive with concrete.

For steel framing to win wider acceptance in the construction industry, it would require the establishment of a new delivery model that offers steel on a one-stop, performance-guaranteed basis. The combination of a design/construct offer under the new delivery model would provide a very competitive value proposition.

References


5.0 PROJECT MANAGEMENT ISSUES

5.1 METHODOLOGY

By Robert Mitchell
The Warren Centre

5.1.1 PROJECT OBJECTIVE:

The governing objective of The Warren Centre for Advanced Engineering at the University of Sydney is to foster excellence and innovation in advanced engineering throughout Australia, thereby helping to create wealth in the nation and facilitating relationships between industry, government and academia (The Warren Centre 2005).

This project intends to deliver benefits to Australia by delivering improvements in the building construction and development sectors by way of removing roadblocks (changing practice), encouraging the use of steel framing in larger buildings and attracting a new generation of skills into the steel value chain.

At the highest level of abstraction this project seeks to:

(a) Understand the differences between the Australian environment and practice and the environment and practices in other developed economies with higher steel usage in building.
(b) Change Australian practices to take advantage of those differences where they will benefit the building construction and development sectors.

5.1.2 ENGAGING THE STAKEHOLDERS IN RIGOROUS DEBATE

Based on the experience developed in 18 successful projects (The Warren Centre 2003) spanning its 23-year existence The Warren Centre has developed a project methodology that relies on deep engagement, based on self-interest, of the primary stakeholders in the project’s sector of interest as the means of:

(a) developing a practical understanding of the issues
(b) maximising the immediate change in practice as a consequence of the project
(c) advocating further change across the sector

Each of the above is further elaborated below.

5.1.3 BOOTSTRAPPING A STAKEHOLDER TEAM

The original thoughts leading to this project were brought to The Warren Centre by Geoff Winter, a former BHP steel engineer who had a knowledgeable outsider’s perspective of the steel fabrication industry. Mr Winter worked with David Ansley (an engineer, innovation and supply chain specialist) and Sandy Longworth (Project Director and former Chair of The Warren Centre) to scope out a project under a Warren Centre umbrella. After desktop research and many one-on-one discussions with stakeholders a hypothetical ‘value chain’ was created (Figure 1) showing the following stakeholder groups from which to recruit a project team:

- steel makers
- steel distributors
- steel fabricators
- architects
- engineers/Fire engineers
- detailers
- fabricators
- quantity surveyors
- consultants
- construction companies
- developers
- project managers
- project funders
- software providers.

Figure 1: Structural Steel Value Chain: It’s all a bit chaotic
Recruiting members one by one led to the formation of a growing Steering Committee representing the stakeholders and major sources of funding for the project, project teams for each of the Issues Groups and a management team whose main task was to move the project towards a conclusion with the assistance and input of the participants. Most meetings early in the project had as an agenda item: “Who else should be part of this team?” The resulting management structure underpinning the project methodology is shown in Figure 2.

5.1.4 PRACTICAL UNDERSTANDING OF REAL ISSUES

Approximately 180 people and 140 organisations have been involved in the project to date. Just over half of these participated in the initial case study phase and in the series of seminars held to ‘market test’ the recommendations, both of which had a significant impact on the content of the project.

Approximately 50 people volunteered their time and intellect to the various project teams and approximately 30 people drafted papers in relation to this project that are included in this project documentation. Short biographies of all those listed as Project Authors appear in Appendix C.

The breadth of skills, experience and interest demonstrated by the large number of people involved ensures that the project has access to the vast majority of information available of relevance to the subject. Moreover it ensures that the issues investigated by the project and the recommendations coming from it are of practical significance to the industry.

5.1.5 CHANGED BEHAVIOUR

The Warren Centre experience indicates that the strongest vectors for real change are the individuals actually engaged with the project. Active participation in the debates, articulating their own ideas and the subsequent peer review both modify and strengthen understanding of what may be possible and how to get there. Experience in all prior projects indicates that active participation leads to changed behaviour generally in the form of implementation of the project’s recommendations even before they are formalised in project documentation.

In short, once the light bulb of a new idea is lit participants do not wait to be told to put that idea into practice. Furthermore, with ample opportunity for informal discussion before and after project meetings, the relationships that develop between participants encourage investigation of new business opportunities for mutual benefit, which may or may not relate directly to the substance of the project.

5.1.6 MULTIPLE CHAMPIONS FOR CHANGE

While no research has been completed to test the hypothesis in The Warren Centre context it is well known that involvement in any pursuit can cause the participants to feel a sense of ‘ownership’. This is particularly likely if they can see the influence of their beliefs in the project output. As a direct consequence of this, each committed participant is not only likely to implement elements from the project in their own situation, they are likely to tell their peers about it and encourage them to do likewise. Thus, maximising involvement tends to maximise both direct and indirect implementation.

5.1.7 SEEKING OUT DIFFERENCES

The overall methodology of the project is shown graphically in Figure 3.

Case studies

After a period of discussion and review of potential issues it was decided to hold a series of meetings to discuss the performance of a number of recent building projects. Eleven projects were presented by project participants in the form of preliminary case studies in six case study sessions held in Sydney, Melbourne or Adelaide as follows:

- Session 1: Latitude building, Sydney & Dubai twin towers
- Session 2: 209 Kingsway (BMW) and Queen Victoria Village (BHP Billiton), Melbourne
• Session 3: Brisbane Airport carpark and Carrington House, Sydney
• Session 4: Rhodes Waterside, Sydney
• Session 5: Flinders Link and Adelaide Airport, Adelaide
• Session 6: 50 Lonsdale St and Southern Cross Office Complex, Melbourne

Summaries of each of these case studies and the discussion are presented in Appendix B of the report.

5.1.8 ISSUES GROUPS

A long list of related and interdependent issues resulted from the preliminary case studies and associated work. The project Steering Committee met in a facilitated workshop with the objective of sharpening the focus of the project. Facilitator Catherine Jacob proceeded to:

1) extract a complete list of 45 issues
2) group those issues into 12 key issues
3) select six root cause issues that together were seen as ‘causes’ of the remainder.

The tools used for the workshop are well known quality management tools that have been extensively used all over the world for the past 20 years.

Team leaders were chosen for each of the Issues Groups and the management team worked with them to recruit group members from amongst the steering committee and elsewhere, taking care to ensure that an appropriate mix of skills and interests were represented on each group.

Each of the Issues Groups followed its own path:

Leadership

This Group was led by Reg Hobbs from Flagstaff Consulting Group Melbourne. All group members were Melbourne based and all meetings were held in Melbourne.

The group brought together a wide selection of both client base and decision maker-based members from the engineering, architecture, fabricating and construction sectors as well as government, institutional, developer and financier employees and executives.

The group base in Melbourne brought a wider coverage of member input to the project, as did the spread of case studies from Melbourne, Adelaide and Brisbane.

The group met regularly and interacted by the efforts of their leader in the combined group meetings.

Proposed Timeline

<table>
<thead>
<tr>
<th>4 weeks</th>
<th>2 weeks</th>
<th>4 weeks</th>
<th>16 weeks</th>
<th>6 weeks</th>
<th>2 weeks</th>
<th>10 weeks</th>
</tr>
</thead>
</table>

Research potential issues → Confirm Major issues → Plan issue analysis → Conduct analysis, seek wide input → Report issue findings → Propose solutions → Public input & report

Figure 3: The approach
The key matters addressed were: risk management, sustainability, changing perceptions, education and safety. A number of seminar sessions were held as well as a site visit and consultation with the proprietor of the recently completed Schiavello Systems industrial and administration complex in Melbourne. The group flagged up the increasingly important subject of sustainability and in particular ‘Green Star rating’ which resulted in the creation of a small study sub-group and the production of a position paper with recommendations for continuing work – all of which are contained in the report.

The group’s work has been significant in providing input to the formulation of the key recommendations, in particular owners criteria for project decision-making.

Value Chain

This group, brought together by Aruna Pavithran, principal of Lucis, comprised builders, fabricators, engineers and suppliers. An early decision was made to restrict the group’s work to medium-rise buildings. This class of building was considered to be more representative of the next generation of buildings likely to be constructed in more decentralised locations than the major cities’ CBDs.

The terms of reference focused on providing empirical factual data drawn from cost time and risk construction records relating to five recently completed buildings, four steel framed and one concrete framed.

Outcomes of the work reported on the cost and time effectiveness of both forms of construction and addressed the industry’s perception that steel was more expensive than concrete. Specifically, attention was directed to construction time in both building modes. Risk was also investigated by detailed analysis of costing assumptions and final contract outcomes, to establish what level of risk was perception as distinct from reality.

The conclusions of this group reinforced the recommendations relating to the packaging of the construction processes (i.e. D&C), the better use of planning and execution software and the need for industry performance data.

Relative Value Proposition

Dick Prince and Brian Mahony co-ordinated the work of this group, which consisted of input from developers, engineers and fabricators. The terms of reference covered strengths and weaknesses of steel versus concrete, compared perceptions with fact, identified decision makers when they act in the construction cycle and the major factors influencing them and cost and time data. The group considered the availability of competitive steel design alternatives and the extent to which fire-engineering knowledge and fire-protection costs inhibited the production of a compelling value proposition. Early fabricator involvement to provide costing and manufacturing input, i.e. connection etc, was studied and not found to be common practice.

The group studied the Steel Construction of New Zealand program, which was introduced to support fabricators in providing compelling value propositions.

Consideration was given to the need for completed building cost data to be made available to decision makers by ASI. The outcomes of this group overlapped with costing, technology and the value chain and confirmed the final recommendations.

Technology

The Technology Group was led by Sandy Longworth and comprised members from engineering, IT, detailing, construction management, fabricating, fabricating equipment and welding technology, steel and steel product manufacture and fire engineering. Regular meetings were held at ASI headquarters in North Sydney.

Terms of reference covered emerging technologies, in particular 3D and interoperability, detailing and NC output, smaller projects and the application of 3D and visual construction aids, building information model (BIM) and virtual building, fire engineering, automated fabrication and trends in off-site construction.

A number of group members with recent UK experience provided valuable input regarding UK and UK engineering and fabricating practice. Two of the group members visited leading UK fabricating operations during the course of the group research. A report is tabled in Appendix A8 on one of these visits to Barrett Steel Buildings Limited and Severfield Reeve Ltd, both producers specialising in building structural works and employing high degrees of automation.

The group conducted a survey amongst engineers, fabricators and detailers to determine the take-up of 3D technology, compatibility of user software systems, interchange of model data, availability of preliminary material take-offs and production and facilities to use NC data. The results of the survey are discussed in Section 5.6.3.

Consideration was given to off-site construction, in particular modularisation and the interfacing of steel...
framing with facades and fenestration. This work studied construction trends and the likely impact and changes in work practices and employee training resulting from increasing computerisation, decentralised manufacture, higher dimensional accuracy and the facility to handle change.

Braced steel core construction and the benefits gained from removing the concrete service core trade was studied. Fire engineering was also addressed, in particular the differences in the UK’s ‘deemed to comply’ approach to fire protection and the Australian performance-based requirements with a recommended approach to overcoming local practical barriers. While the BIM management tool was yet to be used widely in Australia, consideration was given to this evolving technology and the future impact on the construction cycle and construction asset management.

Significant input was devoted to automated fabrication trends covering NC cutting, drilling and marking, plasma cutting, fully automatic welding, beam lines, beam fabrication lines, robotic clamping systems, gantry robotic welding and protective coating. The group’s work on automation was driven by the potential for much higher productivity given the availability of proven technology, particularly benefits from automated marking and setting out, leading to increased quality control (dimensional accuracy). Furthermore the tried and proven application of automation at all levels in ship building, heavy earthmoving and mining equipment manufacture, railway wagons and containers prompted the group to investigate applications to building structural fabrication.

Costing

The Costing Group was led by Andrew Marjoribanks and covered detailed consultations with fabricators, quantity surveyors and engineers. Concurrent with this work was the undertaking of an ICIP costing model investigation of a typical medium-rise commercial building constructed from steel or PT concrete. This work was undertaken on behalf of the ICIP consortium ‘Beyond 2 – Framing the Future’ by Rider Hunt, quantity surveyors, with input from Cox Richardson architects and Arup engineers. The intention is to use this model for regular comparative costing updates, incorporating technology changes as appropriate.

The group work addressed the relative ease of reliable concrete frame cost estimating compared with steel. It reported on quantity surveyors’ access to current steel costing data and their treatment of contingencies and the conservative nature of this approach. It was recognised that there was a need for commonality of costing base in the form of $/sq m of building or other acceptable unit in place of $/tonne of steel.

Through contact with the Technology Group, consideration was given to the integration of 3D quantity data and fabricators costing input for rapid reliable estimating, particularly of alternatives. This stressed the importance of early fabricator involvement. The output of the Costing Group inter-related to relevant areas of the Value Chain and Technology groups and supported the recommendations.

Standards

It was quickly recognised that while Australia’s adoption of appropriate standards for steel and composite construction was important, this project was unlikely to influence that process and qualified practitioners were adept at using suitable overseas standards where appropriate. Thus this Issues Group was terminated.

While it was necessary to break the project into manageable pieces it was also considered important to avoid developing materials in total isolation. Thus four project workshops were held at which each project group shared their findings, frustrations and aspirations, thus reducing the possibility of duplication and omission and ensuring that each group progressed with substantial knowledge of the other group’s thinking. In addition a password protected-project web site was established to provide all group members with access to work-in-progress from each of the groups.

5.1.9 TACTICAL ALTERNATIVES

The final project workshop focused on creating a long list of recommendations from each of the Issues Groups. The project management team reviewed that list and grouped them under three headings: Communication, Capabilities and Collaboration.

Experienced members of the project team were selected to expand on the listed recommendations and present them to three workshops (Sydney, Melbourne, Brisbane) held in November 2006 with the specific objective of obtaining feedback from as broad a group of interested individuals as possible. The project recommendations were prioritised, modified and expanded upon according to the views expressed by the 250 attendees at those workshops where those views appeared to be supported by a significant proportion of the attendees. A complete record of the feedback provided at the workshops is included in the project report.
Given the wide membership of the project teams and interested others, there is evidence that changes are already emerging from selected industry members.

**5.1.10 CREATING THE MEANS TO IMPROVE**

As referred to above, the most powerful agent for change in The Warren Centre’s arsenal is the altered behaviour of those who are involved with the project, as a consequence of the project process, new information or an alternate view of existing information to which they have been exposed. In addition the project team has identified approximately 100 ‘decision makers and influencers’ to keep well informed on the project’s progress and findings with a view to maximising the impact of direct communications.

The Warren Centre projects also produce three additional outputs, each of which contribute to effective outcomes: seminars, written reports and a permanent embodiment.

**5.1.11 SEMINARS**

Three public seminar-workshops were held in Melbourne, Brisbane and Sydney on 21, 22 and 23 November 2006 respectively. Invitations were sent directly to approximately 950 people selected from The Warren Centre’s database and indirectly to many more by way of the Australian Steel Institute, Engineers Australia, ACEA, RAIA and AIQS and others. All up some 250 people attended. The seminar-workshops had three objectives, to:

(a) communicate with those who had not been involved with the project
(b) test the hypotheses and recommended actions
(c) seek feedback and further alternatives to improve the industry.

The feedback received is documented in detail in chapter 5.6.1 and summarised in the Executive Summary.

**5.1.12 THE REPORT**

This report, written by approximately 30 project participants, is a permanent record of the project and the research and information generated by the various project teams. It will be provided free of charge to all those who have participated in the project in any way, will be available for download (paper by paper) from The Warren Centre’s website and by way of Sydney University Press. Thus, the substance of the project is available for study by any person or organisation with an interest in the subject matter.

**5.1.13 PERMANENT EMBODIMENT**

In practice, this project was delivered only with a high degree of collaboration with, and support from, the Australian Steel Institute. While many Warren Centre projects have created a ‘free standing’ industry association (or equivalent) to continue to champion change as a consequence of a project, the ASI is the obvious candidate to champion change in this instance.

**References**


The Warren Centre for Advanced Engineering 2003, *Pushing the Engineering Envelope*, University of Sydney

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5.2 LINKING THE ISSUE GROUPS TO 3CS FRAMEWORK

By David Ansley
Ansley & Associates Pty Ltd for The Warren Centre

5.2.1 ISSUE GROUPS

As explained elsewhere in this report, a long list of issues impacting the success of steel as a framing material in multi-storey buildings was gathered through interviews with industry representatives and through a series of case study sessions in late 2004 and early 2005. A 'Root Cause Issue Analysis' workshop was held to group these issues into causes and symptoms, and to rank the importance of the causes. This process led to the formation of six (subsequently reduced to five) Issue Groups to investigate and report on the key causal issues:

- Technology
- Leadership
- Value Chain
- Pricing
- Relative Value Proposition

Each Issue Group reported on its key issues and potential solutions, however there were many overlapping issues between Issue Groups, and potential solutions required considerations across Issue Groups.

Thus, while the Issue Group structure was appropriate for investigation and evaluation, it was a very cumbersome structure when it came to framing solutions and devising action plans.

5.2.2 3CS FRAMEWORK

For the Framing the Future project to succeed in overcoming barriers to growth in the structural steel in buildings sector it is essential that its messages to industry participants lead to changes in their behaviour. The 3Cs headings were coined to group the key issues from all the Issue Groups into three action-oriented themes:

1. Communicate
2. Collaborate
3. Capability Building.

Subdividing the findings of the Issues Groups into these topics provides clarity and avoids overlaps.

The ‘3Cs’ are described in further detail in Appendix A2.

5.3 KEY PERSONNEL

By Brian Mahony
The Warren Centre

5.3.1 INTRODUCTION

This section lists those persons who have given their time to the project and without whose valued inputs this project could never have been brought to fruition.

The Warren Centre would particularly like to recognise the contribution of Geoff Winter whose passion led to the project’s inception and who, together with Sandy Longworth and David Ansley questioned the initial hypotheses, created a worthwhile project scope and raised the project funds.

In addition, The Warren Centre wishes to thank those companies associated with the people listed below for making them available to the project.

5.3.2 STEERING COMMITTEE

The role of the Steering Committee has been explained in Section 5.1 above. Listed below are members of the steering committee.

Sandy Longworth, Chair, Steel – Framing the Future project
David Ansley, Director, Ansley & Associates Pty Ltd
Tristram Carfrae, Regional Manager, NSW & ACT Arup
Dr Andrew Davids, Director, Building Structures, Hyder Consulting
Tony Dixon, General Manager, Marketing & Business Development, OneSteel Market Mills
Kym Dracopoulos, Design & Delivery Manager, St Hilliers Property
Professor Michael Dureau, Executive Director, The Warren Centre
Ken Fazakerley
Geoff Graham, Director, BDS Group, BDS Steel Detailers
Peter Gregg, Director, The Warren Centre
Professor Gregory Hancock, Executive Dean, Faculty of Engineering and IT, University of Sydney
James Hebron, Solicitor, Office of General Counsel, University of Sydney
Reg Hobbs, Principal, Flagstaff Consulting
Andrew Marjoribanks, Director, Venlaw Park Pty Ltd
Chris Mathews, ICMP, Pty Ltd
Don McDonald, Chief Executive, Australian Steel Institute
Robert Mitchell, Chief Operating Officer, The Warren Centre
Judy Morgan, Marketing Strategy Manager, BlueScope Steel Ltd
Anthony Ng, Structural Development Manager, OneSteel Market Mills
Aruna Pavithran, Lucis Pty Ltd
Bill Plastiras, Business Development Manager, Baulderstone Hornibrook
Dick Prince, Principal, Evans & Peck Pty Ltd
John Richardson, The Cox Group Pty Ltd
Dean Riebolge, Vice President, Marketing, BlueScope Steel
David Ryan, National Marketing Manager, Australian Steel Institute
Wayne Scott, Director, Pacific Computing
Campbell Seccombe, Manager, Lysaght Technology, BlueScope/Lysaght
Bill Service, Director, Saltcoats Consulting Pty Ltd
Kylee Unwin, Business Development Manager, Alfasi Steel Constructions Pty Ltd
John Webb, Principal, Connell Mott MacDonald
Peter Wilding, General Manager, Commercial Construction, Australand

5.3.3 Management Committee

Sandy Longworth - Chairman
David Ansley, Ansley & Associates Pty Ltd
Trevor Gore, Lucis Pty Ltd
Andrew Marjoribanks, Venlaw Park Pty Ltd
Robert Mitchell, The Warren Centre
Aruna Pavithran, Lucis Pty Ltd
Peter Thompson
Brian Mahony, The Warren Centre

5.3.4 Visiting Fellows

Richard Barrett
Richard is the Managing Director of Barrett Steel Constructions, a 15,000tpa fabricating/contracting company in Bradford, UK. Mr Barrett’s company employs most of the new technology described in this report, which enables Barrett Steel to successfully compete in European markets.

Peter Thompson
Peter Thompson is a distinguished structural engineer who retired from leading structural consulting firm Arup Australia as Director – Structural Engineering. He brings to this project a wealth of experience in a wide variety of structural design assignments with significant experience in steel design.

5.3.5 Authors and Contributors

This report represents the work of many contributors, who are either authors of, or have edited the various sections of this report. The Warren Centre is grateful for the contribution of each of the persons listed below for their invaluable assistance.

David Ansley, Ansley & Associates Pty Ltd
Richard Barrett, Barrett Steel Constructions
Ian Bennetts, Noel Arnold & Associates
Peter Farley, Farley Production Pty Ltd
Ben Ferguson, Norman Disney & Young
Mike Gallagher
Trevor Gore, Lucis Pty Ltd
David Fabian, Minter Ellison
John Hainsworth, ARUP
Reg Hobbs, Flagstaff Consulting Group Pty Ltd
Nigel Howard, BRANZ
Sandy Longworth
Don McDonald, Australian Steel Institute
Brian Mahony, The Warren Centre
Andrew Marjoribanks, Venlaw Park Pty Ltd
Robert Mitchell, The Warren Centre
Anthony Ng, OneSteel Market Mills
Aruna Pavithran, Lucis Pty Ltd
Marcus Reuter, University of Melbourne
David Ryan, Australian Steel Institute
Peter Thompson
Andrew Walker-Morison, RMIT
Emil Zhajlo

5.3.6 Case Studies Group

The persons listed below compiled and presented the initial case studies (See Section 5.6.2), which led to the formulation of the major issues impacting the project. Their contributions were very important in defining the project and are very much appreciated.

Peter Chancellor, Connell Mott MacDonald
Dr Andy Davids, Hyder Consulting (Aust) Pty Ltd
Kym Dracopoulos, St Hilliers
Alex Filinov, BlueScope/Lysaght
Bill Gunther, Van der Meer Bonser
David Humphrey, BlueScope Steel Limited
Nick Lelos, Wallbridge & Gilbert
Lou Piovesan, Bonacci Group
5.3.7 Issues Groups

The Warren Centre is grateful to, and acknowledges the contribution of, the members of the five Issues Groups as listed below.

Leadership

Reg Hobbs, Flagstaff Consulting Group Pty Ltd
Keith Brewis, Grimshaw Architects
Ian Cairns, Australian Steel Institute
Brian Dean, Connell Wagner
Andrew Marjoribanks, Venlaw Park Pty Ltd
Steve Travenar, Bovis Lend Lease Pty Limited
Emil Zyhajlo

Value Chain

Aruna Pavithran, Lucis Pty Ltd
Rodney Boss, Henry & Hymas
Greg Conacher, Profab
Kim Dracopoulos, St Hilliers
Trevor Gore, Lucis Pty Ltd
Damian Judge, Rider Hunt Sydney Pty Ltd
John McKellar, A W Edwards Pty Ltd
Anthony Ng, OneSteel Market Mills
David Ryan, Australian Steel Institute

Costing

Andrew Marjoribanks, Venlaw Park Pty Ltd
Malcolm Boothby, Rider Hunt
Spiros Dallas, OneSteel Market Mills
Glen Miller, KFC Fabricators
David Ryan, Australian Steel Institute
Geoff Thomas, Multiplex
Ken Wilson, National Engineering

Technology

Stuart Bull, ARUP
Alfredo Bustos Ramirez, Tenix Solutions
Peter Farley, Farley Production Pty Ltd
Ben Ferguson, Norman Disney & Young
Mike Gallagher
John Hainsworth, ARUP
Peter Hughes, Welding Technology Innovations Pty Ltd
Sandy Longworth
Brian Mahony, The Warren Centre
Don McDonald, Australian Steel Institute
Max Pearson, DA Manufacturing Co Pty Ltd
Clayton Roxborough, Steelcad Drafting

Relative Value Proposition

Dick Prince, Evans & Peck Pty Ltd
Ian McGilvray, The Cox Group Pty Ltd
Mike Haysler, Hyder Consulting (Aust) Pty Ltd
Jonathan O’Brien, University of New South Wales
Glenn Rashleigh, Laing Bourke Australia
John Richardson, The Cox Group Pty Ltd
Ross Rooke, Australand
David Ryan, Australian Steel Institute
5.4 RESOURCING AND FUNDING THE PROJECT

By Robert Mitchell
The Warren Centre

5.4.1 GENERAL
This section of the report discusses the source of the resources and funding required to bring the project to a successful conclusion. As shown below, contributions to the project are either ‘in-kind’ or monetary grants.

5.4.2 IN-KIND

In common with all Warren Centre projects the majority of the resources committed to the project are represented by the many people who provide their intellect, experience, time and sweat to making the project happen. Leaders within the Steering Committee, the project team and the authors of all parts of this report are all listed in Appendix C.

The Warren Centre for Advanced Engineering would like to take this opportunity to thank all those who contributed to this project, and we thank their employers.

In particular the following organisations need to be mentioned in this context:

- Australian Steel Institute
- Evans and Peck
- Lucis
- Minter Ellison Lawyers
- Sebastian Engineering

5.4.3 CASH

The project’s cash budget was $375,000, most of which was provided by two companies referred to as Principal Sponsors:

- BlueScope Steel Limited
- OneSteel Limited

In addition, as the result of a successful submission to the competitive Industry Co-operative Innovation Program (a Commonwealth Government initiative administered by AusIndustry) the project won access to $175,000 of dollar-for-dollar matching funds. The submission related to The Warren Centre’s Steel – Framing the Future project plus 12 related ASI projects. The consortium making the submission was led by Evans and Peck with the Australian Steel Institute, Lucis, Sebastian Engineering and The Warren Centre as members.

5.5 ASI AND THE ICIP PROGRAM

By Don McDonald
Australian Steel Institute for The Warren Centre

5.5.1 AUSTRALIAN STEEL INSTITUTE

The Australian Steel Institute (ASI) is Australia’s peak steel industry membership body. Its vision is to influence profitable growth for the complete Australian steel value chain, and its mission is to deliver increased use of steel in Australia and improved industry competitiveness by providing representation, technical and marketing leadership, industry development and an independent forum for working on industry issues. ASI’s stakeholders are manufacturers of steel and steel products, distributors, processors, fabricators, specifiers, detailers, suppliers of services and consumables, constructors, educators and students.

ASI’s competitive advantage is its ability to unite and align sectors of the industry to focus on common goals, and to leverage industry efforts and funding to deliver cost-effective outcomes. Through its representation of the vertical channels (supplier/customer) and horizontal channels (competitors), ASI provides independence and credibility to leverage industry influence, and economy of scale to member services.

The organisation has a national structure employing a mix of 20 full-time and part-time staff with a depth of steel know-how and credibility to champion the vision of profitable growth for the industry. Governance and policy setting is by a Board of industry leaders from across the spectrum of Australia’s steel industry. ASI’s core business activities are co-ordinated and supported by a wide range of committees, and taskforces operating under a charter determined by the Board. The full channel and national reach of ASI’s activities provides a united and externally focused industry body committed to adding value to all of its members in the steel value chain.

The ASI provides market development and industry efficiency programs on behalf of the entire breadth and depth of Australia’s steel industry. Market development activities comprise promotion of steel as the material of choice with a prime focus on composite steel buildings. Industry efficiency activities include safety, technology uptake, training and industry knowledge.

In early 2006, the ASI, in conjunction with The Warren Centre and with a consortium of industry members, was awarded a federal government grant of $741,500 to increase the competitiveness of steel in building construction.
ASI operations in the commercial multi-storey building market

1. The ASI has had an internal committee working on increasing the share of steel in buildings for five years. Represented are the steel manufacturers, distributors, fabricators and decking suppliers. This activity is branded Beyond 2. Based on strategies developed by this committee and special funding approved by the Board, the ASI has strongly promoted steel use through case studies, advertising, representation, site visits, brochures and targeted information to key influence groups.

