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.

It is in this context that The Warren Centre concluded that the decline in steel usage for building framing and the commensurate loss of skills at all steps in the value chain was detrimental to national interests, particularly at a time of significant resources and infrastructure expansion.

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.

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.

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.

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.

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.

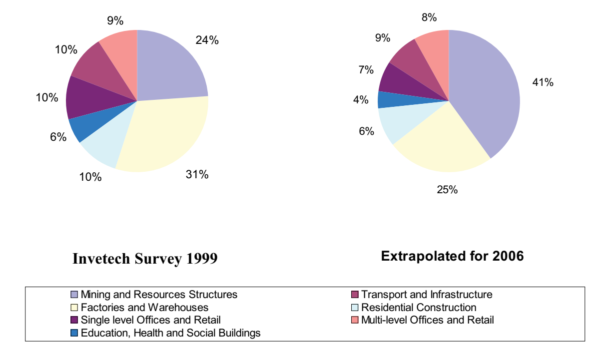

Figure 1: Source: Invetech Survey, 1999

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

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 fabricators 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.

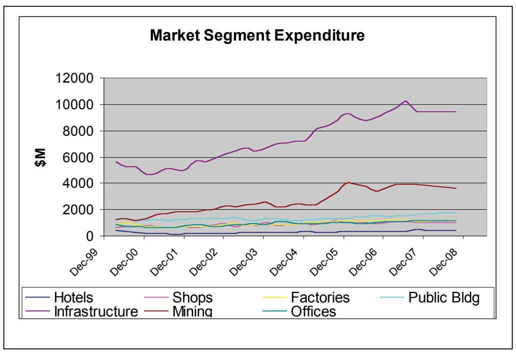

Figure 2: Source: Australian Steel Institute survey, Market Intelligence Company

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

Barrett Steel Constructions for The Warren Centre

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Deputy President, British Constructional Steelwork Association (BCSA)
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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

Year	Steel (%)	Other materials (%)
1980	33	67
1985	43	57
1990	51	49
1995	56	44
2000	67	33
2005	71	29

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.

Cardington fire test

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.

Fire test on intumescent coated Fabsec beam

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 is also easier to achieve when it is all under one roof, where the design can be passed through to 3D CAD packages and on through to the workshop.

Design & Build has become an important part of the sector; it is estimated by the author that 40 per cent of multi-storey steel frames and 90 per cent of single-storey frames in the UK are Design & Build, and that market share figures for Design & Build have increased significantly during the past 10 to 15 years.

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.

CSC Fastrak Structural steelwork analysis and design	*Basic 3-D model Structural design*
TEKLA Structures 12	*Structural detailing in 3-D Lotting, DSTV files*
FabTrol MRP	*Routing, Batching, Prioritising, Material allocation & nesting*
steel projects	*Add Fit-up scribe data Process data into machine format*
FICEP	*Make steel*

Figure 1: Sequencing of the Integrated various IT systems

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.

Offloading with telehandler

Offload Safe system

Airbags forming loading dock

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.

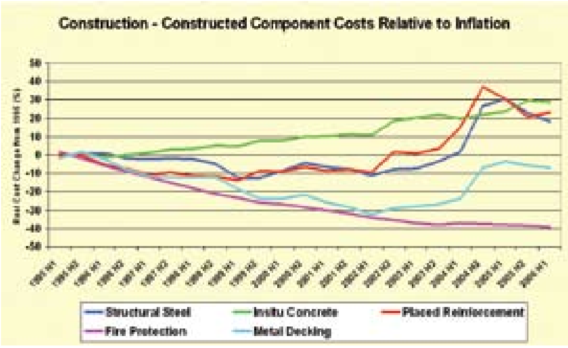
The first graph shows the main raw material costs relative to inflation. Over the whole period the real cost of steel sections has dropped slightly, whilst the two main components in concrete, ready mix concrete and reinforcement bar, have risen by about 20 per cent.

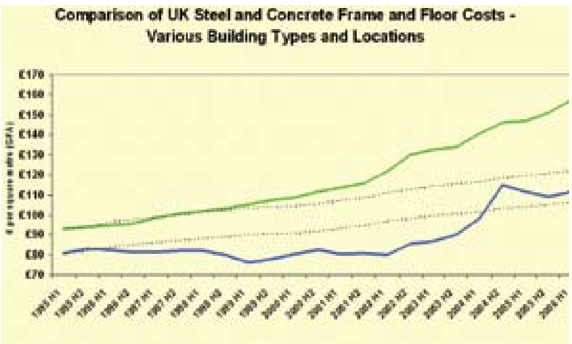
The second graph builds in the full cost of the constructed component, in particular the on-site labour costs. The rise in real labour costs over time is offset to some extent by rises in labour productivity. Interestingly, the real cost of steel decking has declined by nearly 10 per cent. Most importantly 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/m^2

to £111/m² ($190.70/m² to $264.60/m²). Over the same period the cost of the concrete frame has risen from around £90/m² to £158/m² ($214.54/m² to $376.64/m²). This dramatic shift is a major cause for the rapidly increasing market share for steelwork in the UK.





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.

Sector	%
Offices	71.9
Retail	70
Leisure	70.1
Education	68.9
Health	68.3
Residential (multi-storey)	26

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 out-stripping 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.

1.5 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.

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The University of Sydney

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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.
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