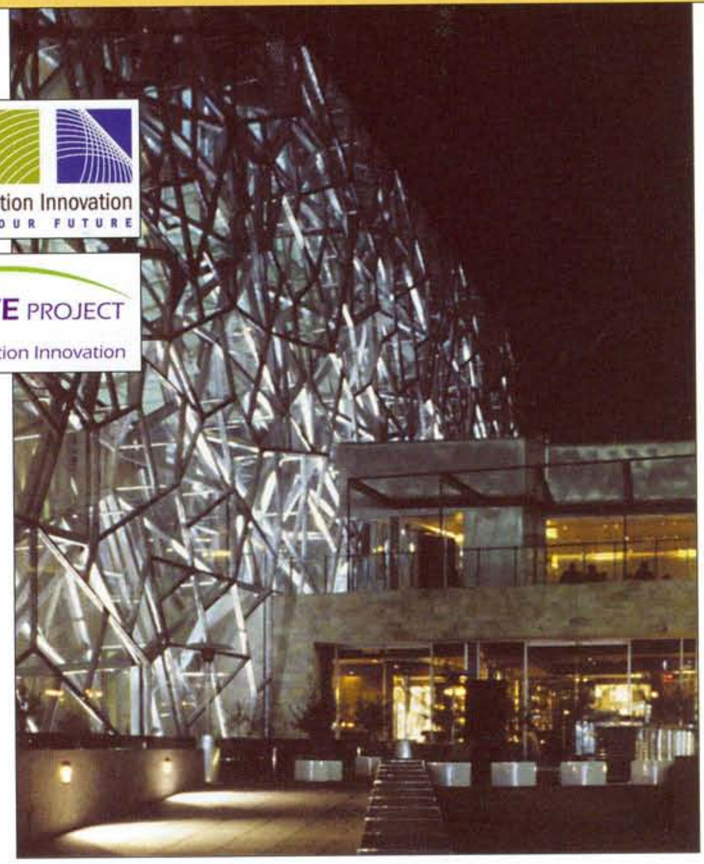
Performance-based building codes and fire engineering yield innovative design solution



The Project

The Ian Potter Centre: NGV Australia is a centrepiece of the Federation Square development in Melbourne. Federation Square is one of Australia's civic and cultural icons, incorporating multi-media, art, museum and office buildings.

The Ian Potter Centre: NGV Australia was constructed by a private sector managing contractor and was completed in 2002 for approximately $65 million.

The Achievement

Part way into the project's design and planning stage, the managing contractor decided to pursue steel alternatives to the intended concrete and masonry building design. This decision was mainly driven by doubts about the capacity of a concrete deck to withstand the proposed constructional loads.

As time and budget issues were beginning to cause concern when the switch to steel occurred, a solution that minimised cost and delay was imperative. The design team, which included the architects, the building surveyor, the fire engineers and other consultants, explored a number of options, with unprotected steel emerging as the best solution. If the steel did not have to be protected, it would aid in meeting the objectives of reducing cost and time, as the process of applying fire protective coatings to steel is expensive and time-consuming.

As well as demonstrating that the use of unprotected steel would not increase the cost of the project or delay its completion, the design team needed to demonstrate that it would not:

- endanger the occupants of the building if there was a fire; and
- increase the expected level of property damage if there was a fire (property damage was a critical consideration, given the value of the intended contents of Ian Potter Centre: NGV Australia).

The team had to show that unprotected steel would perform at least as well as the generally accepted construction materials of masonry and concrete. The comparison was necessary to comply with relevant building regulations. Under the BCA, buildings could be designed to meet certain performance requirements by either:

- following the prescriptive, 'deemed-to-satisfy' requirements set out in the BCA itself (i.e. a design based on concrete and masonry construction – Type A construction); or
- demonstrating that a solution equivalent to the deemed-to-satisfy case could be adopted, even if arrived at in a different way or with the use of different materials (e.g. the use of unprotected steel based on the application of fire science and engineering).

The team was ultimately successful in demonstrating time and cost savings with comparable fire safety outcomes.

SELECTED PROJECT PARTICIPANTS

Client:	Victorian Department of Infrastructure – Office of Major Projects / Federation Square Management Company
Managing Contractor:	Multiplex
Architects:	Lab Architecture Studio in association with Bates Smart
Fire Engineers:	Arup Fire
Organisations consulted in preparing this report:	ARUP and Federation Square Management Company

The use of fire engineering tools, particularly cutting-edge quantitative risk assessment techniques (QRA), reduced construction costs for the Ian Potter Centre: NGV Australia at Federation Square in Melbourne by 4 to 5%.

