Costing study confirms concrete's competitive edge

Executive summary

A recent independent study of the relative constructed costs of structural framing solutions for medium- and high-rise construction conducted by WT Partnership confirms concrete's competitive edge in Australia over other construction systems. The study was completed for Sydney, Melbourne, Brisbane, Adelaide and Perth and is summarised below.

- Concrete framed structures with post-tensioned floors on permanent metal deck formwork are the most cost effective solutions for the medium-rise buildings studied. In comparison, the cost premium for a steel framed structure ranged from 26% (Adelaide) to 85% (Sydney), **see graphs 1 to 5**.
- Concrete framed structures with post-tensioned floors on conventional formwork are the most cost effective solutions for the high-rise building studied. In comparison, the cost premium for a steel framed structure ranged from 22% (Adelaide) to 65% (Sydney), **see graph 6**.
- Concrete framed structures remain more competitive than steel framed structures across all spans studied – 8.4 m to 16.8 m.
- Depending on site-specific requirements, there are no construction programme disadvantages with concrete framed structures when compared with steel framed structures.

Introduction

The Australian commercial construction industry is renowned for its efficiency and innovation, leading the world with its use of innovative concrete frame construction, design and technologies. Concrete framed designs have consistently delivered low cost, low risk, high speed and high quality medium- and high-rise buildings in a highly competitive market.

Cement Concrete & Aggregates Australia (CCAA) set out to gain a complete understanding of the Australian commercial building industry, in order to see how the concrete industry might add further value to this sector. CCAA identified a range of multi-rise building projects across Australia, and interviewed all members of the supply chain – builders, engineers, architects and suppliers – in regards to the major value points relevant to the building structure. After examination of the results of these interviews, CCAA identified that a better understanding of the comparative costs of different framing solutions was required.

TABLE 1 Structural grid options*

Four structural grid options for a 10-storey medium-rise building
8.40 x 8.40 m
10.80 x 8.40 m
12.60 x 8.40 m
16.20 x 8.40 m
One structural grid for a 30-storey high-rise building
16.80 x 7.20 m

**All grids suited to typical car-park layouts*

TABLE 2 Design options

10-storey medium-rise building

Structural framing systems

1 Reinforced concrete (RC) frame with permanent metal soffit formwork
2 RC frame with conventional soffit formwork
3 RC columns, post tensioned (PT) floors with permanent metal soffit formwork
4 RC columns, PT floors with conventional soffit formwork
5 Steel frame, RC topping slab on permanent metal soffit formwork

30-storey high-rise building

Structural framing systems

1 RC frame with conventional soffit formwork
2 RC columns, PT floors with conventional soffit formwork
3 Steel frame, RC topping slab on permanent metal soffit formwork

TABLE 3 Floor area zone of each structural grid option

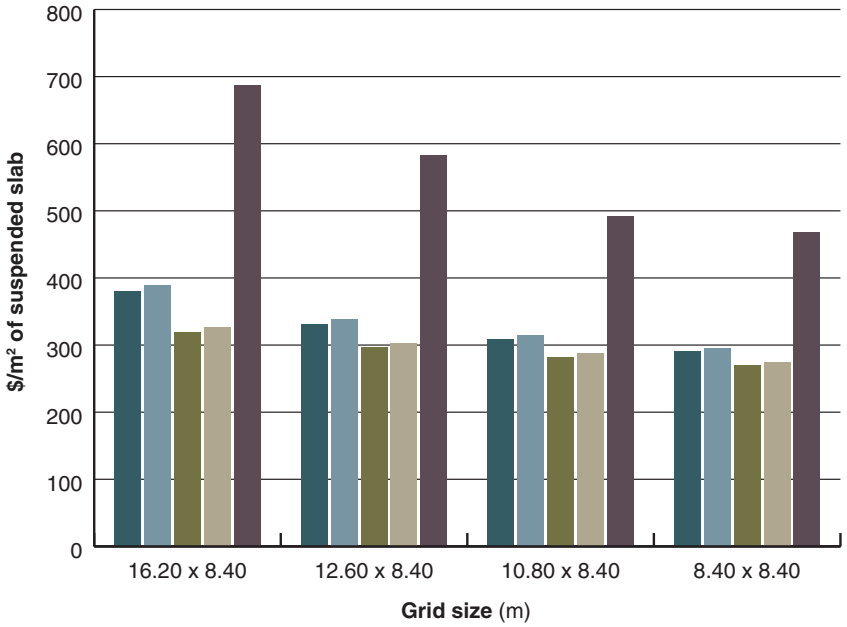
10-storey medium-rise building

Grid size (m)	Area per floor (m^2)	Total suspended floor area (m^2)
16.20 x 8.40	1,201	12,010
12.60 x 8.40	947	9,470
10.80 x 8.40	819	8,190
8.40 x 8.40	649	6,490