2. Outputs from this committee have been to increase the share of steel in use in commercial multi-storey buildings from 3 per cent to 13 per cent. The committee has:

- commissioned a competitive analysis of concrete-framed buildings.
- conducted three independent surveys of attitudes and perceptions of key decision makers, and undertook three market-share analyses.
- provided a comprehensive and wide-reaching communications program delivered to large numbers of decision makers nationally. This program included seminars, technical journals and publications on:
  - floor vibrations
  - composite design and construction
  - fire engineering on shopping centres and carparks
  - building design advice and referral
  - bolts issues
  - world-best practice in steel construction
  - leading-edge developments presented by several international experts.
- published numerous in-depth case studies in *Steel Australia*, the steel industry’s magazine; published and disseminated 12 case study flyers in the past 12 months.
- conducted seminars for a considerable number of case study presentations on steel buildings in conjunction with Engineers Australia.
- provided forums for architects in conjunction with the RAIA for events such as steel protection, fire engineering and carparks.
- conducted site visits for key buildings in steel.
- based on research – conducted a media campaign involving production of three advertisements each individually targeted at architects, engineers and builders. These ads were complimented by editorials on the steel solution within the trade magazines.
- set up a database of 3000+ contacts in the building area and numerous emails sent through this medium advising messages of interest.
- produced and circulated two printings of a ‘Seven Reasons’ for using steel brochure.
- had two series of industry delegations to the UK and NZ and one to Paris to understand and learn from progress.

In addition the ASI has:

- set up a mechanism for mounting the case for steel at the preliminary stage with assistance from the Fabricators and OneSteel Market Mills. It has worked on a number of projects and was responsible for the securing of the King St Wharf project to steel framing.
- engaged architects, engineers and builders in meetings and lunch presentations across the states. A total of 41 separate presentations have been made in the last approx 12 months to leading decision-making companies.
- formed and held National Fabricator Forums with strong engagement from leading fabricators from all states and territories.
- held a comprehensive program of seminars and student lectures across Australia (in a 12-month period to March 2007, ASI held four national seminar series with more than 2300 attendees).
- managed well-attended steel awards events across Australia to showcase the use of steel in construction – in 2006 more than 1300 people attended ASI’s gala steel awards events in Sydney, Melbourne, Brisbane and Adelaide including many leading architects, builders and engineers.
- delivered training courses on steel design, welding and contracts.
- provided technical information and referral, library and bookshop services and code committee input.
- conducted industry workgroups nationally to increase awareness and understanding of the benefits arising from improved integration of existing and planned investments in automated detailing and steel processing technologies.
engaged the steel companies in forming a workgroup on sustainability and published a flyer on this issue.

provided The Warren Centre with significant assistance including:

- writing the case for the steel companies to contribute to the project
- advising contacts for team leaders and team members
- providing venues and support in team membership for each working group and fed into its research and findings
- being the key resource for securing AusIndustry funding and being the prime contact point for liaison during the grant process
- membership of the Steering Committee of The Warren Centre project and being very active on the team of four of the five working groups.

5.5.2 THE ICIP PROGRAM

By David Ryan
Australian Steel Institute for The Warren Centre

The Warren Centre collaborated with the Australian Steel Institute (ASI) to submit a suite of related projects including Steel – Framing the Future seeking funding from the Commonwealth’s Industry Cooperative Innovation Program (ICIP). The submission was successful and a grant of approximately $750,000 was made to the consortium (named Beyond 2: Framing the Future) led by Evans and Peck and including Lucis, Sebastian Engineering, the ASI and The Warren Centre.

The genesis of the suite of projects was an Attitudes and Perceptions survey conducted by The Market Intelligence Company for OneSteel Market Mills in 2004. As shown in Appendix A7, the market perception was that steel framing had some good elements (relative to concrete) and some bad elements.

BEYOND 2: FRAMING THE FUTURE

A review of the survey by the ASI caused them to postulate a range of technical, communications and measurement tools and actions which are embodied in 12 projects that were considered to be in ‘lock step’ with The Warren Centre’s Steel – Framing the Future project. The 12 ASI projects are listed below:

Data Transfer – Technology Integration

This focuses on the integration of 3D technology for efficient data transfer though to CNC machines to reduce costs and improve accuracy in steel fabrication.

The contract was awarded to Mincom for a report on technology integration, with the ASI responsible for dissemination.

Development of cost models to show relative competitiveness of building systems

The objectives of this project are to have cost outputs for multi-storey buildings as follows:

1. to have substantiated relative cost data that the ASI can take to the market
2. to be able to monitor relative system costs at a high level
3. to disseminate this information back to fabricators so that they are aware of their competitiveness and to mount a program of feeding cost information to the building market.
Standardised structural connection guides

This project is to improve the cost efficiency of fabrication by standardising engineering design for connections. Immeasurable cost efficiency is forsaken in Australia by the individual design of each connection rather than the adoption of standardised connections in construction. This project output is a range of connection guides that will complete and update previous work done by the ASI, integrate it with best international practice and the existing design packages.

Composite connection engineering design guide

As for project four, but for composites. As there is no Australian theory on which to base a composite connection guide this work needs to be completed before beam to beam and beam to column connection guides can be published.

Addendum to structural steel design capacity tables

An update to the Design Capacity Tables for Pipe and Tube as an addendum including new sizes offered into the Australian market and the deletion of obsolete or unavailable sizes.

Composite structures construction manual (builders guide to multi-level steel construction)

Advice to architects and builders on general composite building techniques. This is not a technical publication but one that will simply and quickly provide design information that will enable the production of preliminary layout drawings for composite steel construction.

Engineer design manual for composite multi-storey buildings

This is an engineering manual for use by engineers not skilled in composite building design.

Use of (UK) software on composite design to drive an internationalisation of composite design in Australia

This project is a combination of two projects on composite design. An impasse exists in the short to medium term in the design advice from Australian composite code AS2327.

The British code, which would normally be a basis for modification of the Australian code, has not been updated due to the pending absorption with the eurocode. However the Australian code only covers simply supported beams and does not cover new advanced decking profiles now available. Production or modification of existing software will drive a more efficient design practice for composites.

Engineering guide for cost-effective design of structures for fabrication

This incorporates a practical guide for welding specifications, connections and splices for cost-effective fabrication. Existing program notes for welding design will be updated and the guide for economical fabrication will be updated.

Introduction to steel – an undergraduate development package

This package for undergraduate engineers on the principles of steel and steel in design, follows on from the very successful preliminary and basic kit information available overseas.

Diffusion of the findings of the key industry workgroups from The Warren Centre project

Utilisation of the ASI resources and methods in a seminar series to promote The Warren Centre outputs.

Measures

A repeat of the initial attitudes and perceptions survey to monitor progress of the communications and other media messages being planned.
5.6 PRIMARY INFORMATION SOURCES

5.6.1 FEEDBACK FROM PROJECT WORKSHOPS

By Dani Cooper
For The Warren Centre

GENERAL

The project launch seminars held in Melbourne, Brisbane and Sydney included a workshop session to enable delegates to discuss the project findings and to offer new suggestions. These opportunities to input ideas were well received by delegates. The feedback from the sessions is described below.

STEEL – FRAMING THE FUTURE MELBOURNE SEMINAR, 21 NOVEMBER, THE MELBOURNE BUSINESS SCHOOL

‘The presentations make you think and that’s a start. If enough people get together and think the same thing then maybe something will happen.’

Bernard Regan – FarleyLaserLab

The Melbourne seminar successfully kicked off the series of workshops with more than 100 people attending. Intense, and at times, heated discussions resulted from the workshops on issues such as fire rating, supply, and the role of the Australian Steel Institute and its membership.

The following points were among the main issues raised in the wake of the hour-long workshops by seminar participants.

What issues did the Framing the Future project overlook?

The Environment

Participants felt steel construction had an ‘environmental edge’ over concrete that had been overlooked at a time when issues such as sustainability and climate change are taking greater hold in the public and political consciousness.

Recommendation

The environmental advantage of steel construction needs to be detailed and forcefully communicated within the industry and across the supply chain. This detailed assessment of environmental/sustainability outcomes could also be used to increase government investment in state-of-the-art technology across the industry.

Know Thy Enemy

The Steel – Framing the Future project highlighted how successful the concrete and pre-stressing industries had been in selling themselves in the Australian construction sector. Participants felt the dominance of concrete had led to ‘anti-steel myths’ being cemented in the mind of the decision makers and felt more work needed to be done to debunk these views in areas such as fire rating, lead times, cost and flexibility.

Recommendation

Participants felt a demonstration project or case studies should be undertaken which could provide benchmarks in terms of design, costing, completion times and fire rating.

They also called for a deeper analysis of the factors behind concrete’s success so as to be better able to argue the case for steel and to counter the ‘myths’ across the construction industry about steel framing.

A call was also made for an industry group to compile and distribute information across the supply chain about stock supply, lead times, technological advances in areas such as fabrication and its impact on completion times and real-cost estimates.

Skills shortage

There was consensus that the skills shortage in areas such as engineering, tradesmen, fabrication and design would increasingly impact on the use of steel in construction. Participants stressed the success of the steel industry in the UK could be used as a selling point to promote steel construction among undergraduates and new graduates eager to work overseas.

Recommendation

There was consensus that ‘steel education packs’ needed to be supplied to undergraduate engineering and architecture students to put steel in the forefront of their thinking. The opportunities available needed to be highlighted also.

The sector also needed to invest in technology to increase efficiencies in staff levels and reduce costs, risk and time.
Design

The main issue surrounding design was the lack of available information from industry bodies on alternatives and options in detailing.

Recommendation

A call was made to follow the lead of the concrete and P/T sectors and establish design manuals or a design support service to help designers overcome design issues. There was also general support for a greater use of 3D modelling at the design stage.

Participants also felt it was time to lobby for a change in fire resistance regulations.

Leadership

Participants felt that while the Steel – Framing the Future project stressed the need for greater leadership within the sector, there was no obvious industry-wide ‘leader’ as the ASI was seen as being too narrow in its membership and steel construction an adjunct to the ASI’s main lobby base.

Recommendation

The Melbourne seminar participants felt the ASI was best placed to be the representative body for steel construction, but suggested it more closely liaise with the Structural Steel Fabricators Association Victoria.

However, the SSFV needed to be more inclusive and open its membership to other members of the value chain such as suppliers and to those outside the immediate steel value chain such as fire resistance suppliers.

Framing the Future Brisbane Seminar, 22 November, Queensland University of Technology

‘It’s like a herd mentality. If I were to suggest a change to steel-framed buildings I would have to argue my case, but if I want to proceed in concrete it’s the norm and it’s expected. I don’t have time to run analysis on a lot of different options.’

Perry Milledge, St Hilliers Contracting

The Brisbane seminar featured a smaller turnout than in Melbourne, but was a dynamic event. Participants raised a number of issues that had already been highlighted at the Melbourne seminar, but brought some fresh ideas to the table.

What issues did the Steel – Framing the Future project overlook?

Recent market growth

In 2003 steel held just 3 per cent of the market share in Australian construction. In 2006 it was claiming 13 per cent of market share. Although seminar participants acknowledged this increase came on the back of a small base, they felt it was important to understand what had been the main driver behind the recent growth.

Recommendation

It was felt that some analysis should be undertaken to find out what had led to the increase in the use of steel. This research could also provide case studies with which to educate and inform the value chain of the benefits of steel framing and feed into an industry database that would highlight the sector’s track record in areas such as completion times, sustainability costs.

Fire code reform

As in Melbourne there was much debate about fire protection. A catalyst for the debate was the presentation by Visiting Fellow Richard Barrett, in which he pointed out that fire protection standards in Australia were much more stringent than in the UK, and unnecessarily so.

Recommendation

The workshop participants felt that as a priority the sector needed to lobby for reform of the fire code. To do this it was essential to bring the voice of the fire protection sector to the table, for a better understanding of the technology and requirements available now and into the future.

Demonstration models and costing manuals

Participants felt concrete’s dominant position could only be overturned through increased education and information along the value chain and in the market place.

Recommendation

It was felt the sector needed to follow the lead of the UK and invest in demonstration models and case studies that would highlight the sustainability and environmental credentials of steel framing as well as providing design and costings data.
Framing the Future Sydney Seminar, November 23, University of Sydney

'We have to market steel in a different way. We’ve had a lot of smart concreters come to Australia and they now lead the world but the concrete industry has a levy on every bag of cement to help fund marketing.'

Ken Wilson, National Engineering

The Sydney seminar, the biggest of the three events, ended the series of workshops, focusing again on many of the issues already highlighted above, with similar ideas on the way forward for the steel construction sector. Although mentioned at all three seminars, the rise of the Chinese threat was more vigorously mentioned in Sydney, along with problems over steel pricing.

What issues did the Steel – Framing the Future project overlook?

Price of steel

Steel’s perceived vulnerability to the vagaries of the international commodities market is one of the issues raised against its use in construction. Participants felt more attention needed to be made at communicating the ‘real cost’ of the use of steel framing and how savings can be made in other project areas.

Recommendation

Steel contractors need to be encouraged to invest in new technologies to help reduce costs and improve efficiencies.

Data highlighting the ‘real cost’ of using steel framing needs to be disseminated across the value chain.

The pricing structure needs to change from cost per tonne.

Overseas competition

The recent use of a Chinese fabricator by Linfox to build a warehouse was mentioned at each seminar. Participants felt China and its cheaper labour costs were a real threat to the industry and would discourage fabricators from making significant capital investment. This threat was also tied to the lack of skilled people and new workers entering the field.

Recommendation

Richard Barrett felt the threat from cheaper overseas competitors was overplayed and argued that consistent delivery and shorter lead times would make importing of fabricated steel unprofitable. He also cited his own experience of how capital investment in his factories had paid for itself in major cost and time savings that had led to being able to handle more contracts.
5.6.2 SUMMARY OF INITIAL CASE STUDY FINDINGS

By Sandy Longworth
for The Warren Centre

Over the past decade, the use of structural steelwork in multi-storey buildings in Australia has declined, particularly when compared with other developed nations such as the UK and US. This decline manifests itself in a loss of steel skills throughout the value chain from concept through to completed structure.

While this change should be of concern to property owners and developers, as well as contractors and steel value chain members, it needs to be read in the context of the changing world scene of steel producers and their products.

Rationalisation is taking place in this industry, with fewer bigger steel producers. New products and steel grades are coming onto the market quicker, providing increased scope for the creation of innovative steel structures.

The Warren Centre’s Steel – Framing the Future project has considered 11 case studies of recent projects from Dubai, Sydney, Melbourne, Adelaide and Brisbane. During the case study phase, an issues roundtable identified the six principal root causes of the decline in steel usage in this construction sector as:

- industry leadership
- effectiveness of the value chain
- steel pricing
- international codes
- technology opportunities
- relative value proposition.

Key issues emerging from the case studies which have been grouped under the above headings are as follows.

- Lack of committed leadership from the dominant players in the steel value chain.
- Decision makers, in the main developers, know the price of steel but not the value in the overall project chain.
- Lack of strong relationships between key players in value chain.
- Failure to obtain full cost benefits by making an early commitment to adopt steel.
- Performance-based building codes and fire-engineering practice deliver significant advantages to steel.
- Widely adopted practice of locking in fixed prices for engineering and steel.

- Supply and erection is not conducive to project optimisation which can be beneficial to all players in steel value chain.
- Steel pricing – need for the price setter to lock into pricing.
- Costing approach, use of QSs for top-down target budgeting rather than bottom up.
- Costing with engineer and QS, thus excluding the fabricators.
- Successful steel projects demand a commitment to decision-making up front, particularly with regard to facade treatment and services which, if done in conjunction with engineering and detailing, reflect in benefits to be gained from speed and cost of construction.
- Innovative overhaul of the steel value chain needed.
- Developers’ and contractors’ perception of risk; some adopt steel to reduce risk, others avoid it for same reason.
- A number of projects developed in concrete are switched to steel mainly for reasons of speed, very few projects are switched from steel to concrete.
- Lack of full appreciation of merits of steel construction, e.g. reduced site labour, superior construction environment, speed, prop-free construction, safety etc.
- Versatility of steel medium and sustainability, particularly with projects subject to changed uses or occupancy.
- Potential for jump-start alternatives.
- Larger column-free space.
- Building code deficiencies, composite construction.
- Potential of 3D modelling not optimised, acceptance of model creator and maintainer with model available to all contractors and subcontractors.
5.6.3 TECHNOLOGY UPTAKE SURVEY

SUMMARY

By Chris Humphreys
The Warren Centre

Consulting engineers

Of the 40 consulting engineers, firms that responded to the survey, 70 per cent claimed to use software to aid in the design process of steelwork projects while only 32.5 per cent claimed to use software in the project documentation process (Appendix A12). The preferences of software showed a spread of various packages. In terms of firms’ software preference, Microstran holds the largest single stake at 26 per cent, followed by Spacegass at 13 per cent, AutoCAD and Strand at 9 per cent each, XSteel at 8 per cent, and Revit, Inventor, BoCad, Multiframe, Staad Pro and Intergraph each with 5 per cent.

Of the firms who build software-based models in the design phase, around 40 per cent maintain the model through to construction completion, while 75 per cent would consider passing their model to the fabricator and the same number would see the value in being given a fabricator’s 3D model. Of the 75 per cent of respondents who would value models from fabricators, 95 per cent anticipated their usefulness in the aspects of geometry and scale, 52 per cent would anticipate a reduction in RFI documentation, while 33 per cent would see the value in early standardisation from the model.

Of the engineers that produce and use 3D models, just over half model principal connections, while just over 20 per cent include material lists with documentation. Of the 29 per cent of firms who do not make the model available to the design team, 62 per cent would expect additional fees for such a service.

Report from fabricators

Examining the instance in which a consultant’s 3D model is provided at tender, 55 per cent of fabricators would find interoperability between software problematic, while the same number would use the model for generating material lists and schedules to confirm their offer. Another 63 per cent would expect their detailers to also make use of the model.

Given a 3D model from the consultant, 36 per cent of fabricators believe they could reduce their overall offer.

Report from detailers

The detailers showed the highest rate of 3D software integration, with a 90 per cent usage rate. Again, Xsteel showed high familiarity, preferred by 45 per cent of detailers, with 33 per cent using StruCad, and 11 per cent favouring each of ProSteel and BoCad.

In terms of documentation, 90 per cent of detailers are asked to supply material lists and bolt lists, while 80 per cent are asked to supply separate part and assembly drawings and NC files.

In the instance of a 3D model being supplied to the detailer by the consultant, 90 per cent of detailers claim they would find the model useful. Of those who could make use of the model, all would refer to geometry and size particulars, 78 per cent would anticipate a reduction in RFI documentation, and 67 per cent would anticipate the advantage of early standardisation.

In handling a 3D model from a consultant, 56 per cent of detailers anticipate interoperability problems between software packages, while 67 per cent would benefit from the inclusion of principal connections in the model. About 67 per cent of detailers believe the provision of the consultant’s 3D model would affect their responsibilities. In terms of their overall offer, 57 per cent of detailers believe their offer would be greater given the 3D model, while 43 per cent estimate their offer would be less.

Of the detailers and fabricators that responded, the majority claimed to have outputs of greater than 4000 tonnes per year, with a reasonably even spread across building and industrial sectors. The consulting firms represented in the survey tended to be predominantly smaller ones, with 70 per cent of responding firms consisting of less than 25 people, 25 per cent of firms consisting of more than 75 people. Some 41 per cent of consulting firms claimed that the majority of their projects are predominantly steel framed.
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### STEEL USAGE IN AUSTRALIA HAS BEEN SEGMENTED BY BLUESCOPE AS FOLLOWS; (REF BSL 2004)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Share</th>
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<tbody>
<tr>
<td>Agriculture</td>
<td>8%</td>
</tr>
<tr>
<td>Dwelling Const</td>
<td>6%</td>
</tr>
<tr>
<td>Non-dwelling Const</td>
<td>13%</td>
</tr>
<tr>
<td>Engineering Const</td>
<td>21%</td>
</tr>
<tr>
<td>Manufacturing Plant and Equipment</td>
<td>14%</td>
</tr>
<tr>
<td>Vehicles and transport</td>
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</tr>
<tr>
<td>Mining</td>
<td>17%</td>
</tr>
<tr>
<td>Other</td>
<td>8%</td>
</tr>
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</table>

### SHARE BY TYPE OF APPLICATION IN THE BUILDING AND CONSTRUCTION INDUSTRY FOR NON-RESIDENTIAL (REF NIER 2004)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Share</th>
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<tbody>
<tr>
<td>Hotels</td>
<td>4.9%</td>
</tr>
<tr>
<td>Shops</td>
<td>16.3%</td>
</tr>
<tr>
<td>Factories</td>
<td>6.4%</td>
</tr>
<tr>
<td>Offices</td>
<td>22.9%</td>
</tr>
<tr>
<td>Other Businesses</td>
<td>12.7%</td>
</tr>
<tr>
<td>Education</td>
<td>13.7%</td>
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<tr>
<td>Health</td>
<td>8.8%</td>
</tr>
<tr>
<td>Total</td>
<td>$7116m</td>
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### SHARE OF STEEL FRAMING (COMPOSITE CONSTRUCTION) IN COMMERCIAL (OFFICE, SHOPPING CENTRES AND SHOWROOMS) MULTI-STOREY CONSTRUCTION (REF TMIC 2005)

<table>
<thead>
<tr>
<th>Year</th>
<th>Share</th>
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<tbody>
<tr>
<td>2002</td>
<td>3%</td>
</tr>
<tr>
<td>2003</td>
<td>3%</td>
</tr>
<tr>
<td>2004</td>
<td>9%</td>
</tr>
<tr>
<td>2005</td>
<td>13%</td>
</tr>
</tbody>
</table>

### APPROX VALUE OF A % MARKET SHARE IN COMMERCIAL BUILDINGS

- 1% = 2,500t (est OneSteel)
- 13% = 32,500t

### SEGMENTATION BY SIZE (COMMERCIAL BUILDINGS) TOTAL $7 BILLION (REF ONESTEEL)

- 2003
  - 431 projects > $5million
  - 18157 projects < $5million
### Commercial High-Rise Breakdown by State (Ref TMIC)

<table>
<thead>
<tr>
<th>State</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>NSW</td>
<td>29%</td>
</tr>
<tr>
<td>Vic</td>
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</tr>
<tr>
<td>Qld</td>
<td>16%</td>
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<tr>
<td>SA</td>
<td>13%</td>
</tr>
<tr>
<td>WA</td>
<td>9%</td>
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</tbody>
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### Breakdown by Location (Ref TMIC)

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage</th>
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<tbody>
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<td>CBD</td>
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<tr>
<td>Metro</td>
<td>57%</td>
</tr>
<tr>
<td>Regional</td>
<td>19%</td>
</tr>
</tbody>
</table>

### Tender Process (Ref TMIC)

- Fully Documented Tender Process: 49%
- Design and Construct: 40%
- Other: 11%

### Number of Floors in Commercial Buildings (Ref TMIC)

<table>
<thead>
<tr>
<th>Number of Floors</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three or less</td>
<td>59%</td>
</tr>
<tr>
<td>Four or more</td>
<td>61%</td>
</tr>
</tbody>
</table>

### Share of Building Materials (Approx 2004 TMIC)

- Reinforced concrete: 35%
- Post-tensioned or pre-stressed concrete: 21%
- Structural steel: 9%
- Pre-cast (Ultrafloor): 13%
- Timber: 7%
APPENDIX A2

THE THREE ‘C’S: COMMUNICATE, COLLABORATE, CAPABILITIES

A2.1 GENERAL

The many issues discussed during the course of this project have been summarised in Section 3 and described in detail in Section 4 of this document. In order to minimise overlaps between the Issues Groups and to provide clarity, the outcomes from these discussions have been distilled into three main topics as outlined below.

These topics are:

- The need to communicate
- Collaboration
- Capability

These topics are listed below. The recommendations, as discussed earlier in Section 2 are further refined from the considerations of the ‘3Cs’ as described below.

A2.2 THE NEED TO COMMUNICATE

By Trevor Gore
For The Warren Centre

A2.2.1 Abstract

This paper discusses the need for improved communication at all levels of the steel construction industry value chain. Communications to the value chain, between and within entities in the value chain and to the external bodies of government and the innovation community are considered. The cost to the Australian construction industry as a whole for poor project documentation and communication standards is reported as being more than $10 billion, with the steel construction sector contributing around $700 million to that total.

Despite a recent uplift in the use of steel framing material in construction, it now commands only 13 per cent of the commercial, multi-level construction market, whilst in other countries its market share is significantly higher. The more successful countries appear to have a high degree of central co-ordination of communications within the steel construction sector. Australia, on the other hand, appears to be less well served by a central body, which co-ordinates communications amongst all the steel construction stakeholders.

The steel construction sector does not communicate well to its potential clients, preferring to talk in ‘construction speak’ rather than the language of developers and investors whose primary concern is that of sustainable returns on investment. At the project level, communication between, and even within, individual value chain entities is generally recognised as being adversarial, rather than that of people working co-operatively together, sharing the same vision and objectives for the project. Communication with government and the innovation community is woeful, this being reflected in the level of government support for the whole construction sector, which is much less than other industries that are no more deserving.

The cost to the construction industry in Australia of poor project documentation and the resulting communication confusion is alarmingly estimated by one source to be more than $10 billion annually. Concerted action is required by both industry bodies and value chain participants.

A2.2.2 Introduction

Even after some recent recovery, the use of steel as a framing material continues at low levels in Australia. It now represents just 13 per cent of the medium-rise construction market, which is substantially lower than the market share it enjoys in other countries. In New Zealand, for example, steel has a market share in this sector of 40 per cent and in the UK, Japan and the USA the figures are 70 per cent, 67 per cent and 50 per cent (ASI communication; SCNZ, 2006).

In New Zealand, the steel construction industry is heavily influenced by Steel Construction New Zealand (SCNZ), an industry group dominated by the fabricator sector with the objective of promoting awareness of the advantages of steel construction, promoting excellence in the delivery of steel construction solutions and encouraging training and career development within the steel construction sector. In the UK, Japan and the US, the Steel Construction Institute and The British Constructional Steelwork Association, the Japanese Society for Steel Construction and the American Institute of Steel Construction fill similar roles. They provide readily available technical information, solution centres, estimating tools, professional development and in most cases free consulting assistance to help promote the awareness and use of steel in construction. The technical support provided by these organisations is prolific, as is the continuous activity involved in communicating their messages to interested parties, thus raising awareness of steel as a solution in the construction sector.
Co-ordinated, consistent and reliable communication throughout the industry by these organisations is at least in part responsible for the more successful outcomes in these countries.

Australia, on the other hand, appears to be less well served by a central body that co-ordinates communications amongst all the steel construction stakeholders¹ at the macro level, while facilitating the adoption of new technologies for the sharing of information within and between the links in the value chain at the micro level. To increase the use of steel framing in construction in Australia and to establish a sustainable period of growth for the industry there is a clear need for effective communication between the relevant parties in the right language at the appropriate time.

Across the entire construction industry, the cost of not addressing the various aspects of communication is alarming. Poor documentation (communication within and between value chain participants) is estimated to add 10-15 per cent, ($12 billion) to project costs in Australia (Engineers Australia, 2005). By failing to communicate successfully with government, the construction industry is missing out on $1 billion to $1.5 billion (ABS 2006a, ABS 2006b, Lucis analysis) of operational support, to give just two examples. Inadequate communication of steel's value proposition to the construction industry stifles its growth prospects.

Concerted action is required by both industry bodies and value chain participants.

- For the property development community, it is necessary for the steel construction industry to communicate a value proposition in terms of sustainable return on investment (their language) rather than in terms of spans between columns and Occupational Health and Safety issues on site.

- The steel construction value chain as an entity requires timely access to design and costing tools that reflect the current reality of conditions in the market. There is a real need for regular building construction steelwork costs to be issued to the decision makers, engineers, quantity surveyors, architects, builders, developers and estimators.

- For the participants in the value chain, the communication and sharing of project design and construction information in a unified format and in a timely manner will reduce cost and time of construction to the benefit of all. Within the individual links of the value chain, the individual contracting companies need to have a means of passing hard-won knowledge between projects and to the next generation of architects, engineers and builders who will reap the benefits already discovered by overseas organisations. IT innovations can satisfy many of these requirements.