Development and application of these innovative tools was driven by introduction of the performance-based Building Code of Australia (BCA), and resulted in the use of unprotected steel for the structure of the building, thereby saving approximately:

- $3 million in construction costs; and
- several thousand dollars per year in on-going maintenance costs.

The Innovation

The innovation on the Ian Potter Centre: NGV Australia examined by this study has three main elements:

- use of the performance-based BCA;
- use of QRA; and
- use of unprotected steel.

The innovation was in the adoption of these approaches and their combination to achieve project benefits. Globally, since the early 1990s, there has been a shift to performance-based building codes, with the BCA making the change in its 1996 edition. Performance-based codes have made it easier to develop alternative building designs.

On the Ian Potter Centre: NGV Australia project, the performance-based BCA allowed the design and approval process to be completed at least twice as quickly as it would have been under the pre-1996 BCA. This speed, 3 months compared to 6 to 12 months under the old system, was a key driver of the unprotected steel innovation.

Unprotected steel emerged globally in the early 1990s, but has been used for very few large buildings (where fire safety is particularly challenging). The fire engineers on the Ian Potter Centre: NGV Australia noted that they "knew of only three previous examples of unprotected steel use in large building developments in Australia". Its rate of use is expected to rapidly increase in the future as designers and computer technologies catch up with the new opportunities, and as clients adjust to new approaches.

The use of unprotected steel was also facilitated by QRA, which allows building owners and developers to evaluate the risks of fire against their corporate objectives and make optimal decisions consistent with their risk management policies.

QRA techniques are commonly used in the building and construction industry, for example by transportation and environmental engineers. However, the use of QRA to assess the fire resistance of structural steel is a new field globally, which emerged in the mid-1990s in conjunction with performance-based building codes, and large increases in computer power that are necessary for modelling and testing. Indeed, there are only about 50 experts in fire and steel safety worldwide, attached to a handful of universities, research centres and private companies.

The Benefits

Using QRA, the fire engineers were able to show that unprotected steel would deliver fire damage outcomes equivalent to those of protected steel. An exercise modelling fire damage showed that if unprotected steel was used, in all but the three key support columns (which were protected for risk management reasons), the overall cost of fire would be $8,500 per year, averaged over the 25-year design life of the building.

By contrast, if the building had been constructed using the BCA's deemed-to-satisfy concrete method (Type A construction), the overall cost of fire would be $8,700 per year. Therefore, unprotected steel (including the fire safety systems for contents protection) was shown to offer a fire cost projection broadly equivalent to the BCA deemed-to-satisfy compliant concrete. Without the need to apply expensive fire protection finishes to steel, approximately $3 million was saved in construction costs.

Although maintenance benefits of unprotected steel were not fully quantified, the fire engineers also considered that "several thousand dollars per year were likely to be saved, because unprotected steel does not require monitoring or re-coating".

The inspection process for protected steel would have been very costly at the Ian Potter Centre: NGV Australia, as 60 to 70% of the steel is largely inaccessible, being behind wall cavities and in ceiling spaces.

Further, all of the steel would have been inspected gradually over a five to 10 year period and parts of the building would have been shut down during many of the inspections, due to the requirement for a dust-free environment within the galleries.

The use of structural steel also eliminated numerous difficulties associated with construction using concrete. A concrete structure would have required complex propping and temporary structural support that would have created problems in accessing the Ian Potter Centre: NGV Australia site. Eliminating the need for these works saved the project an additional $1 million. Also, the lightweight nature of steel meant that smaller cranes could be used, and structural elements were more manageable on site.

Finally, the use of steel rather than concrete provided architectural and functional benefits, with more flexibility in the architectural layout, more effective use of space and increased size of fire compartments.

The Implementation Process

The key to the benefits achieved by the use of unprotected steel was the QRA, which, in turn, was particularly useful because of the possibilities opened up by the performance-based BCA. The managing contractor drove the design shift from concrete to steel, based on its experience of the benefits of steel. The design team drove the use of unprotected steel, reaping time and cost benefits, principally by employing QRA.