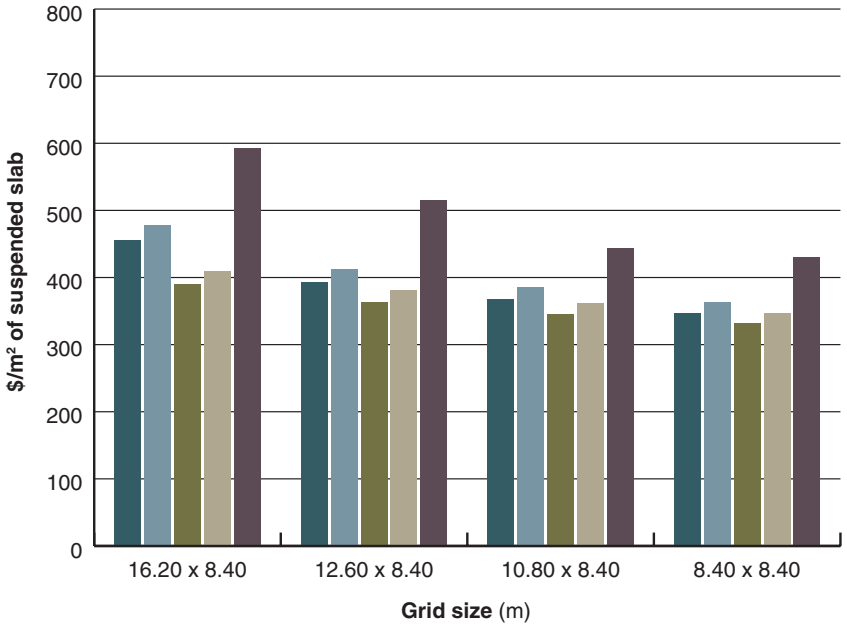
30-storey high-rise building

Grid size (m)	Area per floor (m^2)	Total suspended floor area (m^2)
16.80 x 7.20	2,669	80,070

Graph 1 10-storey medium-rise building **SYDNEY**



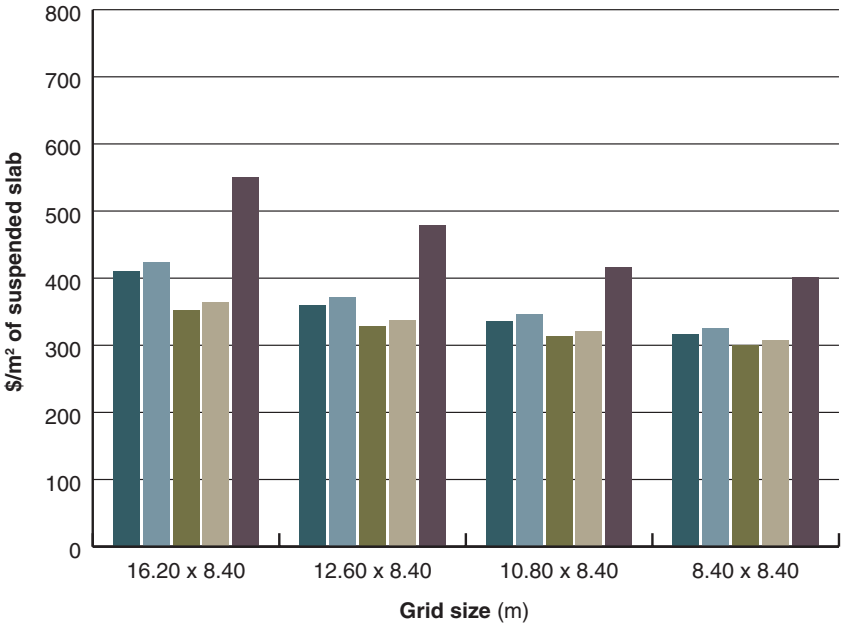
Graph 2 10-storey medium-rise building **MELBOURNE**