- The very low amounts of research and development, and operational support that the construction industry receives directly from government, when compared with other industry sectors, can only be attributed to a failure to adequately communicate a compelling value proposition to government and the innovation community.

A2.2.3 Communicating with the developer community

Investors (developers) don't really care what materials are used in the frames of their buildings. They have a much more outcomes-based focus. They are looking for performance in an uncertain world where needs will change over time and their investment must deliver returns in spite of that. They want whole of life-cycle (25-30 years) solutions to a set of functional requirements. A Melbourne workshop for industry stakeholders (developers, builders, users, financiers, lawyers) co-ordinated by The Warren Centre Framing the Future Leadership Group, in December 2005 found the following:

- The traditional values of total development cost and project delivery reliability remain important.
- Assessing and managing the risks associated with the above are critical to success.
- Emerging values of building usage flexibility and sustainability are of increasing importance and cannot be ignored.

The first two themes are concerned with assuring the certainty of the anticipated investment amount. The third theme is concerned with the value and longevity of the investment return.

These themes have been prevalent in other workshops at other times, for example the Australian Institute of Steel/The Warren Centre Framing the Future workshop, in Sydney, August 2006 and are reflected in overseas markets (SCI 2002. However, those of the Australian

¹ Including but not limited to investors, developers, architects, engineers, design and construct builders, project managers, quantity surveyors, fabricators
steel construction industry value chain interviewed2 in a third-party market survey reporting in January 2005 (The Market Intelligence Co 2005) have a differing perception. Their perception of the important factors to the main decision makers included cost (unsurprisingly) but otherwise focused on issues such as fire rating compliance, Occupational Health and Safety/Human Resources management on construction sites, and ease and speed of construction (which is different from delivery reliability). Interestingly, the words ‘risk’ and ‘sustainability’ occurred only twice each in this 218-page report, both in the context of unprompted comments from respondents. So the steel construction value chain participants are clearly stuck in their own construction project paradigm and need to ‘get on the same page’ as their customers.

The three themes above form the framework within which the value proposition to developers and investors needs to be communicated. It’s not about spans, level floors and fire-rating compliance for these. They are taken as givens in order to be in the game. It’s about producing a reliable return over time for the investor from a sustainable (and a sustainably delivered) asset.

Acceptance that steel framing offers a superior value proposition will undoubtedly encourage market share growth. A market share of 26 per cent, double that currently enjoyed, yet not unreasonable compared with overseas markets would mean $7 billion of extra building projects in the steel, multi-level, commercial construction sector and a doubling of the use of fabricated steel in that market. Current steel usage in the sector is estimated at 32,000 tonnes per annum.

A2.2.4 Communicating to the value chain

Much decision-making relies on a process of elimination. What’s wrong with something is used as an elimination factor before what’s right is considered. The steel construction industry in Australia presents plenty of elimination factors if we listen to the views of the customers (investors/developers).

Quotes from industry participants at the Leadership Group workshop, December 2005:

1. ‘Time and cost blow-outs are prevalent with steel, also IR issues.’
2. ‘With a tight timeframe, we have no confidence in the steel industry.’

3. ‘We always have a look, but steel just doesn’t stack up, issues with design.’
4. ‘Shortage of skilled designers and fabricators.’
5. ‘Quality and reliability is an issue.’
6. ‘Fire proofing is costly with steel.’

Numerous other quotes in a similar vein are available.

Whilst comments of this type could be dismissed as ‘myth and legend’, there is no smoke without fire. The industry in Australia is obliged to address these negative views if it is to grow.

Urban myth and legend flourishes in the absence of hard facts. Consequently, hard facts must be available and must be communicated. This requires information that is not only accurate and credible, but is perceived to be accurate and credible because it was generated in a credible way by credible people and is used by credible organisations.

A recurring discomfort for decision makers is the perception of value, or lack of it, delivered by the structural steel industry. Whilst ever controversy rages about the price and availability of Australian structural steel and the price of imported steel in Australia’s oligopolistic market, the buyers will invariably be concerned that there are limited choices, that they can’t buy well, and are getting less than best value. While this perception remains in the market there will always be a disincentive to consider steel as an option. With concrete there is the perception of greater choice with alternative places to go if you don’t think the price is right. The steel makers and the steel construction industry need to work collaboratively to deliver a consistent message backed by reliable costing information.

A further cause for concern is the common practice of quoting fabricated steel prices in terms of dollars per tonne (Marjoribanks 2006). Clearly, depending on the complexity of the building design, the cost per tonne will vary significantly by project. Quoting fabricated steel in terms of a cost per tonne can be misleading, and unsurprisingly it causes difficulties in costing projects. At best, cost per tonne is an average cost for manufactured steel sub-structures for a project. It is a project statistic, it is not necessarily a cost that can be used transferably for other projects. Commodities are priced in dollars per tonne. Currently, fabricated steelwork is not a commodity. In Australia today, other than in low-rise applications (sheds) it is as bespoke as a Savile Row suit. Mass of steel/m² of office space is somewhat more helpful, but architects and engineers want to know steel statistics for various types

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2 152 interviews in total, comprising 37% engineering personnel, 26% building/construction personnel, 18% architectural personnel, 12% project management personnel, 12% quantity surveying personnel, 11% property development personnel, 7% other (multiple response question).
of buildings and how the current rates are varying in various regions of Australia. Better a price for the steel and a separate price for the manufacturing and finishing, delivery and erection if required. Often there can be a trade-off between the quantity of steel to be used and the amount of manufacturing work (and therefore cost) involved. Using more steel can mean simpler engineering design and lower manufacturing cost and therefore work out cheaper. This is a factor that a statistic like cost per tonne completely hides. So action is required to make costing more understandable and more transparent.

Information regarding design flexibility and sustainability throughout the life of the building must remain high on the list of the wide variety of reliable information that needs to be communicated to value chain participants. Australia does not have a recognised steel industry sustainability policy or strategy. On the other hand, in the UK for example, the Steel Construction Sector Sustainability Committee has a published strategy (SCSSC 2002) and published guidance for their clients and professional advisors (SCSSC 2003). Clearly Australia is well behind the times in this respect.

The evidence clearly supports an argument for the routine provision of communications regarding the cost of steel construction relative to other methods, sustainable design methodologies, the current prices of steel and for estimating the fabrication and erection costs. While the methodologies might remain relatively stable over time, labour rates and material prices (as examples) would need to be routinely maintained.

In the US and New Zealand as examples, the information outlined above is provided via the solution centres supported by the American Institute of Steel Construction and Steel Construction New Zealand, much of it online. A similar approach could be adopted in Australia with the best-placed co-ordinating body currently being the Australian Steel Institute.

A2.2.5 Communicating within the value chain and within entities

In 2003, the UK Department of Trade and Industry together with the Steel Construction Institute and the British Cement Association in their paper ‘Learning from the Best’ showed that considerable improvements in performance are achievable and that benefits have been realised by those organisations within the UK construction industry that have adopted new ways of working. ‘Learning from the Best’ uncovered five main themes of innovation. One of these themes was named ‘Collaborative Working’.

Collaboration is the process by which the parties to a project operate in a mutual rather than antagonistic manner to align their interests for the successful outcome of the project. This is significantly different from the way most construction contracts in Australia are structured today. Many have experienced projects with numerous hand-offs between the various contractors and consultants, with battle lines drawn up between the parties; where the concept of making the margin out of variations is rife, and the majority of risk is transferred to those least able to resist, rather than to those most able to manage it.

‘Collaborative working’ cannot exist without effective communication.

The SCNZ (2003) identified poor documentation as being the ‘single biggest problem reducing efficiency in construction’ reporting ‘poor documentation initiates variations and nobody wins’. Engineers Australia (2005) reported that the ‘adversarial climate and blame culture make communications more difficult’. It advocates that ‘the primary ingredient of successful project delivery is people working co-operatively together, sharing the same vision and objectives for the project. The contracting arrangement will be framed around goodwill and fair dealing in an open communication environment’.

There has to be both a will and a way: $12 billion per year is the figure put forward (Engineers Australia, 2005), as the estimated loss Australian wide due to poor communication and documentation. Even a fraction of this amount should provide enough incentive for there to be a will. Advances in information technology provide a way.

Advances in IT mean that ineffective documentation and communication need not be the norm. Three-dimensional computer-aided design (3D CAD) and Building Information Modelling (BIM) are but two available technologies (Hainsworth 2006). BIM is a technology that links computable data to 3D geometrically co-ordinated computing objects. So if an engineer needs to change a beam depth for example, the architect can see that ceiling heights have changed, and an electrician can see that the cable trays may have to be re-arranged, because all the relevant data is linked and everyone who needs to, has access. The potential to reduce requests for information, variations and consequently costs and construction time is readily apparent.

Effective communication between collaborating entities within the value chain by using available information
technology has the immediate potential to reduce rework and ineffective application of effort which currently contributes to the reported $12 billion loss (Engineers Australia 2005).

A2.2.6 Communications with government and the innovation community

In 2003/04 the total business expenditure on R&D (BERD) in Australia was close to $7.6 billion (ABS 8104.0, 2006a) at an average annual rate of increase over the past five years of 20.8 per cent. This is just short of 1 per cent of GDP but is below the OECD average of 1.53 per cent.

In 2003/04 the whole of the construction industry spent a total of $234m on R&D. This represents 0.15 per cent of total sector income. By comparison the manufacturing sector spent 1.03 per cent of total income on R&D.

Of the money that was spent on R&D by the construction industry, only 0.4 per cent was contributed by the various levels of government. The rest was paid for directly by the construction industry. By contrast, 5.2 per cent of the manufacturing sector’s R&D spend was contributed by the various levels of government. Of all the 15 ABS industry sectors, only one other sector (transport and storage) received less R&D support from government.

In 2005/06, construction anticipates spending 27 per cent less on R&D than it actually spent in 2004/05. Only one industry sector (personal & other services) is expecting a larger percentage drop (ABS 8104.0, 2006a).

Furthermore, in 2003/04 the funding from government for operational costs was only 0.02 per cent of total income, the least of all sectors, whereas for transport and storage and manufacturing, as two examples, the figures were 4.5 per cent and 0.2 per cent; orders of magnitude greater (ABS 2006b). The average over all industries was 1.61 per cent of income or $27.5 billion.

We can conclude that the construction industry is significantly underspending on R&D compared with other sectors. The Federal Government is not supporting construction R&D and is not supporting operations.

For an industry that contributes 5.1 per cent of Australian GDP (2002/03) (ABS 2004), this is not an equitable state of affairs. If the construction industry secured government funding at the 1 per cent of revenue level $1.5 billion would be available to help secure the future growth of the industry by providing a stimulus for investment in advanced communications solutions including 3D CAD, BIM and similar applications. This level of funding would provide a significant jump-start.

A2.2.7 Delivering the message

While the need for more effective communication should now be undisputed, and resources have been identified to help fund the effort, who will grab the nettle?

Co-ordinating industry information ranging from costing protocols and sustainability policies to career development material is best handled by a cross-industry body. In Australia in the steel construction sector, the Australian Steel Institute is currently the best-placed body to adopt at least some this responsibility, but will need to work closely with, for example, the Green Building Council of Australia to make-up lost ground in the sustainability area.

However, there remains a significant responsibility on the industry participants themselves to change things for the better. Communicating between themselves, within themselves, to their clients and to government can only be their responsibility. The time to start is now.

References


A2.3 COLLABORATE TO SUCCEED

By Andrew Marjoribanks
For The Warren Centre

A2.3.1 Introduction

The use of steel in commercial and other non-residential applications has reached a low point in the past few years, getting as low as 3 per cent in 2002, recovering to 13 per cent in 2005 (Australian Steel Institute research data), but still not at any level comparable to its use in the UK, (70 per cent, British Constructional Steel Association) or New Zealand, (40 per cent, Steel Construction New Zealand). A number of reasons are put forward for this state of affairs, a major candidate being the complexity of the steel construction supply chain and the dissonance between its links.

Multi-link chains are not of themselves inefficient or incapable, as we see in other industries and in the UK and New Zealand steel construction sector, so it is clear that there are practices that can be adapted to the Australian steel construction industry that would lead to more successful outcomes.

A fundamental feature of successful supply or value chains is the extensive collaboration between the parties involved and how this is enabled by infrastructure they develop to communicate with each other, and the organisational model they adopt to relate to each other.

A2.3.2 Establishing a collaboration infrastructure

An issue addressed frequently during the Framing the Future study has been that the multi-link nature of the constructional steel supply chain is a major reason why steel has not been successful. Multi-link chains can be successful and there are quite a few examples. The Australian house building industry is efficient and successful (Housing Industry of Australia data on productivity improvement), and it relies on the collaboration of many independent trades and other entities to succeed. Also the delivery of IT solutions very often relies on inputs from a number of independent specialists working in collaboration to deliver their product. In part this happens because the participants work within an effective collaboration infrastructure which allows easy communication and access up and down the chain.

In looking at the steel supply chain there are a number of areas in which the infrastructure could be improved to enable more effective collaboration.
The development of common standards and communication tools is one example. The expanding use of 3D modeling and Building Information Management (BIM) systems offers the opportunity to integrate the supply chain in a way which has not been possible so far. As 3D models develop, all participants in the supply chain will become party to a common and binding database. As the models will be built from the input of all participants 'clash detection' before commencement of construction will be possible, and a major increase in efficiency and reduction in cost achieved. Such models should also contain accurate dimensional data which then becomes a more reliable input for shop detailing ahead of fabrication. Improvement in the collaboration infrastructure (i.e. compatible design and modeling software) between design engineering, shop detailing and fabrication would be a significant step in integrating these links. Achieving this level of interoperability of software throughout the chain requires strong direction, and this might well come from professional and industry bodies, or a specialist industry group as has happened in the UK (British Constructional Steel Association, www.SteelConstruction.org).

BIM, according to Arup (Hainsworth & Bull 2007) is the ability to add information other than geometry to a 3D model and can be used for various purposes including:

- Automated scheduling of quantities
- Supply chain integration – automating the procurement process
- Direct manufacture – for example CNC machining direct from the model
- Facilities management
- Virtual construction

Clearly the development and adoption of BIM will lead to better integration of the whole supply chain. Benefits one can foresee include:

- Time, cost and error reductions at hand-off points
- Automated approval process
- Reliable, rapid communication of changes to all project participants
- Real-time visibility of progress throughout the supply chain – issue resolution, impact of changes, progress reporting, contract performance

BIM is in its infancy in Australia, but is becoming widely used in Europe where it is increasingly being specified as a condition of engagement. Collaboration and investment in this technology will undoubtedly generate success and reward.

The evolution of this technology will also demand the development and adoption of enabling standards for such items as data formats, process and document definitions, contractual terms and provision for repetitive fabrication and composite designs.

Hand in hand with this progress needs to develop a better costing methodology to integrate with these emerging systems. The current practice of costing by the tonne leads to wide variation in cost per tonne between simple and complex designs, and the cost of variations to a design once construction is in progress can also be very unpredictable. This in turn leads to quantity surveyors adding contingency and other provisional costing to steel work (‘the fear factor’), and adds to the perception of unreliability and increased risk with steel construction. A rational costing methodology closely linked to a database of current costs (at any given time) of the specific elements of a design e.g. $/m2 price of steel section, connections, penetrations etc, would serve the whole value chain and lead to steel construction having a higher ‘trust factor’.

Achieving success in this area is highly dependent on collaboration between steel fabricators, quantity surveyors, engineers, architects and detailers to report the detail cost elements of constructional steelwork, and to keep this information current, on say, a quarterly basis. The Australian Steel Institute using an ICIP grant made available in 2006, has commissioned a quantity surveying company to undertake a study which will establish an initial set of such cost data and which will become the basis for discussion and further progress in this area.

One further observation is that with a much improved collaboration infrastructure in place, it should be possible to have an earlier involvement in the decision processes of developing a project, with the power of modeling and reliable costing able to give clients, builders and others a steel alternative at lower levels of risk than those perceived at present.

A2.3.3 Adopting a successful collaboration vehicle (alliances, partnerships, design and construct)

By Sandy Longworth
For The Warren Centre

If the constructional steel supply chain is indeed disjointed, and if that is a major deterrent to further market penetration by the steel sector, then a solution is to weld the chain together, totally or in part, to enable seamless delivery of a project to a client. This could be done in ways ranging from an informal arrangement
between a designer, detailer, fabricator, possibly a steel supplier, possibly a quantity surveyor, who would combine their resources to offer a client or a builder a steel solution, through to a design and construct entity which would own all the design, detailing, fabrication and other elements necessary to undertake projects. Such a service is dependent on collaboration and requires strong leadership (Mahony 2006) (Ryan 2006).

A working group within the Steel – Framing the Future project is examining the forms which alliances could take, and has identified four models. The group assumed that the alliance, whatever its structure, would only consider selected projects, where it was felt superior solutions could be offered. These would in general, be steel alternatives to an already scoped and budget-priced concrete solution. In such cases it was assumed that the principal (builder/developer) would already have established both preliminary budget prices and program schedules for the concrete solution, giving a benchmark to work against. An expert construction lawyer joined the working group to provide advice on possible legal structures that might be considered in order to facilitate the delivery of a design and construct (D&C) structural steel frame alternative to concrete.

Model 1 (Business as usual)

The consortium, as a team, would offer its services to execute a series of subcontracts for the principal. They would table a combined price to which they would be committed, should they believe they have a superior solution.

In favour of this model is its simplicity, and the potential to make savings in time and money through co-operation. Against it, is that it is very little removed from current practice, savings initiated in one area but realised in another are not necessarily shared and, more importantly, there is no compelling benefit for the principal.

Model 2 (Sub-alliance)

As in 1, with the consortium members subcontracting directly with the principal, but working as a team in a sub-alliance with some form of formal arrangement to share gains and losses.

This might be more attractive to the principal, if it is seen as genuinely improving timely delivery and cost. From the members’ point of view, the ability to share gains and losses would be an advantage, except that time savings might be difficult to harvest as cash.

On the downside there is no focus of responsibility, so the principal is still reliant on separate subcontracts.

Model 3 (Specific Corporate Entity SCE)

The SCE maybe established as a subsidiary of a substantial entity with at least some construction industry allegiance, such as a steel producer or major distributor. This organisation could have an entrepreneurial marketing or project management shareholder, as two of many possible options.

This arrangement would give focus of responsibility and one face to the principal. It would have the ‘brand backing’ of the major shareholder, even if the major shareholder was at arms length from it. It would have a number of engineers, fabricators and specialised subcontractors on its register, and be able therefore to handle more than one project at a time.

Advantages of this model include:

- Can use subcontractor’s insurances.
- Can optimise delivery i.e. construction schedules, design freeze points, payment schedules and generally save time for both the project and the subcontractors.
- Has flexibility to match providers of services to projects, evening out workloads etc.

Disadvantages:

- Requires a new entity with overheads which have to be recovered before there is any gain.
- Requires strong project management employed by lead entity.
- Financial structure and selection of alliance members critical to gain client confidence.
- Temptation to introduce competitive pricing between subcontractor partners, e.g. fabricators, which would be a disincentive to joining, and to sharing innovation.

Model 4 (Special Purpose Company SPC)

The SPC is incorporated with D&C consortium members as shareholders. There could be other shareholders, possibly involved in the construction industry but not directly in the area of SPC interest, but the SPC would not be a subsidiary of another company. It would subcontract with its various consortium member shareholders to provide the various services required in delivering its contract with the principal.

The advantages are much the same as Model 3, single point delivery, insurance, optimising etc.

The disadvantages:
• Does not have ‘brand backing’ as in 3.
• Does not have same degree of flexibility as 3.
• May not be able to handle same spread of projects as 3.
• Requires equity commitment by each shareholder.

Obviously there are many variations possible on the above themes. ‘Factors affecting selection of particular models’ are discussed in some detail in a discussion note provided by David Fabian of law firm MinterEllison (Appendix A5). The final comment is worth quoting as an overview on this topic:

‘It is a commercial, rather than legal question, whether it would ever be viable to establish a corporate vehicle, in direct response to The Warren Centre Steel – Framing the Future project, which amounted to a management enterprise supporting a panel of suppliers, engineers, fabricators and specialist subcontractors. Two considerations would be the commercial and financial credibility of the vehicle and the willingness of the participants to align themselves under its banner.’

A2.3.4 Learning from New Zealand and the UK

By David Ryan
Australian Steel Institute for The Warren Centre

These countries are of interest because they have achieved a much greater use of steel in construction (40-70 per cent) than in Australia (13 per cent as reported by The Market Intelligence Co in a survey commissioned by the Australian Steel Institute). In both countries building construction accounts for the majority of steelwork fabrication – some 80 per cent to 90 per cent, which probably explains the deep involvement the steel sector has had in this area in those countries. It is almost a reverse situation in Australia where the 800,000 tonnes per annum of steel consumed by the fabrication industry is largely used in mining, industrial, agricultural and civil engineering infrastructure, with multi storey building construction occupying a much smaller portion in the order of 10 per cent (ASI research data).

Nevertheless there are learnings to be had.

A report (Ryan, Ng & Pearson 2006) details the progress in 10 years from a 10 per cent market share by steel to the current 50 per cent. Essentially it is a ‘collaboration for success’ story, with Steel Construction New Zealand (SCNZ) being the vehicle developed to concentrate the focus of the fabrication industry, and enable and stimulate the collaboration between it and engineers, designers and other members of the supply chain. A rational costing methodology, called the Steelwork Estimating Guide and based on fabricator input was a key piece of collaboration infrastructure that allowed preliminary costing of designs and created a reliable source of cost information for discussion and decision making between quantity surveyors, engineers builders and others.

In the UK, Corus (formerly British Steel), the Steel Construction Institute (SCI) and the British Constructional Steel Association (BCSA) have created a strong steel construction culture over the past 20-25 years or so. In current UK practice it is understood that a great deal of the work is undertaken by steel construction companies who have their own design, detailing and fabrication capabilities and are able to offer design and construct services, so that the supply chain is virtually compressed into the one organisation. This is the ideal design and construct vehicle and it could emerge in Australia, as it has in the UK, through a strong fabricator/leader taking on the role of prime design and construct contractor and engaging the engineer under sub-contract or in a profit/loss sharing alliance to provide a strong incentive for the close collaboration with the fabricator needed for success. Nevertheless issues of collaboration do arise.

In 2003 the SCI and the British Cement Association co-operated in an initiative called ‘Learning from the Best’. It drew on the experience of a number of demonstration projects and was itself part of an ongoing program called ‘Rethinking Construction’. It adopted a number of themes, each backed by case studies, one of which was collaborative working:

‘A key benefit of collaborative working is seen to be the provision of a platform for innovation. Early involvement of all parties means that there are plenty of opportunities to put ideas across and successfully propose innovations, so encouraging further suggestions.’

This report’s conclusion on collaborative working is also worth recording as a learning for collaborators looking for success in the Australian steel construction industry:

‘Companies working together in partnership as part of a truly integrated supply chain has led to a different culture within many of the demonstration projects. The differentiation should be recognised between site based partnering and partnering in project procurement. The former has been found to help foster the necessary trust to achieve a better way of working and to eliminate old-style adversarial attitudes. But the latter has led to an
improvement in business performance, enhanced value for money, the reduction of risk and a platform for innovation’.

References

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Mahony B, UK visit report (Appendix A8)

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A2.4 CAPABILITY

By Brian Mahony
The Warren Centre

A2.4.1 Background

Capability is one of the key planks emerging from the project considerations and is mainly underpinned by the findings of the technology issues group. This group identified the need for increased utilization of tried and proven technology to provide an attractive framing alternative in the Australian construction context. This technology can be applied to all areas of the steel frame delivery chain including:

- Design
- Detailing
- Supply
- Fabrication
- Erection
- Associated activities such as composite construction flooring

The steel value chain, when compared with its confreres overseas, has not been pro-active in leading the way with new technology. This is most apparent in the fabricating sector where the skills shortage is acute and the potential benefits from automation significant.

A2.4.2 The Proposition

- The market for multi-storey buildings could be quadrupled and we would still have a lower steel penetration than the UK.
- The total market for steel fabrication could be increased by almost half a billion dollars and the steel usage by 100,000-200,000 tonnes.
- The cost of fabrication per tonne can be reduced by between 10 per cent and 40 per cent by the utilization of the technology described above.
- Customers can be given much greater design freedom at little additional cost.
- The supply chain can be shortened and simplified, reducing lead times for customers and capital requirements and estimating uncertainties for suppliers.
- Much of the benefit can be transferred to engineering and infrastructure fabrication resulting in significant savings in current Australian fabrication market areas.
A2.4.3 Technology

BIM

The foundation of the new technology is the Building Information Model, which enables design information to be imported/exported through a wide range of software packages to avoid costly reworking and error in remodelling of elements. There is an increasing range of software, which through ‘interoperability’ enables program packages to talk to one another, making engineers, detailers and fabricators work output quicker and easier. Capacity to handle change is an attribute of the system.

The BIM lives on after completion of the building and in a sense becomes a whole of life management tool for the asset.

Structural Model

The engineers and detailers packages, such as Xsteel, StruCad etc, tie in and form part of the BIM. The basic framing commences with a 3D structural model, which initially provides a database of dimensions and loadings. The model is linked to a structural design package, which then provides the section details for each member of the frame.

Data from the structural model is then available to other participants in the supply chain, provided it can be manipulated, i.e. interoperability.

Detailing

The detailing of structural elements from the model may well take place within the engineer’s scope of responsibility, with the detailer building an independent model as a true dimensional check. The ability to react quickly to design changes, both at detailing and design levels is an important prerequisite in the steel value proposition. Typical detailing systems such as StruCad, BoCad, Xsteel, Prosteel are presently utilised for detailing from 3D databases.

Fabrication

In the modern fabrication shop, the planning process starts with a review of the detailer’s digital outputs to determine:

- Opportunity to optimise erected costs of frame by re-design of sections without compromising design intent.
- Quantity take-offs for the steel and inventory check against in-house stocks.
- Erection plan for the steel which defines the order of delivery and hence the order of fabrication.
- Standardization of connections and other weldments.
- Preparation of CNC inputs for the fabrication machine’s utilising systems such as FastCam or FastBeam.

The advanced technology for the actual fabrication of the frame is well described in the paper on the layout and equipment required for the cost-effective production of structural steel for buildings. Such a shop would utilise equipment from the following major suppliers:

- Beamlines from companies such as Ficep, Kaltenbach, Vortman, Vernet Boehringer etc.
- Plate cutting/drilling machines from firms such as Farley-Laserlab, Ficep, Peddinghaus, Kaltenbach.
- Welding lines from Kronendonc, ESAB, FRO.

Supply

As well as the fabricators take-off, the 3D database is also used by steel products distributors for the supply of optimal lengths to the fabricators (with some pre-work) as well as steel metal decking for the composite construction works.

Erection

The on-site erection technology for steelwork has been largely driven by safety considerations where connections are made from either scaffolding or cherry pickers. Overseas developments include:

- Japan
  Some promising technology for rapid, environmentally superior construction.
  The Obayashi Big Canopy system was developed in Japan. This system involves the installation of a fully enclosed construction system, with noise containment, which is jacked up off the erected steelwork and which provides for all-weather, 24-hour construction.

- United Kingdom
  Various ‘quick-connect’ systems for beams to columns have been trialled in the UK to minimise erection time. These systems have not been universally adopted but may become more attractive as the production of weldments and their placing in beams and columns becomes more cost-effective.
APPENDIX A3 LEADERSHIP ISSUES

STRATEGIC ISSUES IN CHANGING THE PERCEPTION OF THE STRUCTURAL STEEL SECTOR

Reg Hobbs
Flagstaff Consulting Group for The Warren Centre

A3.1 Introduction

During the development of every project there will be a point when the project team stands at the ‘fork in the road’ and has to make the critical decision as to which structural framing solution it will adopt.

In Australia, in spite of all the demonstrated benefits of steel framing it is clear that it takes significant confidence and commitment to adopt steel framing, whereas the concrete frame is a decision that is readily made (rightly or wrongly) without any apparent fear that it may be a wrong decision.

The deliberations of the Leadership Issues Group often returned to the theme that building designers generally consider their task to involve less stress and potential problems if they select a concrete-framed structure. The construction participant made it clear he considered that a builder constructing a concrete-framed project considers that they are more in command of their own destiny than when relying on the steel supply chain.

Given the stated lack of such inhibition in the building sector in the UK and the long-standing prevalence of steel framing in North America, why such perceptions prevail in Australia is a salient question.