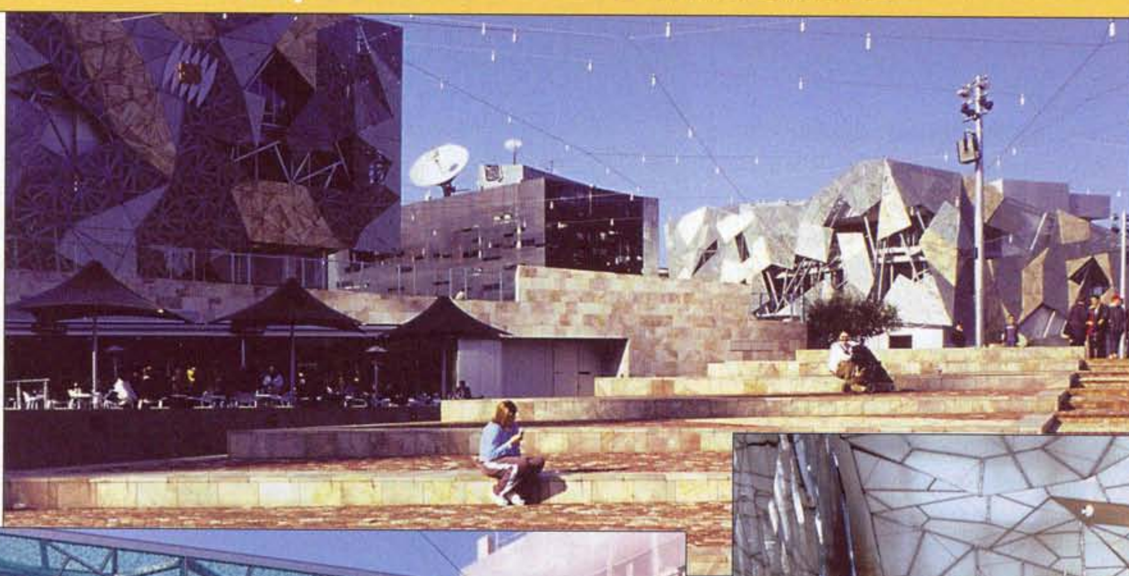
Risk assessment techniques, such as QRA, are used to evaluate the frequency and probability of threatening events such as fires. Once risks are assessed, options to reduce the risks can be examined and costed, and the most effective option adopted.

There are a number of approaches to risk assessment for fire safety decision-making. One of the most complex of these approaches is QRA based on fault and event scenarios. Fault scenarios can be used to identify mechanisms of failure leading to fire starts. Event scenarios can then be drawn up and evaluated to identify the probability of the fire going from ignition to various stages of fire development and the levels of threat to occupants and property.

In Australia, this approach is known as an Evaluation Extent 3 or System Risk Evaluation approach, as defined in the Australian Building Codes Board Fire Safety Engineering

Guidelines

In the case of the Ian Potter Centre: NGV Australia, the concept of five states of fire growth was used in the risk assessment in order to assess the probability and consequences of various times to activation of the fire safety systems and human intervention.



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Further, a number of events and factors were incorporated into the analysis and the associated probabilities enumerated in order to determine the overall probability of fire development and damage to property. These three features: the five fire states, the application of QRA to property and the method of probabilistic analysis, are cutting-edge. They have been used only rarely globally, and were adopted by the fire engineers on the project through their linkages with international experts, such as engineers with the National Research Council of Canada.

Overcoming Difficulties

One of the primary challenges in the adoption of the fire engineering/unprotected steel innovation was addressing the safety concerns of a number of stakeholders, including the client, about the new approach. Members of the design team were able to effectively use fire engineering tools, and a cooperative approach, to educate the stakeholders about the relative risks and allay their fears.

One of the key reasons for concern, particularly for the client, was that the QRA approach to fire safety engineering is an analytical process, as opposed to a physical testing-based approach. Acceptance of the QRA results requires understanding its theoretical underpinnings, and appreciating the logic that leads to the outcomes. These can be more conceptually difficult than results based on physical testing of materials.

QRA is a significant departure from prescriptive, rule-based approaches to building construction, and this may also have been a reason for concern. Despite the capacity of QRA to arrive at what are, in many cases, safer and less expensive construction methods, there is still a residual tendency for many stakeholders to prefer uncomplicated rules prescribing conventional building materials and methods. Put simply, QRA is harder to understand than prescriptive rules and this can result in risk-averse responses to its adoption. However, as this case study demonstrates, it is possible to reduce this problem using education and a cooperative approach.

Lessons Learned

- Performance-based building codes promote innovation.
- Innovation is enhanced by international linkages with global experts.
- Computer advances can be crucial to innovation in other areas.
- Risk aversion needs to be addressed within the Australian building culture, as it continues to act as an impediment to novel innovation.
- Education and a cooperative approach can help overcome objections to innovation.
- Performance-based approaches to fire engineering have the potential to deliver design/structural innovation which results in more functional buildings, equal or better levels of fire safety, increased cost effectiveness in construction and through-life performance, and more flexibility in design. BA

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