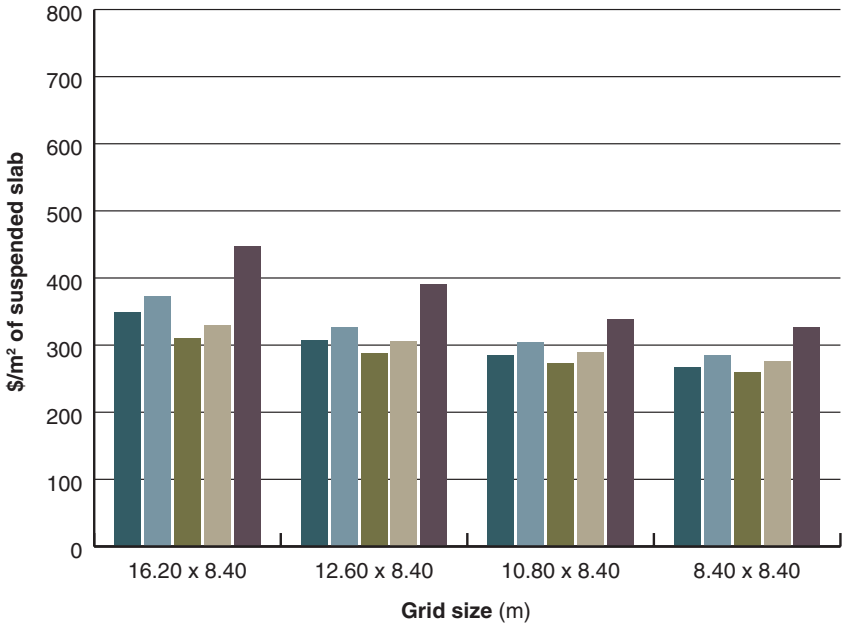
GRAPHS 1–5 10-storey medium-rise building

- RC frame; metal soffit formwork
- RC frame; conventional soffit formwork
- RC columns; PT floors; metal soffit formwork
- RC columns; PT floors; conventional soffit formwork
- Steel frame; RC toppings on metal soffit formwork

Graph 3 10-storey medium-rise building **BRISBANE**



Graph 4 10-storey medium-rise building **ADELAIDE**



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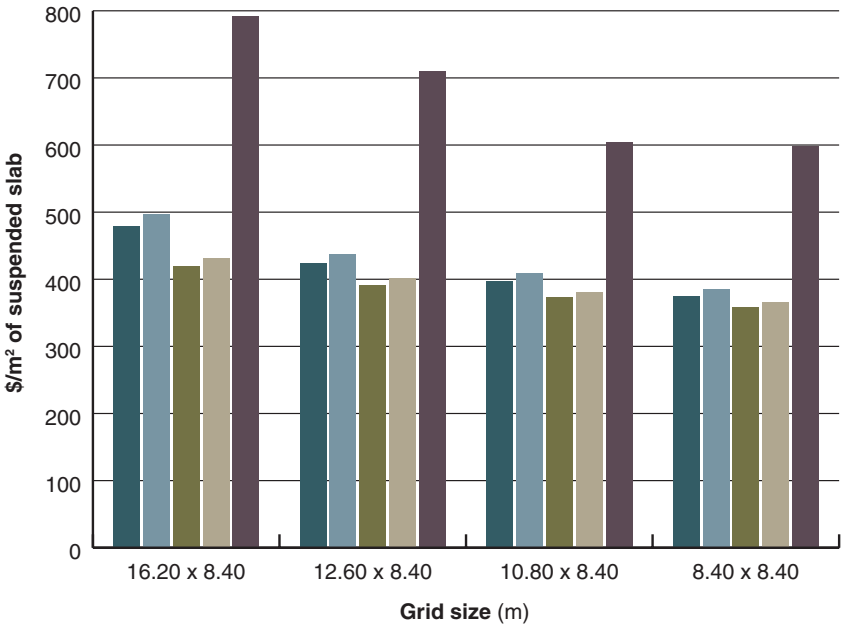
Graph 5 10-storey medium-rise building **PERTH**