After careful consideration of the minutes of the meetings and extensive review of a wide range of Australian and international literature regarding both steel-framed and concrete projects the Chairman of the Leadership Group has developed a very strong conviction that there is a need for reform of the structural steel sector in Australia.

It may be that many of the parties in the supply chain are comfortable with their current trading positions and see no need to change their commercial approach and methods of operation. However if the industry is genuine about increasing market share in building projects to the levels reported for the UK then a significant ‘market shock’ might be necessary to drive the necessary reform. Then it is likely that ‘new leaders’ will rapidly emerge.

The following discussion considers some of the key issues to which these ‘new leaders’ will need to respond.

A3.2 Appreciation of client needs

The steel sector appears to be unduly preoccupied with the notion that potential specifiers and users are misinformed in not understanding the merits of the product and that this can be set right by effective communications, case studies and advertising.

Throughout the study it was notable how many salient issues and concerns raised by parties from outside the steel sector were responded to by steel sector parties along the lines that ‘their perception is wrong’. The sector needs to consider whether such an approach actually changes perceptions or whether more tangible demonstrations of the value proposition are required.

Any parties seeking to lead the process of changing perceptions of the steel sector will need to achieve consensus within the sector as to what the needs of such specifiers and users really are.

It is somewhat concerning that there continues to be undue focus on the ‘wholesale’ structural aspects of purported reduced construction times, labour reduction on site and structural cost savings rather than a holistic view of the ‘retail’ outcomes of the parameters of the complete structure, façade, services, finishes and fit-out of buildings.

A building is not an engineering project – it is a ‘designer asset’, with sophisticated underlying engineering systems. The success of the completed edifice will be judged by reference to the architecture, finishes, reliability and running costs of services as well as the comfort of users. It was clear from Leadership Group meetings with developers, financiers, lawyers and government that they don’t really care how it is framed, they are only interested in the outcome and other qualities such as operation and maintenance costs, occupant acceptance, life cycle and environmental sustainability.
Steel industry participants appear to focus on how their product can be used in a structural frame, rather than the parameters of the building the designers are trying to achieve. Structural engineering is but a small part of the qualities of the building that make it marketable and satisfactory for specific occupants. As was apparent from the workshop in December 2005 the typical developer, owner or tenant really doesn’t care what the framing is as long as the building delivers the desired outcomes.

The past five years has seen unprecedented change in office design concepts, the importance of office planning in organisational values and in the importance of environmentally sustainable design.

In addition to traditional considerations such as cost, time and constructability, current architectural and fit-out designs are demanding significant improvement in aspects of completed buildings in areas such as:

- Green Star ratings.
- Buildings that generate more collaboration and interaction between staff, currently resulting in many buildings with very large floor ‘plates’.
- Flexible office planning and ability to change layouts many times in the life of a building.
- Floor flatness and levelness – floors without camber.
- Unimpeded use of glass partitions and sliding door systems as well as large areas of open-plan design.
- Minimal vibration, footfalls and sound transmission.
- Unimpeded transit of services in ceiling spaces and unimpeded ability to change layouts.

Concrete-framed buildings have been proven to be able to provide most of these functional outcomes with relatively little stress for the designer and constructors. It is not a ‘given’ that steel-framed buildings in the form usually promoted by the Australian steel sector can achieve these without special provisions.

It is also apparent that a commonly encountered pre-occupation with reducing cost and floor to floor heights (by means of minimising beam depths) does not necessarily deliver the foregoing objectives. The steel sector may need to focus on deeper, stiffer beams including sections with larger penetrations for services transit regardless of whether this affects cost competitiveness.

A3.3 What is the product? A need to focus on a steel/concrete composite solution

The steel sector in Australia appears to have difficulty articulating the nature of the product it is selling, hence it is not surprising that the wider design, construction and development community has trouble recognising the specific ‘solutions’ being offered.

The notion of steel framing is the basis, and the sector would undoubtedly be grateful to sell full building frames similar to those historically used in North American buildings (including steel-framed building cores).

The reality in Australia is that the mainstream construction sector moved from that model decades ago. Unless there is some unique feature of building geometry that requires the steel core then it can be expected that a typical Australian building will have concrete core elevator shafts, fire escape stair wells and services risers. Once this position has been reached it is inevitable that the concrete core will be the natural primary bracing element against wind forces for the building.

The columns of a multi-level building may be a variety of steel, concrete or composite elements. As has been indicated by the paper prepared by Emil Zyhajlo it is most likely in Australia that there will be concrete trades involved in some from of encasement of whatever steel section is adopted.

The floor slabs will be concrete, whether or not floors are steel framed, so this leads to the inevitable question of what is the nature of the product the steel sector is selling?

Hence it is perfectly clear that the steel sector is selling primary beams to support floor slabs and any associated sales of steel columns and steel decking is a bonus.

Perhaps the product would be better defined as ‘steel beam flooring systems’ rather than ‘steel framed buildings’?

There is also a preoccupation with selling a composite floor design that has been in use for decades that features a steel primary beam (with or without fire proofing), transverse steel decking and shear studs.

It is quite conceivable that the Australian steel sector is concentrating too much effort on a design solution that, while it represents value for money, is rapidly becoming outdated.

Many other variants including partially concrete-encased steel composite beams are not readily available in the Australian market, whereas these are showing great potential in countries such as Germany. This appears to be because Australian suppliers and
fabricators have not at this stage demonstrated an inclination to extend their operations to concrete encasement.

Such prefabricated composite elements would be of significant interest to designers, developers and constructors of low-rise buildings and many contemporary office buildings where exposed floor soffits are often adopted and a visually attractive beam profile is desired⁴.

Contact with parties who have experience in the UK and European construction industries allowed parties such as the German firm Stahl + Verbundbau GmbH⁵ to be identified.

This firm’s name translates literally as ‘steel and composite construction’. It supplies a range of pre-encased steel sections with many designed to be of interest to architects for exposed structural treatments.

No companies offering such products as a ‘standard line’ have been identified in Australia and it is understood that where such composite elements are contemplated it is likely to be necessary for the builder to separately engage both a steel fabricator and a pre-caster to achieve the desired product.

It is considered that this is an area where parties such as the ASI could devote some effort to improving the product offering in Australia; in encouraging international companies such as Stahl + Verbundbau to establish here; or in supporting local suppliers to manufacture such products.

### A3.4 Industry profile and presentation

The steel industry presents a somewhat confusing face to the Australian professional and business community. It is readily perceived as an industry where there is a lack of choice (therefore offering poor value) and that there are discordant views as to the direction of the sector.

At the time of this report the financial media, trade press and engineering journals were providing substantial coverage of the OneSteel – Smorgon Steel ‘merger’, BlueScope taking a substantial equity position in Smorgon Steel, Mittal having merged with Arcelor, Tata making offers to acquire Corus and other possible merger and acquisition activity involving Russian, Korean and Japanese steel groups. The deliberations of the ACCC in relation to the proposed OneSteel – Smorgon Steel merger are complex and may be easily misunderstood by potential users and specifiers in the building sector who do not have a sophisticated understanding of the steel industry.

Australian construction and property sector participants are highly sensitive to price and where they perceive they do not have a range of choices in sourcing a product they are very likely to look for other solutions. To a construction contractor the concrete-framed solution can often provide a more competitive answer as the steel content is relatively small and there are many suppliers available for each of the concrete supply, formwork, pre-stressing and concrete placing trades. Consolidation in the global cement industry does not appear to concern users of concrete as there are a number of ‘independent’ concrete producers in each State. Companies such as Adelaide Brighton Cement, ICL (Victoria) and BGC (Western Australia) are seen to present strong competition for the Eastern States’ ‘majors’ and in any event a builder can follow the lead of Grollo and produce their own concrete.

Although some of this industry consolidation will also affect the market for concrete reinforcing steel the value of this is small in the context of the overall building cost. There are already well-established international sources of steel reinforcing bar and wire operating in Australia; with the prospect of increasing competition from China, India and Russia.

An example of the confusing image the Australian steel sector presents to the potential client base is a special supplement on steel published in The Australian newspaper on September 2, 2006. The lead story was titled ‘Consolidation Fever’⁶ and the main advertisement on the front page was placed by the Australian Steel Association Inc.

This advertisement claimed that the member companies of the Association ‘… have no choice when it comes to supply from BlueScope, OneSteel or Smorgon Steel in that their only competitive supply source is imports’ and that ‘the three local steel producers also import but they attempt to frustrate our import supply by their use of taxpayer-funded anti-dumping investigations’.

This is a very confusing image for the industry to project to industry and the public.

A further example is that while in some advertising and

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⁴ Some examples are the award-winning National Australia Bank buildings at Melbourne’s Docklands and the Schiavello building in Tullamarine.

⁵ www.stahlverbundbau.de

⁶ Relating to the proposed merger of OneSteel Limited with Smorgon Steel Limited and the likelihood of an effective duopoly, as well as merger and acquisition activity in the world steel market.
trade journals OneSteel Limited vigorously promotes structural steel framing, reference to its internet site in October 2006 and following the links ‘Products/End Use Applications/Construction: Buildings/Office’ leads to product information which is predominantly about reinforcing bar for concrete elements.

Such ambiguity cannot be beneficial to the cause of promoting structural steel beams as primary framing elements.

Feature advertisements in journals such as in Engineers Australia (2006) placed by the Australian Steel Institute make claims that steel ‘...reduces on-site risks and OH&S exposure due to off-site fabrication and a smaller workforce on site’. Such statements are not supported by statistical data relating to workforce accidents for the whole steel sector in Australia or internationally.

It is recommended that the industry needs a thorough reappraisal of the manner in which it invests in promotion.

Promotion of solutions and statements that the industry has recognised past issues, has now reformed and is able to offer customers world competitive value are likely to be of much greater appeal to potential users of steel framing.

A3.5 Proposals for reform

While the usage of structural steel for building framing is lower than the industry may consider has been achieved in other countries there does not appear to be any ‘distress’ among the suppliers, fabricators and erectors about this. In fact they appear to be rather well placed for forward workload and it is hard to imagine they see a particular need to dramatically change the nature of their businesses.

It is difficult to contemplate any significant change in behaviour unless the need arises from a significant downturn in Australian economic conditions (unlikely in the short term) or there are other industry factors such as major structural reform, new international steel construction groups entering the Australian market (unlikely) or there is a real prospect of increased activity in imported fabricated steelwork (possible for buildings and already prevalent in the engineering sector).

It is apparent that it will be beneficial to the development of competition in this sector (and therefore the need to change) if there is active encouragement of imported steel sections and overseas fabrication.

The ASI could play a key role in assisting with reconciliation of quality matters and standards.

A significant additional reform would be the emergence of a larger pool of Australian companies who do all shop detailing, fabrication and erection themselves. The industry would benefit from more ‘steel contractors’ rather than being limited to sourcing the steel frame components from the currently more prevalent ‘steel fabricators’ who often outsource detailing, may erect themselves or may arrange an external erector. While there is nothing unusual about such practices, the deliberations of the Leadership Group indicate that the issues of dealing with detailers and sub-contract erectors on sites are a disincentive to the use of steel framing.

The other area of reform that is available is to develop increased focus on provision of structural steel solutions for smaller commercial buildings and suburban offices rather than landmark or high-rise buildings. The volume of sales that could be developed in this area is substantial. Development of this market will require more effort in the area of providing design aids in the area of composite sections to smaller, less technically resourced engineering consultancies and possibly further development of Australian standards in the area of composite structures.

A3.6 Absence of concrete case studies by the Steel – Framing the Future project:

It is of interest that the case studies undertaken in 2005 involved predominantly steel-framed buildings and that there was no objective benchmarking of the performance of such buildings (both during construction and in service) against comparable concrete-framed buildings, other than qualitative statements from the participants.

This must be regarded as a significant limitation of the Steel – Framing the Future project and there are questions arising as to the objectivity of reference to outcomes of these case studies in forming conclusions.
When the Leadership Group began its deliberations there were two major steel-framed buildings under construction in Melbourne, being the subject of case studies by The Warren Centre and reported as being examples of the ‘state of the art’.

In the following 12 months a significant number of major office buildings11 have started construction in Melbourne or are currently being designed. It is apparent that many of these buildings have not adopted steel framing for these buildings and it is unlikely that there will be any, even those being constructed by the builder12 who adopted steel for two of the buildings that were the subject of the case studies.

The list of case studies did not include relevant buildings such as the Schiavello Headquarters building at Tullamarine (which was the subject of the Victorian Master Builder of the Year Award for 2005). It was intended that this building be designed with exposed steel framing as an architectural feature, however perceptions of Sustainability issues, availability of steel sections to meet the timeframe and cost caused the owner-developer to adopt a concrete-framed solution, albeit with extensive use of steel-framed roofing and steel decking for slab soffits between post-tensioned concrete primary beams. A visit to this project was arranged late in the study, however it was not subjected to the same level of examination as other case studies.

It is recommended that future case studies need to be conducted to develop an objective understanding of the reasons why the take-up of steel-framed buildings in Melbourne has not matched the expectation of increased usage following the ‘success’ of the Southern Cross and Lonsdale Street buildings.

A3.7 Sustainability

It is interesting to note that the issue of Sustainability was not recorded in notes from the early deliberations of the Steel – Framing the Future project team and the ‘root causes’ analysis. Many members of the Steel – Framing the Future team expressed opinions to the Chairman of the Leadership Group that it was not a material issue.

Hence the starting point for discussion of this issue was the question of whether it really was an issue that had real potential to affect the adoption of steel for building framing?

The answer has been provided in many respects by the Property Council of Australia (PCA), which publishes standards observed by almost all property investors and tenants for grading of office buildings.

During 2006 the PCA included minimum ‘4 Star’ and ‘4.5 Star’ Australian Green Building Council ratings as requirements for grading of buildings as ‘Premium’ and ‘Grade A’.

The PCA’s chief executive Peter Verwer was quoted in the Australian Financial Review (October 12, p52) saying there was no going back and although the PCA green standards were at best-practice level he has ‘no doubt they will go up in the future’.

The perception that steel lags in the sustainability area in Australia is reinforced by government publications, such as the Australian Greenhouse Projections 2004, which show the concrete industry improving its position with reference to emissions, while the steel industry stays static.

It is also of note that while the Australian Cement Industry Federation (with all major cement and concrete manufacturers as members) is a member of the Australian Government’s Greenhouse Challenge Plus13, BlueScope and OneSteel are conspicuously absent from the list of participants.

The Green Building Council of Australia has published guidelines for Green Star ratings which reward use of recycled materials with ratings points. The concrete industry has managed to position itself well in these ratings through the recycling of fly ash and blast furnace slags. On the other hand the recycling requirement for steel to gain points in the system virtually excludes Australian structural steel, which is made by smelting ore and is only 25-30 per cent recycled content. (Australia produces 7.5-8 million tonnes of steel per annum and the best efforts of scrap collectors can only realise 1.6-1.8 million tonnes, which makes scrap a highly prized material, and anything but landfill).

In contrast with the Australian position, steel is perceived as having strong sustainability credentials in the UK. Richard Elliott, Head of Construction of British Land (a $30 billion UK property owner and developer), delivered a paper on steel and sustainability at the British Constructional Steel Association International Conference in London, November 2005, in which he both detailed the extensive discipline adopted by British Land on sustainability matters, and

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11 The Cbus Property development in Bourke Street, the AXA Building at Docklands, the Ericsson building at Docklands, Waterfront City Docklands (mixed use), 399 Bourke Street (mixed use) and it appears the very large ANZ headquarters is most likely to be concrete framed.
12 Multiplex Constructions.
listed what he regarded as steel's strong sustainability credentials. Coincidentally, in the same month, in the context of non-financial investment risks, the UK Financial Times ran an article on the environmental issues facing the construction industry, dwelling largely on concrete's difficulties. ‘Waste concrete from demolition accounts for about 500kg of waste per person in the EU, of which only about 5 per cent is recycled,’ it said. Interestingly, the accompanying photograph was of steel beams on a construction site, although steel itself was not mentioned in the article.

Closer to home, the group was made aware of some of the work on sustainability and steel undertaken in Australia, notably the papers produced by Peter Scaife and associates at the University of Newcastle. The group was also made aware of the GBCA's misgivings about this work, and its perception that the steel industry is behind in tackling sustainability issues.

It was also noted that the International Iron and Steel Institute has done much work in this field and currently has a major study in progress involving many steel companies from around the world.

Members of the Steel – Framing the Future project team have now had meetings with a board member and also the chief executive of the AGBC. The position of the AGBC is now much better understood and there is scope for the steel industry to participate in future development of the Green Star rating documentation.

Notwithstanding this it should be noted that it can be expected that the issue of recycling will continue to be a key consideration for the AGBC. It is unlikely that they will simply accept the proposition advanced in the Scaife paper (and other steel industry documentation) that because a piece of virgin steel will be recycled somewhere in the world, some time in the future that Green Star rating points should be awarded. It is apparent that a desire to exhaust all available options for sourcing steel sections produced from recycled material may persist.

This leads to consideration of the potential for larger sections being produced in Australia using Electric Arc Furnace or similar technologies.

It is of interest to compare the Australian situation with the US where the following is a direct quote from the US Government’s Department of Labor (Bureau of Labor Statistics n.d.):

‘The least costly method of making steel uses scrap metal as its base. Steel scrap from many sources—such as old bridges, refrigerators, and automobiles—and other additives are placed in an electric arc furnace, where the intense heat produced by carbon electrodes and chemical reactions melts the scrap, converting it into molten steel. Establishments that use this method of producing steel are called electric arc furnace (EAF) mills, or minimills. While EAFs are sometimes small, some are large enough to produce 400 tonnes of steel at a time. The growth of EAFs has been driven by the technology's smaller initial capital investment and lower operating costs. Moreover, scrap metal is found in all parts of the country, so EAFs are not tied as closely to raw material deposits as are integrated mills and can be placed closer to consumers. EAFs now account for over half of American steel production and their share is expected to continue to grow in coming years.

‘The growth of EAFs comes partly at the expense of integrated mills. Integrated mills reduce iron ore to molten pig iron in blast furnaces. The iron is then sent to the oxygen furnace, where it is combined with scrap to make molten steel. The steel produced by integrated mills generally is considered to be of higher quality than steel from EAFs but, because the production process is more complicated and consumes more energy, it is more costly.’

Andrew Marjoribanks has provided the following advice regarding the potential for ongoing development of EAF-produced steel in Australia.

The EAF process lends itself to scrap melting and is widely used for this purpose, hence ‘recycled steel’. However it can also accommodate ‘virgin feed’ in the form of HBI, DRI, Iron Pellets and even iron ore. It can also be fed with pig iron. The BOS process requires scrap up to 25 per cent in each batch to keep it cool. It can use more. Averaging Australian steel production over EAF and BOS, Australian steel is about 35 per cent recycled content with both processes using about the same annual amount of scrap.

So EAF steel isn’t always 100 per cent recycled, nor is BOS steel always 100 per cent virgin. What determines the ratios are scrap availability and quality.

As far as availability is concerned, scrap supply is a constant worry to EAF people, particularly in buoyant markets when price soars. South-East Asia especially has a very high demand for scrap and imports it from the US, Europe and anywhere else it can get it. Consequently a scrap substitute sold on an annual contract basis from a reliable supplier would be very attractive. This was the business case for BHP’s ill-
fated HBI plant. The original Venezuelan plant and technology was about 25 per cent the size and seemed to run satisfactorily.

On other fronts there is a lot of scrap substitute sold to the EAF steelmakers simply to ‘eke out’ the supply of scrap. NUCOR, the well-known US EAF steelmaker, sunk millions into a venture in Trinidad hoping to use tar waste, or similar, from the oil industry to beneficiate Brazilian ore fines to make a scrap substitute, but was not able to succeed. Again the driver was to reduce exposure to the volatility of scrap supply and price.

On the quality front, making reinforcing bar from scrap is fine, most of the time anyway, because the demands on steel chemistry are not high, and ‘tramp elements’ like copper, tin antimony and the like can be tolerated. Once steel chemistry becomes more demanding then scrap selection becomes critical.

One solution for the EAF producers is to ‘dilute’ their scrap with virgin iron units such as DRI, pellets, pig iron or even ore, although the energy cost to break down ore is very high. Dilutions of up to 25/30 per cent for this reason are not uncommon. As a footnote to history, Newcastle Steelworks would probably have shut 10 years earlier had it not been for its marketing strategy of making high-quality bar feed for export in a world where it ended up being the last ore-based (i.e. uncontaminated) producer.

So specifying EAF steel in the belief that that in itself will achieve a 95 per cent recycled content would be wrong. It may not even be desirable, depending on the level of specification set for, say, critical structural steel components.

For Australian steelmakers there simply isn’t enough scrap to sustain any more EAF steelmaking than currently exists. Even if there was to be a sudden upsurge in availability, and collapse in price given scrap’s almost perfect price elasticity, the more likely outcome would be that the BOS steelmakers would increase their scrap ratios to take advantage, and export more.

It is considered that notwithstanding the practical difficulties of the Australian situation concerning scrap availability there will be a growing desire for EAF-produced steel sections in Green Star-rated buildings. This obviously has implications for the Australian steel producers and their existing production facilities. If international suppliers can provide such sections they may be sought by parties who are keen to use steel, but are prepared to demand EAF production as the source.

During the course of the study, the work of Professor Markus Reuter, a metallurgist, who is Professor of Sustainable Technologies at the University of Melbourne was identified as being highly relevant to the consideration of the sustainability aspects of steel.

His background in the steel industry and work with the automotive industry on including recycling strategies and metallurgical aspects in the design process offers much for the steel industry to consider.

Although the timing of the study did not permit development of this aspect it is recommended that the steel industry study his work and involve him in ongoing development of initiatives in the sustainability area.

Although it is understood the ASI has a committee working on the industry’s response to the sustainability issue it is considered that a body providing neutral ground, such as a university or The Warren Centre, will be more likely to achieve success in working with the PCA, AGBC and related groups to achieve consensus on the measures to be adopted for assessment of steel framing’s sustainability credentials.

If nothing else the Steel – Framing the Future study has brought sustainability from a matter that was not recorded as being a ‘root cause’ in early workshops to one that will now command attention from the steel sector.

References

Engineers Australia 2006, Vol 78 No 9, September 2006, page 9


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14 Formerly of the Delft University of Technology (The Netherlands) and the University of Stellenbosch, South Africa.
### A4.1 Introduction

This appendix comprises background material to the Value Chain Issues Group report described in Section 4.3 above.

### A4.2: Case Study Descriptions

#### Building W
- 13,500 m² GFA
- 3,000 m² site
- Structural decking slabs and tilt-up panels
- 14 month build program
- $12.8m construction cost

#### Building X
- 7,200 m² GFA
- City centre site, 1344m²
- 1 basement car parking level, 5 above ground floors
- 14 month construction period
- $9.2m construction cost

#### Building Y
- 17,300 m² GFA
- 4 basement floors (separate project), G,1-7, plus rooftop plant room
- Steel columns, structural decking slabs, set back floor to floor façade, louvres
- 12 month planned build program
- $41.5m planned construction cost

#### Building Z
- 45,000 m² GFA
- City centre site
- 1 basement car parking level, 11 above ground floors, (ground, 5 levels suspended parking (show rooms), 5 levels offices
- 22 month build program (effective 8 month construction period)
- $68.4m planned construction cost

#### Concrete comparison
- 10,000 m² GFA
- Comprises 55% of a two building project
- Basement (separate project), G,1-5
- Post-tension concrete construction
- Compressed 7.5 month build program
- $20.4m construction cost

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<td>• Delays due to difficult site (sand, high water table)</td>
<td>• Delay in delivery of glass panels for façade by 16 weeks, requiring reprogramming of trades</td>
<td>• Re-design and some re-construct due to late increases in roof top plant room mass</td>
<td>• Offset lifts/services core</td>
</tr>
<tr>
<td>• Detailing issues concerning the tail/drainage on external walkways</td>
<td>• Resequencing of pour required for safety reasons</td>
<td>• Some floor sag and bounce</td>
<td>• Sprinkler based fire protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Conventional “leap-frog” formwork and pour construction</td>
</tr>
<tr>
<td>Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Floor area increased by 6,000m² (13.3%) after commencement of construction</td>
<td>• Change of floor to floor spacings after commencement of construction</td>
<td>• Delivered to time and close to budget</td>
<td>• Compressed delivery Program reduced by 3 months prior to commencement</td>
</tr>
</tbody>
</table>
A4.3: METHODOLOGY

Comments on the data

The data gathered for this assessment is sourced from many parties involved in the value chain of each building. In each case, most of the quantitative data is sourced from the Builder, with supplementary information sourced from the Owner/Developer. A complete data set for each building comprised:

- Project plans – forecast and actual
- Construction budget – forecast and actual
- Pre-construction costs and elapsed time
- Details of rectifications and variations
- General overview of the construction and pre-construction process

The data collected for each case study is represented in Table 7 below.

Definitions for analysis of cost and time

For the purpose of this assessment, several categories of cost have been largely ignored for comparison purposes, other than as a component of total cost. This is to make the buildings as comparable as possible by removing discretionary features or items extraneous to the frames. These are:

- Fitout and Finishes: includes façade, sun shading and louvers, floor coverings, tiling, partitions, ceilings and painting.
- Engineering Services: includes electrical, hydraulics, fire services, mechanical and lifts.
- Foundation and Basement: includes earthworks/excavation, piling and piling.

The remaining categories, which have formed the basis of the quantitative aspect of this assessment, are:

- Structural steel: Steel supply and labour.
- Structural concrete: Concrete supply, formwork/reo and placement.
- Construction: Preliminaries, site services, trade costs, wages and builder's margins. 'Erection' has been used to describe a subset of this category, and excluding builder's margins and external construction items such as landscaping.

<table>
<thead>
<tr>
<th>Table 1: Data collection summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building W</td>
</tr>
<tr>
<td>Project plans</td>
</tr>
<tr>
<td>Construction budgets</td>
</tr>
<tr>
<td>Pre-construction</td>
</tr>
<tr>
<td>Rects and vars</td>
</tr>
<tr>
<td>General overview</td>
</tr>
</tbody>
</table>

Figure 1: Value Chain total cost comparison
APPENDIX A5

NOTE ON CONTRACTUAL MODELS FOR STEEL FRAME DELIVERY

WARREN CENTRE FRAMING THE FUTURE

Preliminary discussion note on contractual models for engaging to undertake a composite steel building frame

By David Fabian
Minter Ellison - Lawyers

A5.1 INTRODUCTION

(a) The D&C group considered with David Fabian a variety of legal arrangements that might facilitate the objective of making a structural steel frame more commercially attractive than a reinforced concrete solution.

(b) It was common ground that significant commercial drivers are likely to be non-legal and to involve fundamental considerations of relative cost and time.

(c) Key considerations relating to the contractual arrangements were, therefore:

- Ensuring the contractual arrangements were not a disincentive to the head contractor.
- Identifying ways to make the contractual arrangements a positive enhancement of a structural steel option for the head contractor.
- Ensuring the contractual arrangements are not commercially/legally impractical for the contractor/consultant proponents.
- Ensuring the commercial arrangements optimise the commercial opportunities for proponents in ways beyond being ‘business as usual’ (acknowledging that a substantial increase in volume might be a sufficiently attractive outcome for some, but not necessarily all proponents).

(d) It was also acknowledged that the discussion was purely an abstract academic discussion and not intended to impose any commercial obligations as between any of the participants (whether of confidentiality, right of participation or of first refusal, or otherwise).

A5.2 POTENTIAL MODELS

From the spectrum of potential contractual models, a small number was specifically discussed:

a) Model One: Three traditional subcontracts with each of the design consultant, the supplier and the fabricator, accompanied by representations from each participant of their intention to work collaboratively. (This model raises sub-options of the steel supplier being contracted direct to the head contractor or to the fabricator, or the fabricator being contracted direct or as a subcontractor to the supplier; there are also potential questions about Trade Practices Act representations and implied collateral contracts).

b) Model Two: Same as Model One, but supported by a formal alliance between the three subcontractors, the existence of which is disclosed to the head contractor.

c) Model Three: Same as Model Two but including the head contractor as an alliance member.

d) Model Four: A lead SPV, particularly for an individual project (supported by the above spectrum of potential subcontracts/performance support).

e) Model Five: A multi-project trading entity with commercially negotiated shareholdings across various disciplines, which progressively develops its own ‘brand’.

f) Model Six: A ‘branded’ lead contractor which is a subsidiary of a ‘branded’ enterprise (with or without parent performance support), which subcontracts with the other participants (with or without an alliance regime).

A5.3 FACTORS AFFECTING SELECTION OF PARTICULAR MODELS

a) Each of these possible models has potential commercial advantages and disadvantages, including considerations relating to individual corporate policies and constraints as well as potential tax considerations. Ultimately, the model chosen for a particular project or strategy will be influenced by a multiplicity of commercial drivers to which the proponents and the head contractor may be subject.
b) The more commercially and legally sophisticated the structure, the more likely it will appeal to a head contractor.

c) Typically, the head contractor would be looking for single point delivery responsibility from a competent, financially strong entity supported by an acceptable level of professional indemnity protection (which might be afforded through harnessing the existing insurances of members).

d) Alliancing, shared savings, or other incentive mechanisms (whether visible to the head contractor or not) may well be structured into most models in ways that make them more commercially valuable to the proponents or to the head contractor or both.

e) It is certainly feasible to develop models that would support multi-party relationships provided they are otherwise commercially viable. That would be driven by commercial forces, but contractual tools can be employed to facilitate commercial viability.

f) It is a commercial, rather than a legal question, whether it would ever be viable to establish a corporate vehicle, in direct response to The Warren Centre’s project, which amounted to a management enterprise supporting a panel of suppliers, engineers, fabricators and specialist subcontractors. Two considerations would be the commercial and financial credibility of the vehicle and the willingness of participants to align themselves under its banner.

Dated: 12 October 2006

David Fabian
Head of Division
Construction, Engineering & Infrastructure

MINTER ELLISON

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SYDNEY NSW 2000

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Direct fax: 9921 8088
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APPENDIX 6 SUMMARY REPORT ON VISIT TO NZ SCNZ, HERA AND NZ FABRICATORS

By David Ryan
Australian Steel Institute for The Warren Centre

ACCOMPANIED BY MAX PEARSON AND ANTHONY NG.

Companies visited
HERA, SCNZ – AGM.
Auckland Steel
D&H Construction – Queensbridge apartments
Grayson Engineering - Auckland Museum, Auckland Business School sites
MJH Construction – Wellington Hotel site
Stevenson Structural Engineers – Holiday Inn site

Purpose of visit
To bring to the ASI, the Marketing Committee and to The Warren Centre an understanding of the SCNZ organisation, its strengths and weaknesses and whether there were any learnings for the Australian steel industry in regard to increasing share of steel in buildings.

Background
Five years ago the ASI was involved in a delegation about the time of the inception of SCNZ and observed the share of steel in building construction increase from 10 per cent to 25 per cent. In the past five years, the SCNZ has increased this to 40-50 per cent. The strength of the organisation is the focus by fabricators on market growth and the strong involvement of the major fabricators in the association.

Summary

- The NZ building industry is not as sophisticated or competitive as in Australia. Competition with steel is by reinforced concrete and post-tensioned concrete is not a force. Floor to floor heights are an advantage with steel in NZ but not in Australia and the common building methods are hybrids involving a range of pre-cast and steel construction, in the main. Fabricators specialise in

the frame and generally do not enter into contract for the deck or stud welding. Pricing for steel in building construction was observed to be on a par with successful Australian fabricators. Steel rates for simple heavy stick and beam fabrication were NZ$3500 to NZ$4500 per tonne depending on market conditions.

- The SCNZ is run by the fabricators and it has galvanised them to look at what they can do to effectively improve their image and effectiveness as an industry. Their major market is building construction and this market, at current share, represents about 80 per cent of the available volume in this country. There are learnings from the way they have galvanised as an association.

- The substantial support from HERA, the NZ research association, has been necessary to date but with incorporation as a separate body, SCNZ is planning its own course. HERA meantime is proposing to regroup as a metals association with HERA, NASH and SCNZ (plus others) as component bodies.

- There are significant areas of closer co-operation with ASI for both SCNZ and HERA and a regular touch base to enable these common areas to be discussed will be set up.

Learnings for the Australian Steel Institute and The Warren Centre in the market

1. The main focus should be the engineers, builders and quantity surveyors. Each involves a continuous effort to keep steel upper-mind.

2. The marketing effort needs to be supported by a technical effort. In both circumstances steel needs to offer an equivalent to its competition and its value proposition needs to be sold at each level of the decision-making process.

3. Fabricators need to be involved in the sell, so as to personally understand the imperatives and where time, effort and money should be spent.

4. This logic applies to engineering construction as well as building construction.

5. Involved fabricators need to sell the concept of an organisation structure and marketing effort to their colleagues. Only they can effectively do this.

6. Fabricators need to be involved in debate about growing and protecting their market. It is essential that there is a forum provided to do this. (ASI)
It is apparent that each country’s market is different. We cannot directly apply the model from NZ or the UK to our situation. It does however encourage us to look for our own model and develop this to suit the Australian market. This may mean grouping of those fabricators interested in building construction and driving some activities for this group and providing other activities around engineering construction, as it is clear the drivers for various sectors are different. Advice from HERA is to work with only the fabricators who want to support the concepts and focus on a few key activities before moving to other activities and bed them down rather than trying to be all things to all people. At the same time once results are being achieved for the key fabricators to leverage these to gain more universal support. This is in line with the ASI focusing on effective plans driven by the various sectors i.e. AFS campaign for engineering construction and Beyond2 for building construction.

Observations

- A clear observation was the loyalty shown by SCNZ fabricators to the steel suppliers supporting their organisation (in particular OneSteel) - often at a premium.
- It is apparent that the technical support in the form of new publications, technical tools etc are prolific. This provides forums for discussing steel’s effectiveness to the engineering community. The ASI needs to create or borrow this philosophy and areas of apparent co-operation on technical tools and publications are great.
- The redesign and costing facility provisions of the SCNZ provided the results in the market and hence the impetus for the fabricators to lend their support when the HERA and supplier funding dropped away. This financial support was driven by Mike Sullivan, a key fabricator who sold the concept of fabricator financial support to his colleagues. This evolved into a voluntary levy collected by the steel suppliers. A funding model for Australian fabricators’ activities similar to the SCNZ would be complex and any proposal in this regard needs considerable refining before it could apply to our circumstances.
- Beyond2 in future needs to be driven by those fabricators who have a strong interest in this market.
- The NZ fabricators have used consortiums to bid and secure large projects. This mechanism however is fragile due to the competitive forces amongst the industry. Clusters in the form of a large fabricator subcontracting to a range of second tier are common in times of high volume demand.
- The traditional tender process appears to be more common in NZ than Australia where D&C is predominant. Fabricators favour D&C as they have sufficiently good relationships with the builder to influence the design at the early stage. In this area they are much more advanced than in Australia. Partnering with builders seems to be a common approach with repeat business being the goal.
- Detailer shortage is an issue in NZ which for larger fabricators has been solved by the setting up of their own detailer office or company. Three of the larger fabricators we visited had a large detailer office. It is felt that the continuity of work that they now enjoy, due to the increased building market share, has made this decision possible.
INTRODUCTION

- TMIC conducted research for OneSteel Market Mills (OSMM) in 2002 and 2004. The Australian Steel Institute (ASI) as part of its AUS Industry ‘ICIP’ project, commissioned a third study in 2006. Other parties with an interest in this research include OSMM and The Warren Centre.

Objectives:
- To conduct a current, independent assessment of prevailing building construction perceptions, practices and usage within the industry.
- To conduct, then analyse these before and after ASI promotional activities in this area.
- To directly compare findings to Project Suspend conducted in 2002 and 2004 where applicable.

This report presents the results of Phase 1 of the ASI research project.
MATERIAL USAGE/SPECIFICATION

Who Has the Most Impact On the Choice of Material for Suspended Floors?

The Structural Engineer remains key, in terms of the type of material used/specified for suspended floors. The architect and builder also continue to have considerable impact on the material chosen.

<table>
<thead>
<tr>
<th>Who Has The Most Impact on Choice of Material (Unprompted) Main Mentions*</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Respondent base)</td>
<td>2006</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>(169)</td>
</tr>
<tr>
<td>Architect</td>
<td>29%</td>
</tr>
<tr>
<td>Builder</td>
<td>21%</td>
</tr>
<tr>
<td>Quantity Surveyor</td>
<td>16%</td>
</tr>
<tr>
<td>Project Manager</td>
<td>5%</td>
</tr>
<tr>
<td>Developer</td>
<td>5%</td>
</tr>
</tbody>
</table>

* Multiple response question.

Some respondents chose to comment unprompted. Their comments are presented verbatim below.

It’s a bit of a “bun fight” really, depends who is most pushy at the decision meeting. (001, NSW)
Price is usually the main thing. (014, NSW)
That’s me (Construction Manager). (016, NSW)
It’s a team effort - adjudicator will be the project manager but the construction engineer, construction manager, architects and structural engineer all sit at the table and discuss it. (017, NSW)
The design and project manager usually say what they want and then it goes to HQ financial people to see if it works. (019, NSW)
They (Quantity Surveyor) do the cost and time evaluation. (021, NSW)
Depends on the way the project is procured - it is the person who has the most power and influence - the key people are usually the structural engineer, quantity surveyor, builder. (095, NSW)
All have an impact, but the builder and quantity surveyor have more influence. (155, NSW)
It depends on the type of contract. For a big project it would be builders. For smaller jobs it would be a combination of the architect and structural engineering. (096, QLD)
Because of the functionality and cost driven factors, the architect makes the decision. (098, QLD)
5. MATERIAL USAGE/SPECIFICATION
5.1 Who Has the Most Impact? cont’d

Verbatim comments cont’d:

The builder and the quantity surveyor have input. (100, QLD)

He (Quantity Surveyor) tells us what is going to be the most cost effective. (104, QLD)

Equally builder and quantity surveyor. (102, QLD)

If it’s a design and construction together, the builder would have input, but on the whole it’s already done. (107, QLD)

The client, architect and builder all have input. (108, QLD)

It could be the architect or the engineer: it depends on what material is preferred at the time. (109, QLD)

Both (Builder & Structural Engineer) are equal/have an equal impact. (110, QLD)

The structural engineer probably does but it’s very much impacted by floor to floor heights which could influence the owner and the architect. (112, QLD)

It’s almost impossible to answer - if the structural engineer is involved early enough, he has a large input. (136, QLD)

It’s usually builder driven and with the structural engineer - mainly the builder. (138, QLD)

Architect and structural engineer are 50/50. (139, QLD)

MATERIAL USAGE/SPECIFICATION
Main Materials Used/Specified for Suspended Floors (last 2 years)

<table>
<thead>
<tr>
<th>Material</th>
<th>2006</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Concrete*</td>
<td>42%</td>
<td>47%</td>
</tr>
<tr>
<td>Pre-stressed or Post-tensioned Concrete</td>
<td>18%</td>
<td>30%</td>
</tr>
<tr>
<td>Pre-cast Concrete/ Ultraflor/ Hollowcore</td>
<td>4%</td>
<td>7%</td>
</tr>
<tr>
<td>Structural Steel**</td>
<td>26%</td>
<td>24%</td>
</tr>
</tbody>
</table>

* Includes in-situ concrete
** Includes composite structural steel
*** Question not asked in 2002 survey.

Main Material Concrete:
- 2006: 63%
- 2004: 76%

Note: Condek, Bondek and Kingflor are classified under the construction material they are supported on.
### MATERIAL USAGE/SPECIFICATION

**Reasons for Use/Specification (Apart from Cost)**

<table>
<thead>
<tr>
<th>Top 3 Reasons for Choice of Main Type of Material Used for Suspended Floors (Unprompted)</th>
<th>% of Respondents Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster construction time/time on site</td>
<td>27%</td>
</tr>
<tr>
<td>Common/standard/traditional/familiar</td>
<td>20%</td>
</tr>
<tr>
<td>Easy to build/construct/install</td>
<td>18%</td>
</tr>
<tr>
<td>Thinner slab/thickness of flooring/depth of structure</td>
<td>17%</td>
</tr>
<tr>
<td>Fire-rating compliance</td>
<td>12%</td>
</tr>
<tr>
<td>Short lead time/availability of flooring</td>
<td>12%</td>
</tr>
<tr>
<td>Longer spans/column spacing</td>
<td>10%</td>
</tr>
</tbody>
</table>

* Multiple response question

---

### FACTOR IMPORTANCE AND PERFORMANCE

**Factor Importance Ratings Overall**

- Prompted, the key factors of importance in choosing/specifying which construction materials to use for suspended floors (as in previous surveys) are:
  - Overall cost effectiveness of the floor system/material
  - Safety in the construction process
  - Fire rating compliance
  - Easy to build/construct
  - Less construction time/time on site (speed).
### FACTOR IMPORTANCE AND PERFORMANCE

#### Factor Importance Ratings Overall

<table>
<thead>
<tr>
<th>Factors</th>
<th>Overall Factor Importance</th>
<th>2006 (169)</th>
<th>2004 (152)</th>
<th>2002 (143)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td>Respondent Base</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Overall cost effectiveness of the floor system/material</td>
<td></td>
<td>88</td>
<td>90</td>
<td>87</td>
</tr>
<tr>
<td>2. Safety in the construction process</td>
<td></td>
<td>88</td>
<td>84</td>
<td>76</td>
</tr>
<tr>
<td>3. Fire rating compliance</td>
<td></td>
<td>85</td>
<td>86</td>
<td>84</td>
</tr>
<tr>
<td>4. Easy to build/construct</td>
<td></td>
<td>84</td>
<td>86</td>
<td>82</td>
</tr>
<tr>
<td>5. Less construction time/time on site (speed)</td>
<td></td>
<td>82</td>
<td>87</td>
<td>82</td>
</tr>
<tr>
<td>6. Material durability/long lasting</td>
<td></td>
<td>81</td>
<td>81</td>
<td>79</td>
</tr>
<tr>
<td>7. Depth of floor system/lower floor to floor heights</td>
<td></td>
<td>78</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>8. Minimal floor vibrations (i.e. bounce in floor)</td>
<td></td>
<td>76</td>
<td>78</td>
<td>74</td>
</tr>
<tr>
<td>9. Longer spans giving column free space</td>
<td></td>
<td>75</td>
<td>76</td>
<td>75</td>
</tr>
<tr>
<td>10. Ease of installation of services</td>
<td></td>
<td>73</td>
<td>76</td>
<td>78</td>
</tr>
<tr>
<td>11. Sustainability (1)</td>
<td></td>
<td>72</td>
<td>64</td>
<td>65</td>
</tr>
<tr>
<td>12. Familiarity with the system/material</td>
<td></td>
<td>72</td>
<td>74</td>
<td>72</td>
</tr>
<tr>
<td>13. Short lead time/product availability</td>
<td></td>
<td>70</td>
<td>76</td>
<td>71</td>
</tr>
<tr>
<td>14. Ability to deliver material to sites difficult to access</td>
<td></td>
<td>68</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>15. Flexibility to make changes during construction</td>
<td></td>
<td>65</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>16. Number of workers on site</td>
<td></td>
<td>56</td>
<td>59</td>
<td>51</td>
</tr>
<tr>
<td>17. Minimal neighbourhood disruption</td>
<td></td>
<td>54</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>Mean Imp &amp; Perf Ratings for All Factors</strong></td>
<td></td>
<td>75</td>
<td>77</td>
<td>74</td>
</tr>
</tbody>
</table>

#### 6. FACTOR IMPORTANCE AND PERFORMANCE

#### 6.5 Factor Importance cont’d

**By Value**

<table>
<thead>
<tr>
<th>Importance Ratings by Factor 2006</th>
<th>Overall Importance</th>
<th>Importance Rating by Value</th>
<th>Difference in Importance by Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Respondent base)</td>
<td>(169)</td>
<td>Most Jobs &lt;$5M</td>
<td>Most Jobs &gt;$5M</td>
</tr>
<tr>
<td>Number of workers on site</td>
<td>56</td>
<td>17</td>
<td>62</td>
</tr>
<tr>
<td>Depth of floor system/lower floor to floor heights</td>
<td>78</td>
<td>70</td>
<td>83</td>
</tr>
<tr>
<td>Ability to deliver material to sites difficult to access</td>
<td>68</td>
<td>61</td>
<td>72</td>
</tr>
<tr>
<td>Overall cost effectiveness of the floor system/material</td>
<td>88</td>
<td>82</td>
<td>92</td>
</tr>
<tr>
<td>Minimal neighbourhood disruption</td>
<td>54</td>
<td>50</td>
<td>57</td>
</tr>
<tr>
<td>Less construction time/time on site (speed)</td>
<td>82</td>
<td>79</td>
<td>84</td>
</tr>
<tr>
<td>Short lead time/product availability</td>
<td>70</td>
<td>67</td>
<td>72</td>
</tr>
<tr>
<td>Safety in the construction process</td>
<td>88</td>
<td>86</td>
<td>89</td>
</tr>
<tr>
<td>Fire rating compliance</td>
<td>85</td>
<td>83</td>
<td>86</td>
</tr>
<tr>
<td>Flexibility to make changes during construction</td>
<td>65</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td>Longer spans giving column free space</td>
<td>75</td>
<td>74</td>
<td>76</td>
</tr>
<tr>
<td>Ease of installation of services</td>
<td>73</td>
<td>72</td>
<td>74</td>
</tr>
<tr>
<td>Easy to build/construct</td>
<td>84</td>
<td>83</td>
<td>84</td>
</tr>
<tr>
<td>Sustainability</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Familiarity with the system/material</td>
<td>72</td>
<td>75</td>
<td>71</td>
</tr>
<tr>
<td>Minimal floor vibrations (i.e. bounce in floor)</td>
<td>76</td>
<td>80</td>
<td>74</td>
</tr>
<tr>
<td>Material durability/long lasting</td>
<td>81</td>
<td>85</td>
<td>77</td>
</tr>
<tr>
<td><strong>Mean Importance Score</strong></td>
<td>75</td>
<td>72</td>
<td>76</td>
</tr>
</tbody>
</table>
6. FACTOR IMPORTANCE AND PERFORMANCE
6.2 Material Performance cont’d

- Overall cost effectiveness of the floor system/material (Imp. 88)
- Safety in the construction process (Imp. 88)
- Fire rating compliance (Imp. 85)
- Easy to build/construct (Imp. 84)
- Less construction time/time on site (speed) (Imp. 82)
- Material durability/long lasting (Imp. 81)
- Depth of floor system/lower floor to floor heights (Imp. 78)
- Minimal floor vibrations (ie. bounce in floor) (Imp. 76)

* Includes In-situ Concrete.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Structural Steel is behind...</th>
<th>Structural Steel is ahead...</th>
<th>Structural Steel</th>
<th>Post-tensioned Concrete</th>
<th>Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall cost effectiveness</td>
<td>-21</td>
<td>-12</td>
<td>61</td>
<td>82</td>
<td>73</td>
</tr>
<tr>
<td>Safety in construction process</td>
<td>-3</td>
<td>-12</td>
<td>69</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>Fire rating compliance</td>
<td>-42</td>
<td>-30</td>
<td>49</td>
<td>91</td>
<td>88</td>
</tr>
<tr>
<td>Easy to build/construct</td>
<td>-2</td>
<td>+2</td>
<td>73</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Less construction time</td>
<td>-8</td>
<td>-9</td>
<td>74</td>
<td>67</td>
<td>57</td>
</tr>
<tr>
<td>Material durability/long lasting</td>
<td>-33</td>
<td>-21</td>
<td>72</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>Depth of floor system/lower floor heights</td>
<td>-21</td>
<td>-11</td>
<td>57</td>
<td>68</td>
<td>78</td>
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</table>

n=169 n=33 n=75
### 6. FACTOR IMPORTANCE AND PERFORMANCE

#### 6.2 Material Performance cont'd

<table>
<thead>
<tr>
<th>Factor</th>
<th>Structural Steel is behind...</th>
<th>Structural Steel is ahead...</th>
<th>Post-tensioned Concrete</th>
<th>Reinforced Concrete*</th>
</tr>
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<tbody>
<tr>
<td>Longer spans giving column free space (Imp. 75)</td>
<td></td>
<td>-4</td>
<td>74</td>
<td>78</td>
</tr>
<tr>
<td>Ease of installation of services (Imp. 73)</td>
<td>-12</td>
<td>4</td>
<td>59</td>
<td>71</td>
</tr>
<tr>
<td>Sustainability (Imp. 72)</td>
<td>-10</td>
<td>+13</td>
<td>64</td>
<td>51</td>
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<tr>
<td>Familiarity with the system/material (Imp. 72)</td>
<td>-33</td>
<td>-2</td>
<td>71</td>
<td>81</td>
</tr>
<tr>
<td>Short lead time/product availability (Imp. 70)</td>
<td>-14</td>
<td>-2</td>
<td>52</td>
<td>85</td>
</tr>
<tr>
<td>Ability to deliver material to sites difficult to access (Imp. 68)</td>
<td>-13</td>
<td>2</td>
<td>59</td>
<td>72</td>
</tr>
<tr>
<td>Flexibility to make changes during construction (Imp. 65)</td>
<td>-5</td>
<td>+20</td>
<td>54</td>
<td>68</td>
</tr>
<tr>
<td>Number of workers on site (Imp. 56)</td>
<td></td>
<td></td>
<td>72</td>
<td>52</td>
</tr>
<tr>
<td>Minimal neighbourhood disruption (Imp. 54)</td>
<td>+4</td>
<td>+8</td>
<td>63</td>
<td>59</td>
</tr>
</tbody>
</table>

* Includes In-situ Concrete.

#### 6.3 Structural Steel

**Legend for Action Matrices**

1. Overall cost effectiveness of the floor system/material
2. Safety in the construction process
3. Fire rating compliance
4. Easy to build/construct
5. Less construction time/time on site (speed)
6. Material durability/long lasting
7. Depth of floor system/lower floor to floor heights
8. Minimal floor vibrations (ie. bounce in floor)
9. Longer spans giving column free space
10. Ease of installation of services
11. Sustainability
12. Familiarity with the system/material
13. Short lead time/product availability
14. Ability to deliver material to sites difficult to access
15. Flexibility to make changes during construction
16. Number of workers on site
17. Minimal neighbourhood disruption
6. FACTOR IMPORTANCE AND PERFORMANCE
6.3 Structural Steel cont’d

**Action Matrix Guide**

<table>
<thead>
<tr>
<th>Importance</th>
<th>Performance</th>
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<tbody>
<tr>
<td>0-25</td>
<td>Non Essential No Immediate Action Required</td>
</tr>
<tr>
<td>26-50</td>
<td>Secondary Improvement Area Action Required</td>
</tr>
<tr>
<td>51-75</td>
<td>Key Improvement Area Immediate Action Required</td>
</tr>
<tr>
<td>76-100</td>
<td>Key Performance Area Maintain Performance</td>
</tr>
<tr>
<td></td>
<td>Secondary Performance Area Maintain Performance</td>
</tr>
<tr>
<td></td>
<td>Non Essential Maintain Performance</td>
</tr>
</tbody>
</table>

**Importance vs Performance – Structural Steel Overall 2006**

Areas needing immediate attention are:
1. Overall cost effectiveness of the floor system/material
2. Safety in the construction process
3. Fire rating compliance
4. Easy to build/construct
5. Less construction time/time on site (speed)
6. Material durability/long lasting
7. Depth of floor system/lower floor to floor heights
8. Minimal floor vibrations (ie. bounce in floor)
6. FACTOR IMPORTANCE AND PERFORMANCE
6.3 Structural Steel cont’d

The 5 Key Areas Identified for Immediate Attention (via Action Matrix):

<table>
<thead>
<tr>
<th>Area of concern</th>
<th>Structural Steel is behind competitor performance</th>
<th>Structural Steel is ahead of competitor performance</th>
<th>Action Relative to Competitor Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall cost effectiveness of the floor system/material (Imp. 88)</td>
<td>-21</td>
<td>-12</td>
<td>Area of concern. Performance is below market expectations and competitor performance</td>
</tr>
<tr>
<td>Safety in the construction process (Imp. 88)</td>
<td>-3</td>
<td>-2</td>
<td>Below market expectations but in line with competitor performance - possible area of differentiation</td>
</tr>
<tr>
<td>Fire rating compliance (Imp. 85)</td>
<td>-42</td>
<td>-39</td>
<td>Major area of concern. Performance is significantly below market expectations and competitor performance</td>
</tr>
<tr>
<td>Depth of floor system/floor to floor heights (Imp. 78)</td>
<td>-33</td>
<td>-21</td>
<td>Area of concern. Performance is below market expectations and competitor performance</td>
</tr>
<tr>
<td>Minimal floor vibrations (ie. bounce in floor) (Imp. 76)</td>
<td>-11</td>
<td>-21</td>
<td>Area of concern. Performance is below market expectations and competitor performance</td>
</tr>
</tbody>
</table>

THE AUSTRALIAN STEEL INSTITUTE
Familiarity With ASI (What They Do)

<table>
<thead>
<tr>
<th>Year</th>
<th>Familiarity/Awareness:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>ASI 78%</td>
</tr>
<tr>
<td>2004</td>
<td>ASI 82%</td>
</tr>
<tr>
<td>2002</td>
<td>AISC 77%</td>
</tr>
</tbody>
</table>

(Respondent Base: 169 in 2006)
THE AUSTRALIAN STEEL INSTITUTE
Awareness of ASI Publications/Seminars/Forums

(Respondent Base: 169 in 2006)
* Not asked in previous surveys.

Key Publications/Seminars/Forums Mentioned (Unprompted)
- Seminars (20%)
- E-mailed information/kept informed on what's going on (15%)
- Publications/magazines (10%)
- Forums - welding/tubular steel/fire safety/bolts (10%)
APPENDIX A8 UK STEEL FABRICATION - AN EXTERNAL VIEWPOINT

REPORT ON VISIT TO UK STEEL FABRICATORS

By Brian Mahony
The Warren Centre

Date of visits: Monday July 3, 2006

Places visited: Barrett Steel Pty Ltd, Bradford
Severfield Reeve Ltd, Thirsk

Purpose of report
This report briefly describes the visit by Brian Mahony to the above fabricators.

VISIT TO BARRETT STEEL

A8.1 INTRODUCTION

Company address – Dudley Heights Rd, Bradford
Person visited – Richard Barrett – (Managing Director – Barrett Steel and Steel – Framing the Future Visiting Fellow)

I was met by Mr Barrett in Leeds. The works are in Bradford, about 25 mins from Leeds. The site was developed by the Barrett Family about 140 years ago. The present operation was subject to a management buyout in the early 1990s by members of the family (inter alia). Richard Barrett is now CEO of the fabrication operation while his brother runs the distribution centre.

A8.1.1 ANNUAL THROUGHPUT

Annual throughput varies from 15000-18000tpa of fabricated products.

About 70 per cent is return business on a single select basis.

A8.2 BUSINESS PROCESS

A8.2.1 DESIGN

Barretts does most of its work on a repeat D&C basis, using its in-house staff and designing precisely to the stated loadings. For competitive bids on designs prepared by others, it submits an alternative offer, which is invariably cheaper as it is not as conservative as the tender design.

On award of a job, Barrett Steel prepares a 3D model using X-Steel. This model is used to size members, prepare marking plans, determine geometry, estimate member mass and determine erection sequence (which is then translated into transport sequence).

The model is then transferred to a shop-detailing package, which prepares individual drawings for each member, including connections and weldments.

A8.2.2 STEEL PREPARATION

The current jobs are then merged to produce economies of scale in setting up beam line operations for each section to be fabricated.

The operation is based on a ‘just in time’ basis, with very little steel inventory upstream of the fabrication shop. (This may be due to the proximity of the family distribution centre next door). On receipt, sections are stored on roller tables which feed them through a grit blasting station to the paint shop, where all steel is prime coated.

A8.2.3 FABRICATION

The primed sections proceed to a new beam line, which cuts to length, cope and drills each beam. The beam is then etched with its chief identifiers (Job No, Drg No, Mark No, Mass and Truck No).

A parallel process cuts and drills end plates and other weldments, which are assembled into baskets and delivered to a welding station at the end of the beam line.

The end plates and other small pieces are welded on to the beam.

The beams are then coated with a protective coating before being loaded on to road transport (Midland-based companies can access any part of England in less than 24 hours).

The average transit time of steel in fabrication is less than five days.

Intumescent painting for fire engineering purposes is performed externally.

A8.2.4 NEW BEAM LINE

Barretts has recently commissioned a new beam line from FICEP, a well-known Italian steel technology
supplier. As mentioned earlier, this machine cuts, copes and drills, all from NC tapes derived from the detailing package. As usual, commissioning and staff training were key issues in the implementation of the new line.

**A8.2.5 DISTRIBUTION CENTRE**

Barretts operates one of the largest distribution centres in England from the site with a range of more than 4000 line items, including structural and machining steels. Barretts sources steel worldwide based on quality and price.

**A8.2.6 ROLE OF TWC VISITING FELLOW**

After the plant inspection, I briefly discussed the role of Visiting Fellow, *Steel – Framing the Future* with Richard Barrett. He was very enthusiastic about the position and signed the letter of agreement.

We also discussed typical fabricating costs along the lines developed with John Hainsworth. This was an attempt to quantify savings emanating from a fabricator–driven, D&C, 3D approach.
A8.2.7 PHOTOGRAPHS – BARRETT STEEL

Photo A8.2.7.1  Showing low levels of steel stocks upstream of processing

Photo A8.2.7.2  Showing cleaned and primed steel with identifier
Photo A8.2.7.3  Showing new FICEP beam line at work

Photo A8.2.7.4  Showing etched identifiers on beam
VISIT TO SEVERFIELD REEVE

A8.3.1 BACKGROUND

Severfield-Reeve Structures Ltd is the major steel fabrication plant operated by Severfield Rowen Plc, a UK listed public company.

Severfield Reeve (S-R) is located on an industrial estate at Dalton, near Thirsk, in Yorkshire. It occupies a site of about 20 hectares near a disused airfield, which provides overflow land.

S-R produces about 150,000t of fabricated steel per year with a weekly capacity of more than 3000t. It has just completed a 100,000t order for Heathrow Terminal 5 and enjoys a good reputation as a timely supplier to projects requiring very large tonnages of steel. At the time of my visit the plant was booked to full capacity to April 2007. Like Barretts, S-R enjoys a high percentage of repeat business on a single select basis, I met with John Severs, the ‘founding father’ and CEO of S-R, who showed me around the plant. Mr Severs’ early background was in steel erection. He has grown the company to its present status by a sharp focus on safety, steel handling and in-plant logistics, design optimisation, and by introducing new efficiencies to the fabrication process.

A8.3.2 STEEL FABRICATION PROCESS

A8.3.2.1 DESIGN

On receipt of an order, the S-R in-house design team optimises the design by constructing a 3D model of the structure. At this stage, a decision to build from steel sections or fabricated plate is taken. (D&C projects invariably utilise fabricated plate sections). Like Barretts, the 3D model structure is analysed to provide, inter alia, an erection sequence and hence a fabrication/transport sequence.

The 3D model is not a third-party package, but is a US design package modified by the in-house team. It provides design capability for its FabSec 3-plate sections.

The model outcomes are then transferred in digital form to detailing, procurement, beam line, logistics and other automated processes associated with the job.
A8.3.2.2 PREPARATION

Unlike Barretts, S-R keeps large tonnages of raw steel inventory in external storage. This steel is sourced from worldwide suppliers and not necessarily from Corus. For safety reasons, S-R only uses cranes for steel handing as a last resort – all raw steel is transferred by side-loader from yard to process line. S-R does not prime coat the steel upstream of fabrication.

S-R has solved its process line logistics by the provision of ample storage area upstream of each process station. Steel is transferred between process areas on self-powered, rail-mounted bogies, which provide safe unmanned travel and surge capacity between processes. (The bogies are returned to the start of the line by an ingenious return rail system). Fitments such as base-plates and cleats are transferred on baskets on the bogies with their mating structures.

A8.3.2.3 FABRICATION

There are a number of process lines working on both rolled and fab-plate sections. The speed and automated handling of the processes means that labour input is heading towards five man-hours per tonne. Three-plate beams and columns are assembled for a labour input of about one man-hr/tonne.

Both Barretts and S-R have invested in high-speed drilling technology which speeds up the drilling process. Gang drilling has been replaced by a single CNC drill utilising cobalt-tipped drill bits. I observed a 26mm drill working on 20mm plate. Each hole took about 15 seconds with the eight-hole configuration drilled in just over two minutes. S-R claims to have developed its own plate line technology. Camber is built into the beams by cutting the web plates on the camber profile.

Weld quality is assured at S-R by welding inspectors who regularly check the welding machine performance.

The welding stations, where attachments are welded to major sections, (or major sub-structures assembled) are provided with significant upstream surge to enable upstream workstations to continue working if there is a shortage of welding resources on any shift.

A8.3.2.4 PROTECTION

Completed items are transferred on their bogies to the paint shop where the specified coating is applied. S-R applies intumescent coatings in-house, which improves the value of S-R production. (Up to 600t per week of intumescent coatings can be applied).

A8.3.3 PHOTOGRAPHS – SEVERFIELD REEVE

Photo A8.3.3.1 Showing asymmetrical beam in line
Photo A8.3.3.2 Showing high-speed drill line

Photo A8.3.3.3 Showing three-plate beam line set-up
Photo A8.3.3.4 Showing storage areas between process bays

Photo A8.3.3.5 Showing beam line set-up
A8.4 CONCLUSIONS

A8.4.1 GENERAL

Both the fabricators visited run highly efficient fabricating shops. While the scale of the Barrett operation is equivalent to that of the larger Australian operators, the S-R shop is an order of magnitude greater. Nevertheless, there are common attributes between both companies that are transferable to an Australian context.

These are briefly described below.

A8.4.2 CONTINUOUS INVESTMENT IN BUSINESS IMPROVEMENT

Both companies have attained industry leadership by a process of continuous process improvement, where every aspect of the business is subject to close analysis.

The three main areas common to both companies are:

- Design/fabrication interface
  This area begins with the 3D model and embraces the detailing, procurement, construction planning and production of CNC files for fabrication.

- Logistics
  In both companies, the inter-process steel handling and storage costs are minimised by the use of roller conveyor systems and eliminating where possible, the use of labour intensive and less safe overhead cranes. Careful planning of these areas eliminates production delays due to process bottlenecks.

- Fabrication
  Both companies have been willing to invest in the latest steel fabrication technologies, such as high-speed drill lines, plasma cutting, beam lines and high-capacity welding lines.

The gains from investment in these areas have enabled significant reductions in the labour cost/tonne, which is so important in the competitive European market.

A8.4.3 DESIGN/CONSTRUCT APPROACH

The strength of the organisations lies in the ability to execute the work on a D&C basis in close co-operation with the client. Even fully documented bids are subject to an alternative design offer, which showcases the ability of the design team to further optimise the tender design to produce a low-cost price. The high level of single select return custom demonstrates the effectiveness of this approach.

In many ways, the Design & Construct approach mirrors the emerging finding re D&C of the Steel – Framing the Future project, except that all their team members are sourced inhouse.
APPENDIX A9 BUILDING ASSEMBLIES SCORECARD

RE: SUSTAINABILITY VICTORIA
SUSTAINABILITY FUND PROJECT: THE BUILDING ASSEMBLIES AND MATERIALS SCORECARD

A9.1 OVERVIEW

The Building Assemblies and Materials Scorecard project was created to address a number of challenges including:

- How to create a common basis for assessment and comparison across a growing range of tools and approvals processes.
- How to minimise environmental impacts and optimise the performance of building products and materials over their whole life cycle.
- How to generate increased awareness about the potential for the appropriate use of building materials to reduce the total environmental impact of the construction sector.

The project was initiated by RMIT’s Centre for Design, and supported by a range of organisations (refer further below) in October 2004.

Victoria’s Environment Minister John Thwaites advised the project team of its success in October 2005.

Key milestones are the State of Knowledge report in December 2006, stakeholder engagement early 2007, and project completion by December 2007.

To achieve the identified outcomes the project will:

- Prepare an issues and opportunities report (the State of Knowledge report).
- Undertake stakeholder workshops as part of a needs analysis and stakeholder consultation process.
- Develop an LCA-based scoring methodology for a range of common building assemblies incorporating generic building products.
- Use the developed methodology to score a number of generic building assemblies.
- Assist partners in implementing the scorecard in their respective contexts through training and workshops outlining the scorecard’s approach.

A9.2 SIGNIFICANCE AND UTILITY

This initiative comes at a time when there is growing pressure on the building products sector for information on the environmental impacts of building products. This pressure is from a variety of stakeholders including local governments, rating tool developers, eco-labeling organisations and specifiers. However, there is at present no life cycle-based and broadly supported basis for assessment.

This is leading to a plethora of approaches and increasingly diverse reporting demands. The intention of this project is to provide an opportunity for a broadly supported and science-based methodology to be developed with appropriate stakeholder input.

Across the building products supply chain today there is extensive support for true, life cycle-based assessment tools to enable decision-making. It would appear that any assessment approach for building products should be:

- Performance based with regards to environmental impacts.
- Address the relationship between embodied and operational energy demands of buildings.
- Be based on assemblages (the way materials are used in practice e.g. ‘a brick wall’) rather than simply on ‘materials’ per se (e.g. ‘a brick’) over the anticipated building or element life cycle. This is what the Green Building Materials Scorecard is designed to deliver. Partners and supporters for the project to date include the Green Building Council Australia, the CRC for Construction Innovation, RMIT University, VicUrban, the City of Port Phillip, Moreland and Manningham city councils, Good Environmental Choice Australia, the Victorian Department of Sustainability and Sustainability Victoria.
The built environment (buildings and infrastructure) drives around half of the material flows in the Australian economy. Compared to Australian totals, it is estimated that buildings use 30% of raw materials, 42% of energy and 25% fresh water and are responsible for 40% of atmospheric emissions, 20% of water effluents and 25% of solid waste. The built environment represents the most important value chains for many mineral and metal materials and therefore the most important stewardship challenges and opportunities. This is certainly the case for steel, where residential and commercial buildings alone account for an estimated 33% of steel consumption in Australia, before considering engineering, mining and civil infrastructure.

The industry has a proven track record of improving the life cycle environmental performance of steel materials and buildings through eco-efficient production, recycling and the smart design of building systems using steel.

Energy and Greenhouse Gas intensity of steel production have decreased by an estimated 40% over the past quarter century through persistent improvement and the introduction of continuous casting. Fresh water use has been roughly halved 70% of the main process residues (slags) are sold for use in cement blends and construction aggregates, the remainder stored on site and not sent to landfill. The average recovery rate for scrap steel building materials is around 85%. For structural steel the recovery rate is as high as 95%, which matches world’s best practice. Recovered steel is recycled through the basic oxygen and electric arc steelmaking processes or in some cases re-used directly without remelting.

Innovation in the design of building systems that leverage the special qualities of steel is considered the most fertile area for future advance. Good functional, aesthetic and environmental design can leverage the intrinsic qualities of steel, such as strength to weight ratio, surface coatings, weldability and flexible fabrication/dismantling techniques, as shown in the attached case studies. Extending the useful life and value of materials and buildings greatly improves their life cycle environmental impacts.

In highlighting steel’s potential to contribute to building designs with improved overall life cycle environmental performance, there is no intention to imply that steel is ‘better’ than other building materials, such as timber, concrete, aluminium and so forth. All materials have their distinctive properties and advantages in particular circumstances. Environmental impact comparisons between different materials need to consider the value that is being created, the function that is being fulfilled, the need that is being addressed and the aesthetics for particular applications.

Continuous improvement in eco-efficiency during production, world class recycling rates and product development combined with design flexibility and innovation ensure that steel will continue to make a positive contribution to the life cycle performance of the built environment in Australia.

* Provided by OneSteel
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* Provided by OneSteel

**Lighter structures**
The lighter steel frame for the Latitude @ World Square building in Sydney NSW allowed more floor area to be built for the same structural mass with significantly reduced strengthening costs and building foundation footprint.

**Flexible Upgrading**
Existing steelwork at Chifley Tower, Sydney was modified to accommodate a new and more energy efficient air conditioning system and the addition of internal stairs reduced the reliance on lifts.

**Building on Material Value**
Lighter steel frame at 347 Kent Street, Sydney, allowed 8 levels to be added to the existing 15 level building while still tenanted and functioning with around 1,000 people. Lighter steel frame reduced strengthening requirements by >50%. New floors attract higher rent income, since they have better views.

**Design for Re-Use**
Whole steel structures such as stadium seating may be used for another purpose at another location. A good example is part of the Sydney Aquatic Centre, which was demounted after the Olympics and relocated to WIN Stadium in Wollongong.
A11.1 BACKGROUND

While not flagged in the earlier phases of the Framing the Future Project and deemed to be a root cause of steel’s poor take-up in the multi-storey building sector, sustainability and ‘life-cycle assessment’ has subsequently been identified by all project Issues Groups as a deficiency in steel’s relative value proposition in Australia.

The Warren Centre’s project Steering Committee, having met with the Green Building Council of Australia’s executives, Andrew Morison-Walker of RMIT and Professor Markus Reuter of the University of Melbourne’s Department of Engineering, subsequently approached the author to provide an opinion on sustainability in the Australian construction sector with reference to steel in particular.

The objective of this work is to briefly identify the key potential risks and benefits for steel, drawing on the author’s prior work and international experience. This paper draws only on personal experience, gained from working in the UK and US and no substantive work has been conducted to confirm the validity of these observations for Australia.

A11.2 THE SUSTAINABILITY AGENDA

Climate change leading to extreme weather events, drought and desertification, potential ecological collapse, crop failure and starvation, flooding and inundation of low-lying regions, soil erosion and infertility, progressive real decline in resources especially oil and gas, ozone depletion, acid rain, photochemical smog leading to respiratory disease and unaffordable insurance premiums, the build-up of persistent bio-accumulative toxic chemicals in nature, and increased incidence of asthma in children: These are no longer just the impassioned pleas of the environmental advocates – more and more objective scientific data is being amassed to show that business as usual is no longer a sustainable option for mankind.

The public is now aware of, and attuned to, the need for urgent action to protect the environment, especially for future generations, and to do so in a way that is socially and economically viable. This is the sustainability agenda.

The public is increasingly demanding greener buildings to live and work in, greener materials and products to buy and consume, green and ethical companies to invest in and work for and voting for individuals and administrations that align with environmental ethics, especially at State and local levels of governance. Companies and industries that embrace the environmental ethos, and achieve real and sustained reductions in their environmental impacts are enjoying significant business advantages – attracting investment and staff and increasing their sales. These companies are out-performing their competitors in all walks of business.

Moreover, buildings are the biggest source of damage to the environment and considered to be ‘the 40 per cent sector’ with transport typically ‘the 30 per cent sector’. For a typical commercial building the environmental balance sheet reveals that the buildings’ operational energy and water consumption represents about 60 per cent of impacts, employees’ commuter transport accounts for about 35 per cent whilst the materials used for construction and maintenance over the life account for just 5 per cent of the full life-cycle impacts. In designing buildings, the first priorities for sustainability should be predominantly on reducing energy and water consumption in the operation of buildings with materials considerations being of second order importance.

There is a low level of understanding of materials impacts within the design community and these are often given exaggerated prominence in building design. Moreover materials are often perceived as ‘green’ on the basis of single attributes such as recycled content, low embodied energy or from ‘sustainability managed sources’. When full comprehensive life-cycle environmental impact assessment (LCA) is conducted, unexpected results are often found:

- The recycled material with a higher impact than the primary material because of extra transport burdens (some recycled paper products).
- The perceived high-impact material (like steel) that may be used in modest engineered quantities and can result in a net lower impact than a larger quantity of lower-impact material.
- The high-impact material that has properties that allow it to be used in tiny quantities to perform its function compared with alternative lower-impact materials (thin wall copper tube).
• The initially low-impact product that may then require greater maintenance over its life resulting in a long-term higher impact (some flooring products).
• The low-impact product at installation that has a shorter life resulting in a replacement rate that gives higher lifetime net impacts (some flooring materials).
• The high-impact product that saves energy (high-performance glazing systems) or water (smooth bore PVC pipe – lower pumping energy) over its life and easily recovers the environmental burdens from its use over the life cycle.

As a result well-intentioned initiatives can sometimes promote choices that are less than ideal and sometimes completely wrong for reducing environmental impact. Only a comprehensive ‘life-cycle assessment’ approach can reveal the correct choices, but even full ‘life-cycle assessment’ may not provide the right outcomes if the methodology used and the bases data used to derive the results are not uncompromisingly consistent. Most databases of LCA data used internationally suffer from methodological discontinuities and inconsistency between products coming from different industrial sectors.

A11.3 STEEL IN CONSTRUCTION

Internationally, there are two major drivers for change toward sustainable construction:

National and international policy and regulation:

The Construction Products Directive from the European Commission requires industry action on matters of safety, health and environment. The EC has threatened that too little has been achieved on health and environment and it will regulate if greater industry action is not taken. European industry is now responding vigorously to establish Environmental Product Declarations. Imported products will be expected to demonstrate the same commitments. Some European countries already use LCA data in their regulations or planning requirements (Holland – Ecoquantum).

China has set very stringent targets for greenhouse gas emissions from all sectors of its economy, but especially from buildings (Vice-Minister for Construction – Dr Qao Baosxing). These may soon translate into requirements for construction products. The Chinese tradition is for direct government mandate of rapid change (about 40 per cent of all construction worldwide is predicted to take place in China for the next 20 years).

Market initiatives

The US, Canada and India are aggressively promoting the LEED environmental rating system in a market-led initiative for transformation toward sustainability. USGBC has a program aimed at bringing life-cycle-based credits into the LEED environmental rating system, and India and Canada are expected to follow this lead (about 30 per cent of all construction worldwide is predicted to take place in India for the next 20 years). The impact of the LEED program in the US is dramatic – growing 30-fold in three years.

In Australia, the key driving force for change in the environmental impact of commercial buildings is the Green Building Council of Australia’s Green Star certification system. Green Star assesses buildings and gives credits for a large number of attributes spanning management, energy, water, waste, transport implications, internal health and materials. The materials impacts are not thoroughly assessed with an elementary focus on recycled content, ‘environmentally preferred criteria’ as described by the Good Environmental Choice Australia (GECA) standards and Sustainable Forestry as determined by the Forest Stewardship Council standard.

Most commentators on Green Star consider that steel is favoured by this assessment because of the large (value) proportion of recycled material in steel.

At the same time, the concrete industry portray the benefits of concrete in terms of assessments of material embodied energy – typically 0.8 to 1.5 GJ/tonne for concrete compared with 26 to 35 GJ/tonne for steel (9 to 14 GJ/tonne for EAF recycled steel). However, in buildings, steel is used in much smaller mass for the same structural purpose in a building frame. Studies in the UK for the Steel Construction Institute showed:

• That the mass of steel in a concrete-framed building was only marginally different to the mass of steel used in a steel-framed building (it was actually the floor-slab thickness and construction that made the biggest difference).
• For a range of archetypical buildings, frame choice proved of marginal significance to embodied energy and CO2 and that where the concrete-framed building was lower in embodied energy, the steel-framed building was lower in embodied CO2.
• That the frame contributed only marginally to thermal mass for the buildings (compared with floor slabs), conferring no particular advantage for energy integrated or passive solar design.
In low-rise construction in the UK, light steel framing did not appear to perform as well as timber framing in environmental terms over the life cycle.

**Possible Risks and Benefits for Steel**

The biggest risk for steel is a simplistic approach to its assessment – steel is a fairly high-impact material, but it is used in engineered quantities that optimise the effective use of its physical characteristics. When compared on a full life cycle basis using a consistent methodology, steel products will often prove to be of modest impact compared with their equivalents.

The inherent benefits of steel’s high tensile strength to weight ratio, durability and the ability for it to be comprehensively recycled without degrading its properties reflect in the full life-cycle profile. Its high value as scrap further guarantees its future recyclability.

**A11.4 SUGGESTIONS FOR ACTION**

The steel industry is considered well advised to support initiatives to establish a consistent methodology for the conduct of comprehensive LCA in Australia and to promote the results in support of the use of steel for commercial construction. The Building Products Innovation Council probably provides the best forum for advocating this agenda with the other materials sectors.

A consistent ‘level playing field’ methodology coupled to a national database of life-cycle data would provide a basis for developing practical guidance and tools for designers. The use of such tools and achievement of best practice thresholds of performance would provide a basis for a more rigorous assessment in environmental rating tools such as Green Star, NABERS and BASIX, creating leverage for change in the design of buildings toward sustainability.

Individual product manufacturers would also be recommended to investigate their own processes and products using LCA in order to identify and mitigate any environmental liabilities from their current procedures. Having done so (Corus in the UK found this was highly cost-effective to its production processes), they should then seek environmental accreditation from an independent third party (GECA Ref or BRANZ Ref) and promote the environmental credentials of their products to customers and specifiers. They may also wish to promote their products to specifiers through ‘Ecospecifier’ Ref. Continuous innovation and competition within the Australian market will progressively reduce the environmental impacts of Australian steel products giving a competitive edge to the Australian steel industry over concrete framing, but also for export markets, particularly into Europe, but also into China and India as they also increasingly embrace sustainability.

Such an agenda turns sustainability from a potential threat to the industry into an opportunity for change, for innovation and for increasing the competitiveness of steel. It also prolongs the life of the resources needed to sustain steel production.
APPENDIX A12 TECH UPDATE SURVEY

As part of a Warren Centre study into the use of technology within the structural steelwork industry, we are seeking input from key individuals, companies and advisors. Your participation is requested to enable us to gather a snapshot of 3D software applications and practices currently in use, and to help anticipate indicative future trends in the design, supply and delivery of structural steel. Please consider this an opportunity to showcase the expertise of your company or practices, and do please forward this email for other personnel to respond. Your response will be confidential, and should take you no more than a few minutes to complete your discipline’s appropriate section.

Please fax your completed survey to the Australian Steel Institute: +61 2 9955 5406

Responses from Consultants (40)

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<thead>
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<th>Question</th>
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<td>Do you use 3D software to aid in the design process of steelwork projects?</td>
<td>70%</td>
<td>30%</td>
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<td>Do you use 3D software to aid in the documentation process of steelwork projects?</td>
<td>32.50%</td>
<td>67.50%</td>
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![Software Preference chart](chart.png)
Steel – Framing the Future

If yes...

Do you have a current preference regarding software? 92.40% 7.60%
If so, which software? Please state:

Do you keep the 3D model up to date after ‘design’? 40% 60%
Would you see your firm as maintaining the model to construction completion? 36% 64%
Would you consider passing your model to the fabricator for continued use? 73.10% 26.90%
Would a fabricator’s 3D model assist in the approval of shop drawings? 75% 25%

If yes, how?

Geometry/position/section size 95.20% 4.80%
Reduce RFI documentation 52.40% 47.60%
Early rationalisation/standardisation 33.30% 66.70%
Do you model principle connections? 51.90% 48.10%
Do you include material lists with Tender Documentation? 22.20% 77.80%
Would you make the model universally available to the design team? 71.40% 28.60%

If no...

Would you expect additional fees for this service? 61.50% 38.50%

To allow us to group and interrogate our analysis results effectively, can you please offer some background information -

Size of Organisation - Technical Staff in Australia

- < 10: 44%
- 10 to 25: 25%
- 25 to 75: 8%
- 75 to 150: 10%
- >150: 13%
What % of your projects are currently predominantly steel framed?

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What is your main sector of operation?

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<td>Building (low rise)</td>
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<td>Building (multi storey)</td>
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<tr>
<td>Oil/Gas/Petro</td>
<td>13%</td>
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<tr>
<td>Industrial</td>
<td>23%</td>
</tr>
<tr>
<td>Material/Geometry</td>
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Comments:
APPENDIX B – CASE STUDY DESCRIPTIONS

INTRODUCTION AND SUMMARY OF CASE STUDIES

One of the initial meetings of the ‘Steel-Framing The Future project’ was held in September 2004 to discuss the outcomes of 10 case studies involving the construction of steel framed buildings. The overall outcome of this work is summarised below:

‘Over the past decade, the use of structural steelwork in multi-storey buildings in Australia has declined, particularly when compared with other developed nations such as UK and USA.

This decline manifests itself in a loss of steel skills throughout the value chain from concept through to completed structure.

While this change should be of concern to property owners and developers, as well as contractors and steel value chain members, it needs to be read in the context of the changing world scene of steel producers and their products. Rationalisation is taking place in this industry, with fewer bigger steel producers. New products and steel grades are coming onto the market quicker, providing increased scope for the creation of innovative steel structures.

The Warren Centre’s Steel – Framing the Future project has considered 11 case studies of recent projects from Dubai, Sydney, Melbourne, Adelaide and Brisbane. During the case study phase, an issues round table identified the six principal root causes of the decline in steel usage in this construction sector as:

- Industry Leadership
- Effectiveness of the Value Chain
- Steel Pricing
- Technology Opportunities
- Relative Value Proposition

Key issues emerging from the case studies which have been grouped under the above headings include:

- Lack of committed leadership from the dominant players in the steel value chain
- Decision makers, in the main Developers, know the price of steel but not the value in the overall project chain
- Lack of strong relationships between key players in value chain
- Failure to obtain full cost benefits by making an early commitment to adopt steel

Over the past decade, the use of structural steelwork in multi-storey buildings in Australia has declined, particularly when compared with other developed nations such as UK and USA.

This decline manifests itself in a loss of steel skills throughout the value chain from concept through to completed structure.

While this change should be of concern to property owners and developers, as well as contractors and steel value chain members, it needs to be read in the context of the changing world scene of steel producers and their products. Rationalisation is taking place in this industry, with fewer bigger steel producers. New products and steel grades are coming onto the market quicker, providing increased scope for the creation of innovative steel structures.’

Mr C R Longworth has described the proceedings of these case studies as shown in Appendices B1 to B10 below.
APPENDIX B1: LATITUDE PROJECT AT WORLD SQUARE

Notes from Case Study #1 Presentation by Dr Andy Davids, Hyder Consulting, held on 2 September 2004 at 4.00 pm, McCallum and Cullen Room, Holmes Building, University of Sydney.

LATITUDE PROJECT AT WORLD SQUARE, GEORGE ST, SYDNEY:

HYDER POWERPOINT PRESENTATION BY ANDY DAVIDS

Multiplex (Developer and Main Contractor) / Alfasi (Fabricator) / Hyder (Structural Designer)

History: Leightons over 10 years ago built a 7-storey carpark to ground level on the site, and has been dormant until Multiplex purchased the site and re-developed the initial proposal.

The structural steel-framed building is 55 storey’s high, with over 50,000m2 of office space.

The existing core was originally built to level 14, but the Multiplex aim was to increase the footprint size over the original Leightons proposal.

There was some demolition of existing concrete work, but not all was demolished. The ‘demolish all’ option would have taken 4-5 months, so a decision was made to reduce demolition, and at the same time use the existing core to ‘jumpstart’ building construction and therefore constructing the building on 2 fronts.

Steel beam spans from the concrete core to the building perimeter ranged between 12m and 14m. Columns were concrete-filled steel tubes.

Penetrations to all beams were standardised at 800mm width x 400mm depth, in 3 locations across the length of the beam. NOTE: 610UB’s were adopted with these penetration sizes, rather than a structurally equivalent 460UB with increased stiffening to penetrations, which would have minimised weight. The estimated savings by this approach was believed to be in the order of $10-12M.

3-day floor cycles were routinely achieved on the project.

Beams were cut to length and penetrations to the beams were cut by the distributor prior to delivery to Alfasi. Floor vibrations were a key design consideration and Client Acceptance Criteria. Dynamic testing / acceleration testing has been conducted during construction, and the floors have performed better than expected. Note that mechanical services improve vibration characteristics of steel structures.

For Fire Protection, a fire engineering design process was conducted. The only fire protection for the steel is found on the tension members within the Trussed section of the building. Sprinklers have been adopted throughout.

Columns were 500/600mm diameter steel tubes 6mm thickness, filled with 80/90MPa concrete. Reinforcing steel cages were already installed within steel tubes at time of delivery to site, and the concrete was pumped in from the bottom of the columns, which were 3 levels high. Beam connections were via plates cut through the steel tubes, and the plates were designed to be supported in bearing mode on to the concrete within the tubes.

Andy adopted a number of key design principles from experience gained from an actual building which was set on fire at Cardington in the UK. Beam connections were found to have failed during the cooling phase of the fire, and not the heating phase, so with this, the Latitude Project incorporated 80-90mm length slotted holes for the web side plate connections at the concrete core ends of the beams. Also at Cardington, steel columns were found to have shortened by as much as 150mm in height, and therefore the concrete-filled steel tubes on Latitude have been designed to counteract this effect.

Andy pointed out that 80MPa concrete tends to explode under fire conditions (i.e. the cover blows off). 40-50MPa concrete behaves better than this, although still poorly. (Tristram Carfrae). The steel tubes therefore protect the concrete from fire.

For the truss sections, Bisalloy has been used for the tension members, and concrete filled steel tubes again for the compression members.

Key Lessons as perceived by Andy Davids were:

A strong need to understand the Steel Supply Chain (Knowledge-base arising from steel building structures built in Sydney in the 1970's has been lost to the industry today)

The need to ‘build the structure’ first on paper, i.e. put a lot of thinking into how the connections are going to work upfront.
Demolition of the existing concrete structure was carried out in September ’02.

Target Practical Completion is October ’04, with Contractual Practical Completion by March ’05.

The ‘reality’ of the project with the benefit of hindsight is:

The Jump-start was effectively a ‘fast track’ approach, and would not be a typical means for constructing a building.

The Jump-Start was completed late; Keeping the fabrication ahead of erection proved to be very difficult.

Gross floor cycles of 5 days / typical floor is being achieved, but 4 days (net) is the target. Design and coordination is complete for typical floors, and fabrication is 4-5 floors ahead of steelwork erection.

The Latitude Project is still on target for early completion in October ’04.

KEY ISSUES AND DRIVERS FOR STEEL ON THE LATITUDE PROJECT

Andy Davids believed that ‘Certainty of Completion by due date’ to deliver the building to the tenant (Ernst & Young) was a major driver in the choice of framing material by Multiplex due to the impact of Liquidated Damages.

The Latitude site is surrounded by residential towers, and therefore the ‘Residential Action Committee’ was perceived to be a powerful organisation with the potential to disrupt out-of-hours building activity.

The much reduced workforce required for erecting steel on site (26 actual) was seen to be significantly less than the 120+ which would be required for a concrete framed building. It would also reduce the number of sub-consultants / contractors on site as well.

Peter Wilding (on the Multiplex Board at the time of decision making) said that the ‘Agreement for Lease’ is an extremely powerful document, which the Developer must comply with. On the Latitude Project, the client (Ernst & Young) was clearly an extremely well-informed client who had taken independent engineering advice.

Floor to ceiling heights, (not necessarily floor to floor heights, although this obviously affects the number of floors within the regulated maximum building height), and other external factors including optimisation of the Net Lettable Area and Gross Floor Area may also govern development considerations.

The option for a ‘jump start’, whereby Multiplex could construct the building on 2 fronts.

Peter Wilding also mentioned that prior to project commencement, 2 formworking companies were ‘playing games’ and that Chris Mathews charter at the time was to investigate alternate forms of construction. The decision to proceed with a steel option was also made against the background of recently completing a very successful concrete-framed building at 2 Park Street Sydney.

Andrew Merriell believed that factors against the adoption of steel as a framing alternative were:

- Lead times involved in the coordination of services, shop detailing and fabrication,
- Tolerances against the existing concrete core structure,
- Lack of ‘flexibility’, in terms of the difficulty in transferring large lateral loads,
- Capital Cost, being more expensive than a concrete alternative. Actual costs of $3500/tonne were paid for fabricated and erected structural steel on the project. (Note: This compares with current costs of $4000/tonne at September ’04 (Ken Fazarkerley), and about $1400/tonne for structural steel ex Distributor Andy Davids also mentioned the Sydney City Council requirement for Project and Design Excellence. Delivery of steel to site resulted in significantly less disruption than a concrete-framed structure would have.

KEY GENERAL ISSUES OFFERED BY ATTENDEES

Lead times for steel, compared with speed of erection (Cam Seccombe, Kym Dracopoulos), ‘Uncertainty’ surrounding steel due to reduced experience base (Andrew Ross),

Education of designers to focus less on reducing weight of the structure, and more on reducing final cost of the erected steel. (Ken Fazarkerley),
Inconsistency in member sizes and the lack of standardisation (Ken Fazakerley)

Cost of On-costs associated with Health, Safety and Environment (Ken Fazakerley),

How Contracts are written in Australia with respect to Risk (Ken Fazakerley, Andy Davids),

Labour versus preliminaries (Kym Dracopoulos),

Cost of a steel building versus an equivalent concrete building (Kym Dracopoulos)

C. R (Sandy) Longworth
Chairman

5 September 2004
APPENDIX B 2: BMW BUILDING AND BHP BILLITON BUILDING - MELBOURNE

CASE STUDY NOTES

Case study session No.2, held in MacCallum and Cullen Rooms, Holme Building, University of Sydney at 4.00 pm on 30 September 2004

Presentation by Kylee Unwin, Business Development Manager, Alfasi Steel Constructions Pty Ltd.

BMW Building, 209 Kings Way Melbourne

- 12 storey complex with 45,000 m² NLA including car parking
- Builder/Developer: Multiplex. Engineer: Bonacci Group
- Initial design post stressed concrete band beams with post tensioned slabs
- Alfasi proposed a structural steel and metal deck composite construction as an alternative, using Multiplex's engineers, which Multiplex adopted as their preferred method. This resulted in a project alliance with Multiplex.
- The alternative offer was significantly faster than the previously conforming design, and proved to be cheaper overall contractually.
- The Alfasi contract was fixed price with a fixed contract time. The effective duration was 8 months.
- Alfasi ownership of the alternative design concept was a condition upon which the partnership was able to proceed. The alliance involved interface with the engineer leading to rationalisation of beam sizes and maximisation of repetition.
- Contract scope covered steel supply, fabrication and erection, metal deck supply and erection, stud welding and service core walls, supply & fix reinforcement.
- Erection by Alfasi utilised Multiplex cranes for which Alfasi and Multiplex agreed up-front on the correct crane capacity required to speed up erection and increase flexibility
- Service core reinforced walls consisting of metal deck with reinforcement and shotcrete had fire rating approval but erection program necessitated temporary erection bracing
- A form of jump start was adopted whereby construction moved initially from ground to upper floors, permitting time consuming vehicular ramp construction and other complex work at the ground floor service area to continue in parallel with work above
- Part way through frame erection the client requested an additional 15% floor area. This was achieved by adding a full height bay at the front of the building, and the balance of the structure proceeded while the new works were accelerated to catch up. A level of car park was also converted to office tenancy, requiring an height increase which necessitated stub column extensions.
- While the use of shotcrete and reinforcement in conjunction with metal deck for service core walls was innovative, the builder/developer was of the opinion that the bracing requirement should in the future be fully developed in advance for such a solution. This would avoid some issues that this solution introduces.
- Fittings were added to perimeter beams in the shop for safety handrail standards.
- Steel detailing was completed under Alfasi's contract, by positioning USD in house for the required shop-detailing period.
- This case study is not dissimilar to the ‘Latitude’ project, in that a concrete design was initially adopted, to be subsequently replaced by steel after more detailed construction considerations. Had a decision been made to adopt steel up front, it is possible that completion time could have been further reduced.

QVB – BHP-Billiton Building, Melbourne

- Grocon were the developers for this QV site complex, which included the BHP-Billiton Global Headquarters building.
- A structural steel design was adopted to provide floor flexibility with 18.5 m clear spans.
- Building has 29 floors each with an area of 1,700 m² providing 49,300 NLA, the service core is eccentric.
- Alfasi’s structural steel supply fabrication and erection contract was negotiated with Grocon, as time penalties were significant on this project.
- Foundation problems encountered during basement construction, due to a the presence of very bad site conditions prompted the use of a jump start to first floor enabling advance of the structure, pending catch up of below ground concrete works.
- The building was designed with erection columns for the full height of the structure to enable faster progress by avoiding the need to wait for concrete to be poured before advancing to the next level. Concrete encasement was poured on conjunction with the slab directly above the on grid columns. The temporary columns were built into the permanent construction.
• Construction rate averaged 5 days per floor cycle, the rate of advance being at times restricted by the construction of the concrete core.
• Progress rate at the time was significantly faster than similar size projects in the Melbourne CBD, some of which were subject to industrial disruption.
• The main beams that are supported on the service core all had haunches of similar dimensions for service ducts, thus providing flexibility through standardisation, and adopting a similar philosophy to Latitude Building.

C R (Sandy) Longworth
1 October 2004
CASE STUDY NO 3 – BRISBANE AIRPORT CAR PARK EXTENSIONS

Presentation by Grant Weir . Managing Director, Robert Bird & Partners

1. The initial car park contract was design and construct awarded to Barclay Mowlem, in April 2000, with engineers Robert Bird & Partners. It was of banded post stressed concrete accommodating 1200 cars

2. Initial design concept proposed a 4 level structure with a footprint 52m x 160m. The design proposed and accepted was for a 2 level structure with a footprint 70m x 240m and a 10.35m x 8.6m grid.

3. Structural systems investigated:
   * Structural steel
   * RC flat plate
   * Banded post tensioned concrete

4. No relative projected times of construction for the various alternatives were presented. It is expected that the structural steel would have been the quickest but the difference for this size of structure would be marginal.

5. Critical key drivers quoted by the presenter were:
   * Trade availability, ( concrete availability less risk than steel ?)
   * Contractor familiarity, (contractor more comfortable with concrete media than steel ?)
   * Total cost
   * Life cycle cost

6. Key design savings:
   * More efficient building footprint
   * Fewer piles
   * Less core and façade construction, simpler lift system

7. Incentive:
   * Piling capacity offered for two extra suspended floors

8. In 2004 when a decision was made to expand car park, patronage level prevented access to the two lower floors for back propping, essential for concrete construction.

9. While the engineer considered precast concrete, post tensioned concrete and structural steel solutions for the extension, the only practical solution was structural steel which eliminated need for back propping, enabling use of floors below roof level for parking.

10. Total weight of new construction in structural steel was less and when design adjustments were made for the lower building code car live load requirement the contractor was able to offer an additional parking floor.

   The structural steel construction adopted 530 UB 82 primary beams at 10.3 m centres with 360 UB 51 secondary beams at 2.85 m centres utilising a 120 mm composite slab construction with 1.00mm Condeck lost formwork, all galvanised. The design process utilised an ETABS model

11. Construction details involved simple web cleats and plates in the majority of cases with internal continuous columns and individual column lifts on the perimeter to accommodate cantilever beams. Re-usable temporary bracing was adopted during the construction phase

12. The project structural steel tonnage was 1,900 tonnes and the Condeck 700 tonnes.


14. Not using structural steel here would have resulted in significant disruption to the existing facility with revenue loss and general goodwill implications. This is an example where steel is clearly the best solution.

15. The presenter Grant Weir recorded thanks to Brisbane Airports Corporation and Barclay Mowlem Constructions Limited for permission to make this presentation.

Sandy Longworth
20 November 2004
1. The building was designed in 1990 and constructed in 1991, adopting a structural steel jump start to level 3, with 14 stories of reinforced concrete superstructure.

2. The original design concept at development application stage adopted a concrete frame.

3. A design and construct contract was awarded to Multiplex on a bid basis and the builder retained the original professional team including QS.

4. The engineer investigated four structural systems comprising:
   - Full concrete frame
   - Concrete frame with structural steel jump start to level 3
   - Full structural steel frame
   - Structural steel frame with structural steel jump start to level 3

5. Presenter’s analysis indicated that there was little difference between full concrete frame and concrete frame with structural steel jump start to level 3 which was subsequently adopted.

6. Factors relevant to the comparative design exercise were:
   - The prevailing interest rate of 16.8%
   - Time saving between adopted system & structural steel frame with jump start, i.e. 20 days

7. At the time, the construction of the lift motor room was on the critical path, requiring accelerated construction of the slip form concrete service core, thus enabling a hybrid structural steel motor room to be erected on a full height concrete service core.

8. The confined nature of the site posed craneage problems, necessitating erection of the tower crane support within the public property street access.

9. The presenter tabled two comparative extension cases, one examining the cost of the unchanged design in Sept. 2004 adopting a 6.5% interest rate and the other a trial case utilising an interest rate of 17%. Both cases adopted escalation multipliers applied to construction costs, labour and structural steel.

10. While in 1991 the concrete frame with steel jump start solution was marginally cheaper than the structural steel frame with jump start, the re-appraisal under 2004 conditions and the trial case adopting 17% interest rates demonstrated significant savings by utilising concrete.

11. In summary, with this example a concrete solution was demonstrably more competitive.

12. Discussion took place concerning potential benefits accruing from time savings and it was concluded that with a development building for placing in general letting market, the benefits from early completion would not have materially impacted the result. This was driven by the practice of reducing risk by signing up anchor tenants in advance of construction. Those tenants would not usually be willing to move in early as they would likely have a fixed end date on their original lease.

13. What did appear relevant to the overall project theme was a comment from Ken Fazakerley of National Engineering who said his firm was in the final stages of negotiating an alternative structural steel metal deck solution for a three storey building in Canberra and it was looking as if the structural steel alternative would be preferred on cost and time. This project will be tracked with Ken as a potential case study.

14. It is of interest to note that the case study building, from inception, was planned around a concrete frame. Had a decision been made in 1991 to adopt structural steel with provision made for lay up areas on say structural steel hoardings for steel to be held prior to erection, the project engineering and detailing being commenced before moving onto site and thus reducing site on costs and likely savings in commencing lift motor room earlier, then it would seem, given results presented, that structural steel may have been a competitive solution.

15. In 2004 on the figures presented, given changed conditions, it is most unlikely that structural steel could be considered. However it would be fair to say, in 2004, if structural steel were considered for this building, the design would incorporate current performance based fire engineering, metal deck composite construction with, in all likelihood, prop free construction. This would make the steel solution more competitive than the re-priced 1991 design. It is however difficult to see, with the material presented that, even under these revised design conditions, steel being competitive.
16. The material presented by Kym Dracopoulos illustrates the influence of site specific factors on the optimum solution and very importantly that the scene is constantly changing by virtue of structural steel prices, influence of site labour and emerging increases in formwork costs as well as the influences of the economic climate, in particular interest rates. Such decisions may well be influenced by the builders experience base and the relative availability of sub-contract services at the time.

Sandy Longworth
19 November 2004
APPENDIX B5: SACRIFICIAL FORMWORK FOR STRUCTURAL WALLS

CASE STUDY SESSION NO. 5 HELD AT AUSTRALIAN TECHNOLOGY PARK 4.00 PM 10 MARCH 2005

Sacrificial Formwork for Structural Walls

Presented by David Humphrey and Alex Filonov, Lysaght Technologies

The presentation was made in two parts covering an introduction to the concept and the practical aspects of development, including the manufacture of a prototype panel with peripherals and the laboratory trials as well as field trials of the system in a series of projects. This part was delivered by David Humphrey. Alex Filonov followed, dealing with the physical testing and assessment of the structural system including fire and acoustic evaluation.

Part I

The initial concept centred on the development of a prefabricated sacrificial form panel which could be reinforced and concrete filled in-situ and which could be used as a load bearing party wall for multi-storey residential construction. While the wall component was essentially structural it was developed to have acceptable fire and acoustic rating.

The wall shells as developed, proved to be very light and robust, being easily handled and concrete filled, proving to be much faster to erect than conventional brick or block walls. The handling of materials on site was also simplified compared with bricks and mortar.

Prototype panel development utilised the standard 'Mini-Orb' sinusoidal profile galvanised sheeting, incorporating lightweight studs, all screw assembled. The prototype assembly was automated using a pick and place robot with gantry automated screw assembly. Open internal studs have been used for lightness, ease of flow of concrete, which is plasticised with specified reinforcing bar insertion and location. In practice panels would be factory pre-assembled. Field trials indicated that 2 to 3 men could achieve erection rates of 100 linear metres per day.

Peripherals in the form of end, corner and ‘T’ pieces have also been developed as well as a removable flume, fixed to the top to facilitate concrete filing.

The potential to use these elements in conjunction with steel framed construction for lateral shear strength, service core construction and property division walls has been demonstrated from the construction trials. This will no doubt be part of the development programme for this product. Traditional battens and plasterboard can be applied to shear walls where required giving very good sound insulation.

The presentation included photographic records of aspects of site construction, illustrating the lightweight easy handling of the panel shells, which arrive to site in packs and are manhandled into place, temporary bracing struts attached if required, straight length reinforcing bar inserted, temporary concrete filling flume attached and panel concrete filled with a pumped plasticised mix.

Part II

There are no codes providing guidance for the design and development of this type of product when considered as an element subject to shearing forces, as distinct from the more common forms of axial loading and slenderness.

Alex Filonov presented details of the laboratory testing work, the test rig and test results of the work undertaken to assess the wall element performance. Strain measurements were particularly important in order to assess the element's ductility. Clearly for use, where lateral strength was important, such as in multi-storey buildings, subject to wind and seismic loadings, ductility was very important. The relative ductility of the wall elements is significant in the apportionment of lateral resistance in any integral structure.

Finite element analysis was also undertaken for a variety of load conditions and compared with the physical test results. Destructive tests evaluated performance with various levels of reinforcement. Results indicated that horizontal reinforcement was not all that critical.

Acoustic testing has been undertaken at Rintoul Laboratories and fire testing at Melbourne University as well as finite element fire element modelling. Both series of tests gave compliant performance results for the intended use.

The BlueScope Lysaght system developed embodies discontinuous construction incorporating proprietary acoustic fixing clips.

The BCA 2004 code introduced the adoption factor Ctr for most building elements which requires an airborne sound insulation rating. Acoustic testing for shear wall systems has taken into account the Ctr factor.
<table>
<thead>
<tr>
<th>Walls between dwellings</th>
<th>Supersedes BCA Requirements</th>
<th>Current Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne Sound Insulation</td>
<td>Rw not less than 45</td>
<td>Rw + Ctr not less than 50</td>
</tr>
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<table>
<thead>
<tr>
<th>Walls between utility rooms &amp; habitable rooms in an adjoining dwelling</th>
<th>Airborne Sound Insulation</th>
<th>Impact Sound Insulation</th>
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</thead>
<tbody>
<tr>
<td>Deemed to comply or discontinuous construction, or be no less resistant to transmission of impact sound than deemed to comply solutions</td>
<td>Airborne Sound Insulation, must be of discontinuous construction</td>
<td></td>
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Sandy Longworth
The Warren Centre
8 April 2005
**APPENDIX B6: RHODES PROJECT - SYDNEY**

**CASE STUDY SESSION NO. 6, HELD AT AUSTRALIAN TECHNOLOGY PARK**

**4.00 PM  10 MARCH 2005**

Rhodes Project – Sydney

Presented by Bill Gunther project engineer Van der Meer Consulting

**Introduction**

Developer Walker Corporation, builder Walker Constructions.

The project commenced in 2003 and is nearing completion, having been constructed in stages. It is of 4 to 11 storeys providing commercial and retail space and is over 400m in length, with parking for 2000 cars. Approximately 7,500 tonnes of structural steelwork were used in the construction.

Construction is primarily steel framed, laterally braced as necessary, with composite deck flooring utilising 130 to 156mm trapezoidal decking. Deck spans are mainly 3.4m incorporating 25 and 40 MPa concrete. Steel trusses of spans up to 35m have been used in selected areas.

The complex was fire engineered, resulting in the adoption of bare steelwork with sprinklers throughout. Vibration analysis formed part of the design process.

**Fabrication**

There was close involvement between the fabricator, National Engineering, the steel supplier, OneSteel and the Builder. The close liaison between these three groups enabled a lot of the repetitive steelwork to be provided by supplier, cut to length and predrilled, thus simplifying the value chain and reducing costs. Erection was not carried out by the fabricator.

Program revisions caused by tenant leasing delays and changes resulted in the introduction of additional steel fabrication services in order to complete this phase of the project. The project has also been constructed during a period of abnormal steel price increases.

**Fire Engineering**

A fire engineer was appointed at the project inception and worked closely with the developer, steel supplier, fabricator and engineer.

**Advantages of structural steel**

- design flexibility
- versatile material
- ability to handle large spans
- more adaptable for site changes
- speed of erection

**Disadvantages of structural steel**

- requirement to freeze design early
- difficulty with mixed developments, floor loadings, floor levels
- composite design resulting in thin slabs caused difficulties with equipment fixings and concentrated loads
- demands well organised developer/builder/design team if full benefits are to be realised, poor organization invariably results in onerous overruns in cost and time.

**Architect's & engineer's opinion on use of steel for project**

- reliable structure, with flexibility
- requirement to complete all aspects of engineering well in advance to achieve full benefits, which highlights need for well organised service provider skills. There is no margin for learning once the project is rolling.
requirement for early development of mechanical services to avoid costly structural changes and delays

Builder’s / Contractor’s opinion on use of structural steel

- changes require greater co-ordination of trades and sub-contractors
- management of information flow
- variation costs can be significant and difficult to manage

QUESTIONS & COMMENTS

Pricing

Q   how was this handled?

A   developer did all pricing, standard designs were prepared for various area types eg commercial, retail supermarket etc., with material quantities, structural steel input data provided by steel supplier and fabricator, other trades co-ordinated by developer.

Q   what presented greatest difficulty?

A   primarily the delays on part of developer organization in finalising tenant leasing arrangements, in particular for retail space, particularly supermarket areas where set downs were required for refrigeration equipment and compactus facilities for major office tenants, evident that major tenants dictate changes and must be locked in early in project and not along the way

Q   was the fire engineering well co-ordinated

A   yes, assessment was completed early in the project, changes in this discipline were minimal possibly helped by the use of sprinklers throughout the complex

Q   what other problems were there?

A   while there was a lot of repetition and standardisation, there was a need for a ‘learning factor’ on the engineer’s part, code deficiencies were also identified in relation to the use of composite metal deck structures.

Q   was it apparent that there was any economic advantage in adopting codes other than Australian standards for any aspect of the design?

A   no clear advantage was evident

GENERAL COMMENTS IN DISCUSSION

From discussion it became evident that while it was intended to use one fabricator for the project, there were in fact three engaged. No reasons were advanced for this, other than delays and disruption to the contract program. The principal fabricator had in all likelihood to re-schedule his work program with other jobs, to accommodate site interruptions at Rhodes.

Questions and discussion were asked regarding the detailing service and the use and effectiveness of 3D models. There were numerous steel detailers used on the project, presumably to meet the work flow requirement. Burnside drafting produced a 3D model and presumably updated this model for changes. Whether this model was available to all contractors and subcontractors was not established and there was no indication whether it was used for steel erection scheduling.

Volatility of steel prices was mentioned by the presenter as a major issue as were project changes and poor management of these changes. While the presenter’s records did not address the costs of changes and alterations, he ventured an opinion that he felt these could be of the order of 20% of the structural cost.

While not stated by the presenter it would appear that an essential requirement, on the part of the developer, for mixed developments of this type, is to lock in critical tenants and fix their requirements before completing design and issuing workshop drawings. While this is not a steel value chain problem it is very relevant to any developer contemplating adopting structural steel framing.

Sandy Longworth
15 March 2005
APPENDIX B7: FLINDERS LINK - ADELAIDE

CASE STUDY SESSION NO.7 HELD AT CHIFFLEY HOTEL, SOUTH TERRACE ADELAIDE AT 4.00 PM ON 17 MARCH 2005

Finders Link Development presented by Greg Zafiridis, Associate Wallbridge Gilbert, Consulting Engineers.

General Details

This project is a multi-storey mixed development planned for 5 stages which include residential, car parking for 700 cars and office space. The presentation covers stages 2 and 5 covering the car park and office areas respectively. Construction is currently in progress.

Construction is steel framed with composite metal deck utilising in excess of 1,600 tonnes of steelwork, with a site area coverage of 6,600 m².

Presentation

The car park module was designed initially with an adjoining apartment building. Its’ height was limited to 25m and ample cross flow ventilation was provided. These two design decisions resulted in a building that did not require sprinklers or mechanical ventilation.

When the office project became a reality, a complete structural steel solution for an integrated car park and office was a preferred option. The structural requirements relating to fire needed to be understood for this integrated building. Ian Bennetts from the Victorian University of Technology was commissioned by OneSteel to carry out a Fire Engineering Assessment.

Fire engineering evaluation demonstrated that car park columns (concrete filled 400x300x12.5 RHS and 300x300x10 SHS) and beams were acceptable with an FRL 60 min. OneSteel’s Fire Design Note 3, Sept 2002 was the basis for the column design. The car park columns also supported two floors of office space located above the 8 storey car park.

The office building adopted 508x10 CHS reinforced concrete filled elements. Corus Tubes ‘Design Guide for Concrete Filled Columns’ was the basis for the office column design providing an FRL120 min.

Using the Cardington UK test as a reference only, selected office floor beams required FRL 60 min. These beams were all primary and grid line secondary beams. Assessment dictated that they be painted with one coat of intumescent paint which provided 60 minutes protection.

Discussion

It was the presenter’s view that the Fire Engineering Assessment resulted in a cost effective, versatile structural steel solution which was simple to fabricate.

The QS, Currie Brown reported that they worked closely with developer and engineer in the design phase. Steel estimates have subsequently proved reliable being marginally below budget.

No cost data was provided on the water based intumescent paint, provided for passive fire resistance of beams, other than it was expensive. One coat achieved an FRL 60min and two coats FRL 90min. The painting was undertaken after erection and included connections.

Detailing was undertaken by a number of offices utilising different software.

Recorders Comment

The presenter gave a good explanation of trade off’s for additional rentable floor area versus deeper working zone for the steel structure, slab and M & E services.

A more liberal working zone, for a given building height, results in loss of rentable area but does provide greater flexibility for future refurbishment. The alternative is to adopt some form of post tensioned floor system (flat plate or band beams) thus losing the advantages of the steel construction.

Sandy Longworth
Warren Centre
9 April 2005
APPENDIX B8 : 50 LONSDALE ST - MELBOURNE

Case Study 8: 50 Lonsdale Street Melbourne, Office Complex (In advanced construction)

Presented By: Peter Chancellor – Senior Associate, Connell Mott MacDonald

Developer ISPT, Builder Multiplex, Structural Engineer Connell Mott MacDonald, fabricator GFC, Detailer Straightline Drafting, QS Rider Hunt, Fire Engineering Norman Disney Young and Dr Ian Bennetts Victorian University of Technology

General Project Details

Project cost $200 million, 5 basement levels, 34 levels above ground, steel frame composite construction with metal deck, prop free construction, offset core, basement and podium area post stressed concrete construction, floor plate area 1,900 m2.

Presentation

The presenter gave details of a number of major projects undertaken by Connell Mott MacDonald in last 15 years utilising steel, to support his view that 50% of the most recent large city projects in Melbourne were framed in steel.

Projects illustrated were VRC Flemington, Crown Casino, Telstra Dome and Melbourne Central.

Developer’s Builder’s design criteria

- Simplicity
- Emphasis on repetition
- Ease of construction
- Speed
- Preference for off site construction
- Reduction in site trades and labour

Initial project evaluation and costing addressed both concrete (PT) and steel solutions. Both were costed by quantity surveyors Rider Hunt and engineering designs provided for tendering purposes for both steel and concrete options. This was a novation tender. Multiplex were the successful builders and they elected to adopt the structural steel solution.

In making the decision to use steel the builder said that steel presented less risk to the program, with a significant reduction in site labour. The contract time saving was estimated at two months and there were reduced column and footing sizes. It was noted that the alternative designs for steel and concrete adopted similar floor to floor heights of 3.95m and also adopted the same vertical interval for accommodating services. There was therefore no variation in services costs for the alternative structural designs. It was also noted that the steel solution required one additional crane on site and during the project implementation phase there has been a 20% increase in steel prices, which has to be compared with formwork and re-bar increases for a concrete solution.

While details were not presented, other than those stated, it was understood that the builder favoured steel from project inception which was also the case with the Southern Cross project and was satisfied that all factors had been taken into account.

The project grid was 9mx12m, with a central spine beam. The floor plate not being rectangular necessitated a bay of varying span secondary beams, having one support on the central concrete core. Beams were generally 700, 610 and 530 UB sections with imported tubular steel perimeter and square steel internal composite design columns, involving innovative splice details. Floor slabs were 120mm with designated areas strengthened for compactus loading.

A jump start was adopted, enabling construction to progress to level 15. Steel framing extended from the ground level but most columns in podium and below were reinforced concrete, formed around permanent erection columns. A solution, adopting mini steel construction columns throughout the project, was considered but discarded.

The building is fire engineered. Critical beams and connections are fire protected.

Discussion

1. Much of the discussion subjects raised in the previous Southern Cross presentation were relevant to this project, particularly as the builder was common to both projects.

2. Chairman raised a question regarding the engineering firm’s or project team’s cultural differences relating to steel and concrete projects. Presenter said he felt there was no bias when it came to producing and evaluating steel versus...
concrete designs With this project, there had to be pre-ordering, with long lead items, particularly anything imported. There was pre-ordering of jump start columns before documentation. There was therefore a strong leaning towards a steel solution, even though a reversion to concrete could have been made at this stage.

3. The presenter stated that the builder Multiplex wanted to use steel unless there were reasons negating such a decision.

4. Chairman asked about use of a 3D model, which was developed for the podium area by detailer, Straightline Drafting, for common use by the construction team. Questioner asked if a model was produced for the entire project? Presenter said he believed the only model was the one for the podium area.

5. The question of concrete versus steel design alternatives was raised by Bill Brezner who questioned whether there would be a bias if one project team produced both steel and concrete alternatives. The presenter said there was one overall project director but different engineers were used on the various design alternatives.

6. Chairman raised general matter of project information flow and data handling on project. Response was that the ‘Team Binder’ system used by Multiplex proved effective, however most shop drawings were still hard copies.

7. Final comment from presenter was that the project was running very well. The steel fabrication had run smoothly with good interface with the detailer.

Recorder’s Summary

- An appropriate use of steel, particularly optimising the use of jump start.
- Innovative composite column solutions
- While the steel contract was not awarded until relatively late in the program, steel estimating appears to have reflected reliably the changing cost scene
- Comparatively the 50 Lonsdale steel solution appears more complex than Southern Cross project, primarily with respect to beam notchings and penetrations which add markedly to fabrication costs. This is thought to be due principally to the non regular footprint and absence of clear spans.

Sandy Longworth
25 April 2005
APPENDIX B9 : SOUTHERN CROSS OFFICE COMPLEX - MELBOURNE

Case Study Session No. 9, held at Melbourne University Business School Leicester Street Carlton at 4.00 pm 11 April 2005

Project: Southern Cross Office Complex, cnr Bourke & Exhibition Streets Melbourne (under construction)

Presented by Lou Piovesan – Director Bonacci Group Melbourne

Developer/Builder Multiplex, Structural Engineer Bonacci Group, Fabricator/Erector GVP

General Project Details & Statistics

Eastern Tower which is the subject of this presentation is 40 levels, West Tower 21 levels.

Contract D&C valued at $275 million, comprising 6,500 tonnes structural steel, 40,000 m3 concrete, capacity 7,400 occupants, 30 lifts.

Floors 2 to 4 non-typical, levels 5 to 39 repeat, central core slip formed concrete.

Construction of the basement area up to ground floor level adopted band beams and in-situ slabs. This gave enough time in the program for selected steel section procurement ex-Europe, delivery and fabrication of structural steel.

Presentation

Developers design criteria:

- Simplicity of design
- Column free space
- Maximise repetition
- Ease of construction
- Minimum site trades and workforce
- Speed of construction
- Preference for structural steel

Developer having demonstrable experience with steel construction had a strong leaning towards this medium from inception. At the time formwork prices were increasing and the industrial climate in Melbourne favoured off site fabrication.

Stuart Rossiter, Director Bonacci Group, headed the design team at the engineering conceptual stage.

The design exhibits simplicity, typified by a regular grid, 15m clear spans on a 16mx9m grid with 'Condek' metal deck floor, permitting prop free construction with a construction cycle of 8 days per floor.

Beam sizes were standardised using 610 UB’s and 530 UB’s. Slabs were generally 120mm, thickened where necessary for isolated heavier loadings. Connections of primary beams to columns were end bearing and secondary beams to core were web connections.

Services were accommodated in the 1m zone, floor to floor height being 4m, using notches in some beams at core wall junctions and some web penetrations which were stiffened. Columns were fabricated from custom made 460 grade sections imported from Germany.

Fire engineering was undertaken by Lincoln Scott and Phillip Chundel Associates and adopted a fire spray on columns up to the underside of primary beams for passive protection. There was some fire spraying of isolated trimmer beams.

The curtain wall system was fixed to the structural steel by welding using a channel section along perimeter. As this was cantilevering a prototype section was constructed in the shop to verify design.

The mechanical engineers Lincoln Scott did not fully detail services, leaving this to the sub-contractor.

Areas for Improvement

While basic steel design was completed without any reference to fabricator, it was felt that there were benefits to be gained by resolution of curtain wall types and details early in the program to facilitate engineering and detailing of the interface.

While the detailing and fabrication ran smoothly, there seemed to be a reluctance to lock in the fabricator early which would have enabled more interaction with engineer regarding preferred details such as frequency of column splices and preferences for deck configuration and construction. As it happened the interaction between fabricator and engineer concentrated on material supply and preferences in addition to changes. The fabrication contract was a fixed lump sum

Mention was made of the need to lock in special tenant requirements as early as possible, where these impact
on structure, such as special loadings and openings, the effect on fabrication flow being critical. Some decisions for changes came very late for the fabricator.

Discussion

1. The matter of adequate lead time for the fabricator was raised given the varied sourcing of steel materials. While this was a critical factor sufficient time was available and once the shop got into production the program generally kept 5 levels ahead of site.

2. Vibration evaluation was raised, given the clear spans and the extent to which cantilevers mitigated these transients and the measurements taken after erection. Presenter said all vibration frequencies were checked using Murray’s paper and Australian Steel Standard. Discussion ensued indicating potential problems with increasing spans, it being mentioned that final prediction was difficult as there were damping factors from furniture and general office contents.

3. During discussion the presenter said differential shortening between the steel columns and concrete core required a 2mm allowance per floor.

4. To what extent 3D models were used was raised. Plant design, shop detailers for the project prepared a 3D model, which was widely used by the steel, team i.e. fabricator, detailer, engineer and builder. There was a noticeable reduction of transfer of hard copy detail drawing information, much of the approval process being undertaken on line through a central project data base. A feature of the project was the electronic data base and information flow.

5. Passive fire resistance was raised with respect to the lighter secondary beams which were not treated. This prompted further discussion by Ben Ferguson of NDY, concerning the catenary floor behaviour under fire, the stiffness of the columns and the capacity of the floor system to hang off the columns thus reducing dependence of beams for structural integrity.

6. The question of imported steel was raised and the extent to which it was thought this would play an increasing role in the fabricated steel sector in Australia. Response was that it worked for column sections with this project, given the project lead time and could be done again if cost and timing appropriate. While beam sections were locally sourced many of these were provided cut to length and pre-drilled where appropriate, indicating further outsourcing of the value chain.

7. Cost estimating for project structural steel work was discussed. A spokesperson Chris Robinson, from Rider Hunt quantity surveyors advising Multiplex, said project estimates were prepared using selected imported sections and the prices locked in. To what extent other locally sourced basic steel section prices were locked in was not recorded other than the finished steel frame cost was within the project commitment budget. It was mentioned by QS that concrete columns were cheaper than steel but the size was excessive given the column free feature of the building.

8. Frank Bortoletto from Grocon queried floor finish criteria with respect to deflections in view of spans. Pre-cambers were used and there does not appear to be a need for any remedial work in this respect.

9. A final question was raised regarding co-ordination of the M&E services with structural steel frame. In general the basic principle of the beam notches for duct access seemed to have worked but there were some changes required early in the contract.

10. The presenter, in conclusion stated, that he would adopt a steel solution again given the same criteria.

Recorder’s Summary

- The early commitment of the Developer/Builder to steel is a significant plus for the project
- The design criteria, in particular simplicity, connections and column layout in particular were very good
- Detailing, 3D modelling and electronic information flow appear to have worked well for project and value chain efficiency
- Estimating by QS, on bottom up basis providing for imported steel has been reliable
- The project is an appropriate use of steel, producing column free efficient use of space, with possibly the quickest construction time.

Sandy Longworth
16 May 2005
APPENDIX B10: ADELAIDE AIRPORT - NEW TERMINAL

Case Study Session No. 10 held at Chifley Hotel, South Terrace Adelaide at
4.00 pm 17 March 2005

Adelaide Airport - New Terminal

Presented by Nick Lelos – Partner Wallbridge Gilbert, Consulting Engineers

Project Statistics

4,000 tonnes of structural steelwork, 46 km purlins and girts and 55,000 m² of suspended slabs, D&C contract.

Design of the project commenced in Feb 1999 but was put on hold following the Ansett collapse and re-commenced March 2003 with construction starting in December 2003 and scheduled completion October 2005.

Design alternatives for the complex were considered comprising:

- Structural steel frame with metal deck, suspended slab composite system
- Conventional concrete frame
- Post tensioned slabs and beams
- Stressed plank floor system supported by post stressed concrete or steel beams

Factors influencing selection of structural system were, fire engineering which confirmed use of sprinkler systems throughout without passive fire protection and the need for versatility given the nature of the complex.

Structural steel with composite metal deck construction was adopted on the grounds of speed of construction, design flexibility and ease of making future changes over the life of the facility.

While trusses were required in the baggage handling area, general construction details were 9.6m centres for primary beams with secondaries at 3.2m centres, adopting 130mm slabs. Beams were temporarily propped prior to slab pouring.

The roof system adopted 30m steel trusses over the retail area and as mentioned the floor to the retail area above the baggage handling hall was supported on a truss system.

Structural steel roof beams were also used supported on pin ended columns. These beams worked as chords for a horizontal bracing system, which distributed loads to shear walls.

The steelwork was tendered by the builders Hansen & Yunken in 3 packages, one package for the main building and two packages for the concourse structures. 3D modelling was adopted by both steel fabricators.

Information arising from discussion

- While 3D modelling was adopted, it appears that this was used principally by the detailers for co-ordination and control of their work.
- Two different modelling programs were used by steel detailers namely X-steel and AutoCAD.
- A number of detailers from outside South Australia were used on the project to maintain the fabricating schedule with X-steel, AutoCAD and BoCad systems used by detailers. This would appear to indicate that the 3D model was not used by the contracting team as widely as would be expected.
- Shop drawings were used exclusively for approval purposes. It does not appear that use was made of the 3D model to verify member sizes and connection details, thus reducing paper flow.
- Engineer reported that contact with fabricators was not made until design well developed
- A QS was engaged for the project. How the QS’s initial structural steel estimates compared with completed cost was not established during the session.
- The QS outlined the costing approach, namely to categorise the various forms of construction. Tonnage rates per unit area were then applied for estimating. The QS stated that the rates adopted were arrived at after consultation with steel fabricators.. This procedure was presumably executed before awarding contracts to fabricators.

Comments from meeting inferred that escalation in steel prices occurred during the contract.

- The steel contractor undertook erection and stud welding.
- While M&E was relatively straight forward, the contract was awarded late in the program, resulting in some steelwork alterations to accommodate openings in beams.
- The majority of the steelwork was pre-painted to a high level of finish which required double handling.
• Presenter commented that there is not adequate code coverage for composite construction.
• Australian painting codes are not in keeping with overseas standards.

Sandy Longworth
Warren Centre
9 April 2005
APPENDIX C
PROJECT AUTHORS

David Ansley
David has contributed to the project as a key member of the Steel – Framing the Future management team. He holds a Bachelor of Applied Science (Civil Engineering) degree from Queen’s University in Canada and a Master of Business Administration from IMD in Switzerland. His career began in engineering projects in design, construction and project management capacities before he co-founded a manufacturing company and served as executive director throughout its formation, initial public offering and the establishment of operations plants in Australia. David went on to join Accenture where he progressed from Strategy and Supply Chain Senior Manager to Associate Partner, where his work involved providing direction to major international companies in gaining greater shareholder value. He began a private practice in 2002 in management consulting, where he specialises in aspects relating to the commercialisation of new technology and supply chain, marketing and operational strategy and execution.

Richard Barrett
To his role as The Warren Centre’s Steel – Framing the Future project visiting fellow, Richard brought considerable insight as Managing Director of Barrett Steel Buildings, one of the UK’s largest steelwork contractors specialising in Design and Build projects. He is also a Director of Barrett Steel, the UK’s largest independent steel stockholding company. Following the completion of his education in engineering at the University of Cambridge in 1978, Richard worked in the structural design office of the family engineering business Henry Barrett & Sons Ltd, becoming Technical Director in 1985. He then served as Managing Director of the Steel Buildings Division of Henry Barrett Group Plc, a stockmarket-listed engineering group formed from the family company. Aside from his directorships at Barrett Steel, Richard is currently Deputy President of the British Constructional Steelwork Association (BCSA) and Chairman of the BCSA’s National Steelwork Contractors Group, which comprises the 15 largest member companies.

Ian Bennetts
Ian is a civil and fire-safety engineer with experience in the behaviour of steel, composite and concrete structures under ambient and fire conditions. He also has experience in risk assessment and in all aspects of fire-safety engineering. He contributes to the postgraduate diploma course at Victoria University and has close links with the university.

Prior to joining Noel Arnold & Associates, Ian was a Professorial Fellow at the Centre for Environmental Safety and Risk Engineering at Victoria University, Melbourne, where he was involved in the teaching of fire-engineering subjects for the postgraduate certificate and diploma courses as well as supervising and undertaking research in a number of areas – the behaviour of structures in fire, modelling of fires, reliability of sprinkler systems, fire safety of shopping centres, effectiveness of stair pressurisation systems – as well as setting up a test rig for the testing of fire fighting foams at VU’s Fiskville test facility.

Before joining Victoria University in 1999, Ian spent 19 years at BHP Melbourne Research Laboratories reaching the position of Senior Research Associate and becoming responsible for structural engineering and fire research at these laboratories. He was also a NATA signatory for heat and temperature measurement and mechanical testing. During that time Ian contributed to Fire Code Reform Centre Projects, leading Project 6 ‘Fire Safety of Shopping Centres’ and being involved in aspects of Project 2 (materials) and Project 3 (fire resistance). He was also involved in research and testing relating to the fire safety of carparks, office buildings and elements providing support to other elements. The outcomes from this research and testing resulted in significant changes to deemed-to-satisfy provisions of the Building Code of Australia. He has published more than 120 research papers and reports and has made contributions to numerous books including Risk Analysis in Building Fire Safety Engineering by Hasofer, Beck and Bennetts and published by Elsevier in November 2006.
Peter Farley

Peter’s first job was at Williamstown Dockyard where he was involved in preparation of plans and specifications for a major re-equipment program for the yard, where technologies included everything from UHF radio to heavy fabrication and machining.

From there he went to CIG Cutting Systems where he led the development of new products, which resulted in a tripling of sales volumes over three years. After a short time with ANCA he moved to manufacturing management at Stegbar. In 14 months, output increased 40 per cent with a reduced wage bill after a new workplace agreement (20 years before EBAs) and a minor investment in some new equipment and simplifying processes.

After two years as Manufacturing Manager with Tyree Transformers in Melbourne he formed Farley Manufacturing Pty Ltd, which developed and sold advanced technology plate and sheet-cutting machines for everything from air-conditioning ducts to earthmovers and ships. Farley Manufacturing and its successors export more than 70 per cent of their production and have won orders in Europe, the US and Asia, often at premiums up to 40 per cent over the leading German and Japanese firms.

Among the numerous awards he has received are the Prince Philip Prize for Industrial Design and the AGM Mitchell Medal for service to the profession of engineering.

Over the past 33 years Peter has been involved in finding, developing and applying advanced technologies in manufacturing. For the past five years he has been successfully consulting to companies in the US, UK, Turkey & Australia.

Ben Ferguson

Ben holds a Bachelor of Engineering (Mechanical) from Monash University and is registered as a fire safety engineer. Ben holds more than eight years of experience in fire safety design, during which he has worked in regulatory, consulting and design capacities both in Australia and the UK. His project experience covers a considerable and comprehensive range of building types including hotels, transport infrastructure, government and defence installations, low- and high-rise retail and commercial, collective housing, heritage and healthcare. Ben is currently engaged as Manager of Fire Safety Engineering in Norman Disney & Young’s Melbourne office.

Michael Gallagher

Michael’s professional life began as a surveyor, working on projects in Australia and New Guinea. He then completed a Civil Engineering Degree, during which he continued to lend his surveying expertise in tutoring and locum work capacities. In 1975 he began as a design engineer with Longworth and McKenzie Consulting Engineers, where he was engaged with industrial structural design projects at Port Kembla and in Sydney. From 1976 he worked for Civil and Civic (now Lend Lease) as a Project Manager before being appointed Project Director. He led the Lend Lease Development group responsible for the winning bid in the high-profile, commercial high-rise Darling Park project, where he served as Project Director for Stage 1, which involved negotiating the pivotal IBM lease. In 1997 he managed the SOCOG Olympic Overlay program, comprising the implementation of all temporary Olympic infrastructure in Sydney. Since establishing MA Gallagher Holdings in 2001, Michael has been involved in offering consulting services to companies in the fields of property and infrastructure as well as specialising in event industry services.

Trevor Gore

Trevor’s primary realm of expertise lies in technological business strategy, with consulting experience in process management and aspects relating to the commercialisation of new technology. He began his career with global consulting firm Accenture, followed by positions with engineering consulting and
manufacturing businesses, specialising in operations management and process re-engineering. More recently, Trevor has focused on new business start-ups and supply chain solutions in the retail environment. His achievements in these fields have included the successful reform of supply chain architecture in various FMCG companies, the re-engineering of component manufacturing and distribution for companies in a range of sectors as well as a particular project involving the commercialisation of new automotive welding technology, for which he won the inaugural Peter Doherty Prize for Innovation and Commercialisation. Trevor is now with Lucis, a consulting firm he co-founded, specialising in business strategy and supply chain solutions.

John Hainsworth
John holds considerable experience in structural design, originating in the UK. From 2005, he began work in the ARUP Sydney office where he specialises in 3D modelling methods. His skills have been applied primarily in the 3D modelling of steel and concrete high-rise building structures in project bid phases, which has also involved client liaison and production management and co-ordination with respect to supply chain. Recent projects he has contributed to in Sydney include Star City extensions, Chatswood Chase Shopping Centre and a steel-framed office building at 2 Market St. His focus on virtual building has inspired him to lecture and produce written articles on the relatively new subject, which provides for integrated project conceptualisation and optimisation. John now serves as a key strategic member of ARUP’s Virtual Construction service and Building Information Modelling initiative.

Reg Hobbs
After graduating from the University of Melbourne as a civil engineer, Reg worked in engineering, project management and general management roles with Concrete Constructions and John Holland Groups. Over this period, he was closely involved with major projects such as the reconstruction of the Westgate Bridge, the Victorian Arts Centre, Grosvenor Place Sydney, the ASX Centre, Melbourne and Darwin Airport. In 1995 he formed Flagstaff Consulting with several of his colleagues. His consulting group provides services to the infrastructure, mining and construction industries. Reg is also Chairman of ANCON Beton Pty Ltd, which has provided consulting services in concrete technology and construction techniques to Australasia, the Middle East, Russia and the US.

Nigel Howard
Nigel has devoted his professional endeavours to the discipline of sustainable construction. His professional development began in the UK, where he emerged with an educational background in Chemistry from Kingston University. As Director for the Centre for Sustainable Construction in the UK, his work was oriented towards research in all facets of sustainability in building. The result was the development of a range of sustainability assessment tools for buildings and materials. He was responsible for the formulation of BREEAM, Ecohomes and ASCD – the UK’s environmental assessment and rating systems, as well as the UK Life Cycle Environmental Profiles methodology and database and the Life Cycle design tool INVEST. His career in Australia began as Chief Operating Officer for the Green Building Council of Australia. Nigel now works for BRANZ in developing business in Environmental Life Cycle Assessment and Ecolabelling.

Sandy Longworth
The Warren Centre’s Steel – Framing the Future Project Chairman Sandy (CR) Longworth is a graduate civil engineer from the University of Sydney and has DIC qualification in soil and rock mechanics from Imperial College London. He was a foundation Director, past Chairman and is now an Honorary Governor of The Warren Centre. He spent 29 years in consulting engineering relating to heavy industrial, mining and port engineering projects, first as a founding partner and then director of Longworth & McKenzie and later Soros Longworth & McKenzie working on a wide range of projects in...
Australia and SE Asia. The later 15 years of his career have been spent as executive and non-executive director of various Australian coal and base metal mining and exploration companies. In the past he directed the Surface Mining and Coal Bed Methane projects for The Warren Centre.

Don McDonald

Don is Chief Executive of the Australian Steel Institute. His career comprises 14 years in the steel industry, and 20 years in engineering and construction with a substantial involvement in steel design and construction. Don holds an MBA, a Civil Engineering Degree and postgraduate qualifications in structural and municipal engineering.

Before joining the ASI (AISC), Don was employed with BHP Steel for four years as Market Development Manager – Engineering and Construction. He has also held senior positions with leading companies, where he participated in the successful implementation of a number of very large and complex projects in heavy engineering and building construction. He worked for multinational consultants Fluor Corporation (two years) and Jaakko Poyry (four years), and major contractors John Holland (eight years) and Concrete Constructions (two years).

Brian Mahony

Brian graduated Master of Engineering Science in mechanical engineering in 1965. He was a director of major engineering consultant GHD for 18 years during which time he headed up that company's mining and industrial group. Brian specialises in the design and construction of major bulk materials handling projects, with particular expertise in the conceptual design of marine bulk-loading terminals, mainly along the east coast of Australia and in Indonesia. He is the project manager for the Steel – Framing the Future project with responsibility for the administrative aspects of the project. During the project, Brian visited modern fabrication plants in the UK.

Andrew Marjoribanks

Before emigrating to Australia in 1969, Andrew gained a degree in metallurgy from Glasgow University, followed by a period of working with the British Steel Corporation at the Ravenscraig Steelworks in Scotland. On arrival in Australia Andrew began work with John Lysaght Australia Ltd, which later became BHP Steel. Andrew’s specialisation at BHP developed into senior marketing roles, involving the Colorbond® and Zincalume® brands and the steel service centre network. He became General Manager Strategic Marketing, at which point he took responsibility for the Structural Steel Development Group. Following a period as BHP Steel head of external affairs, Andrew moved to Port Kembla where he oversaw the marketing of the company’s slab, hot rolled coil and plate products. Around his BHP career, Andrew has served as Chairman of the Marketing Committee of the International Iron and Steel Institute and Director of the Australian Institute of Steel Construction. He now practices as a consultant specialising in steel marketing and issues pertaining to its sustainability in a construction context.

Robert Mitchell

Robert is the Chief Operating Officer of The Warren Centre for Advanced Engineering. Since 1999 he has overseen the delivery of the Sustainable Transport in Sustainable Cities project and the Building Construction Technology Roadmap project, initiated four other major projects that are still active, and helped to grow all the other activities of The Centre.

He was previously Strategic Development Director of Moore Asia Pacific, where he was responsible for two joint ventures in China and distribution throughout South East Asia.

Robert’s interest in the advancement and commercialisation of technology developed while he was with British Technology Group in London and Philadelphia in the late 1980s and early 1990s. As a Technology Transfer Executive, he focused on
the international commercialisation of technologies originating in the private sector.

A Chemical Engineer (UNSW 1979, Hons 1) and an MBA (IMEDE, Switzerland), Robert has extensive experience in marketing, business development and technology transfer. His early working life was with CSR as Chemist, Syncrude Canada Ltd as Process Engineer, and Esso Australia Ltd as Planning, Process and Reservoir Engineer.

Anthony Ng

By the time Anthony had completed his Master of Engineering Degree at Sydney University, he had worked as a design and structural engineer in various construction and engineering businesses. He then progressed into construction project management roles, with responsibility for design, budgets, capability marketing and client relations. Anthony became a Senior Development Engineer with BHP Integrated Steel before being appointed as Structural Development Manager with OneSteel Market Mills. In this role, Anthony has been responsible for assessing the steel building marketplace and responding to it with innovative marketing and product packaging solutions. He has contributed to steel’s growth in market share of the multi storey building sector. His campaign in this area continues through his responsibility for the production of steel design and building resource guides distributed by OneSteel.

David Ryan

David’s background is in the marketing of steel products. He served as Marketing Manager for British Tube Mills (BTM) Adelaide and Melbourne, a manufacturer of steel tubing. He then moved to structural steel producer Tubemakers of Australia in Newcastle as a Marketing Project Manager prior to taking on the role of Marketing Development Manager. He later joined OneSteel Market Mills where he became Customer Service Manager. During this period, he served as Chairman of the Australian Institute of Steel Construction Marketing Committee. David is currently the National Marketing Manager for the Australian Steel Institute. In this role he oversees marketing activities with a view to influencing the market for steel in buildings, pipe and tube strategy, media and external promotional activities.

Peter Thompson

Peter practises as a consultant with particular expertise in structural analysis and design, reinforced and pre-stressed concrete design, structural steelwork design, project management, planning and evaluation. Peter gained a Diploma in Structural Engineering from the Brixton School of Building followed by postgraduate studies in concrete technology at the Imperial College of Science and Technology. He is a Past Fellow of the UK Institution of Structural Engineers and Past Member of the Association of Consulting Engineers, Australia. Peter joined engineering consulting firm Ove Arup & Partners in 1950, beginning work in the London office before transferring to Perth in 1968 and to Sydney in 1973. He has established a specialisation in early phase structural engineering for buildings, having led many ARUP building projects throughout the Australia Pacific region. In 1991 Peter was awarded the Royal Australian Institute of Architects NSW Chapter Presidents Award for outstanding contribution to the architectural profession and in 1994 he was appointed an Adjunct-Professor at the University of NSW in the Faculty of the Built Environment.

Aruna Pavithran

Aruna Pavithran is a business strategist, writer and entrepreneur. She is principal of the IT and consulting firm Beam Solutions, as well as co-founder of the respected applied research firm Lucis. Aruna brings together an actuarial education, global management consulting experience, a talent for creative expression and an adventurous spirit to create resource-neutral enterprises. Her consulting activities in this field are in the resources, transportation and property development industries. Aruna is a kriya yogi and lives on the Gold Coast of Australia.
Andrew Walker-Morison

Andrew is an architect by and has led RMIT University’s sustainable materials programs. His responsibility in this role has included the commercial development of Ecospecifier and overseeing the first national review of the environmental impact of building materials for the Federal Government. Andrew is a regular contributor of product reviews for design publications such as Inside and Architectural Review. He is currently working on a new lifecycle assessment scorecard for industry building materials in conjunction with Sustainability Victoria, the Green Building Council and VicUrban. Andrew also co-ordinates the popular Green Building and Design Course run in Melbourne and Sydney.

Emil Zyhajlo

Emil’s early career phases consisted of academic lecturing in structural engineering as well as working for a national design consultant. Over the past 25 years, he has practised in engineering and management roles in building construction throughout Australia and the Asia Pacific region. Throughout his tenures in engineering project management and more recently in private practice, Emil has contributed to significant building projects across a variety of sectors. He has been involved with high-rise commercial buildings in Melbourne, Bangkok and Manila as well as numerous large-scale concrete infrastructure projects such as balanced cantilever bridges, tunnels, communications towers, cooling towers and dams. The projects he has undertaken since entering private practice in 2003 demonstrate a similar diversity, encompassing housing, commercial, retail, public space and infrastructure.
ABOUT THE WARREN CENTRE FOR ADVANCED ENGINEERING

The Warren Centre for Advanced Engineering is the leading Australian forum for advanced engineering issues, recognised for its inclusive, forward-looking approach and the wide impact of its many achievements.

The Centre is a self-funding, independent, not-for-profit institute operating within the Faculty of Engineering at the University of Sydney, controlled by representatives from industry and elected by the University's Senate.

It has three principal objectives:

- to stimulate the application and further development of new engineering technology.
- to encourage the integration of innovation and engineering technology into the development of Australia’s public policy and wealth creation.
- to provide independent comment and advice to government and industry on these and related issues.

The Warren Centre:

- identifies and supports major projects that bring together people at the leading edge in selected fields of engineering technology to develop new technical insights and knowledge in those technologies and accelerate their application in Australian industry.
- holds industry forums for companies in specific industry segments to explore opportunities of common or joint interest that will accelerate the development and/or exploitation of technology.
- organises events such as seminars, lectures and conferences that explore contemporary technology issues and disseminates the results of the Centre's activities.
- produces electronic and printed material to promote discussion and build awareness of contemporary, advanced engineering issues.
- recognises people and projects that make a unique contribution to encouraging excellence and innovation in all fields of advanced engineering.

Since opening in 1983, the Centre has gained wide recognition for its unique approach and its achievements in diverse fields of engineering technology and industry development.