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- RC columns; PT floors; metal soffit formwork
- RC columns; PT floors; conventional soffit formwork
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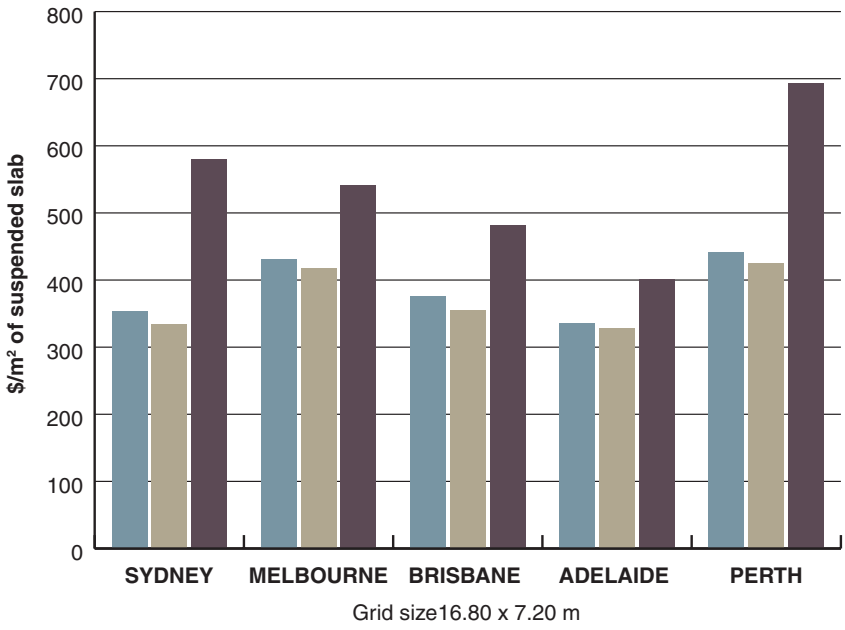
Graph 6 30-storey high-rise building **ALL CITIES, ONE GRID**



GRAPH 6 30-storey high-rise building

- RC frame; conventional soffit formwork
- RC columns; PT floors; conventional soffit formwork
- Steel frame; RC toppings on metal soffit formwork

Study methodology and objective

CCAA commissioned a detailed independent study by internationally respected quantity surveyors and construction cost consultants, WT Partnership, with structural engineering designs by Irwinconsult. The study, believed to be the first of its kind in Australia, comprised two parts. Firstly, it compared five different structural framing systems across four structural grid layouts in five mainland capital cities for a prototype medium-rise (10 storeys) commercial building.

In the second part it compares three different structural framing systems across one long-span structural grid layout in five mainland capital cities for a prototype high-rise (30 storeys) commercial building. Full details of the prototype designs are shown in **Tables 1, 2 and 3**. All costs are based on March 2007 construction tender prices for the different locations.

The analysis aimed firstly to independently quantify the comparative costs of typical, contemporary commercial framing systems used by construction project teams in Australia. A second objective was to identify any shortfalls or barriers that currently prevent the maximum value of concrete construction being delivered, and how CCAA might work in partnership with the construction sector to address them through the development of improved concrete solutions in the future.

Analysis parameters

The analysis focuses on the constructed cost of the footings, columns, and suspended upper floors of a typical prototype building for the different framing system options. Variables and other structural elements common to all designs, such as: site preparation and bulk earthworks; ground slab/basements; structural cores/stairs/lift wells/risers; roof; and builders' preliminaries were excluded from the analysis. Qualitative analysis and consideration was also provided on a range of other variables such as: sensitivity to market-place fluctuations; construction programme; cash flow; net lettable area and risk factors for the alternate designs.

Summary of findings

In their detailed analysis and report for the designs under consideration, WT Partnership found as follows:

COST

- Concrete framed structures are more competitive than steel framed structures in the medium- and high-rise commercial office markets in Sydney, Melbourne, Brisbane, Adelaide and Perth.
- In medium-rise (10-storey) buildings, the cost premium for a steel framed structure ranged from 26% (Adelaide) to 85% (Sydney), relative to a concrete framed structure with PT floors on permanent metal soffit formwork (**graphs 1 to 5**).
- For high-rise (30-storey) buildings, the cost premium for a steel framed structure ranged from 22% (Adelaide) to 65% (Sydney) relative to a concrete framed structure with PT floors on conventional formwork (**graph 6**).
- A cost premium for steel framed structures is consistently evident across both short and long spans up to 16.80 m.
- RC columns with PT concrete floors are the most cost effective framing design.
- Structural steel prices ($/t) in place would need to drop by 35% to 65% (with all other factors held constant) for the steel framed design to be competitive with a concrete framed structure with PT floors on permanent metal formwork. The variance depends on grid size and locality.
- Permanent metal deck form-work is more cost effective than conventional soffit formwork in medium-rise buildings.
- Conventional formwork prices ($/m^2) would need to increase by 40% to 250% (with all other factors held constant) before concrete framed structures with PT floors on conventional formwork became cost neutral with steel framed structures. The variance depends on grid size and locality.
- Steel framed structures can have 100 mm to 300 mm greater floor-to-floor height which increases facade costs plus all vertical structural and vertical services costs. (These additional costs are not accounted for in this study).
- Fire rating (2 hour) adds 5–10% to the cost of the steel structure depending on fire protection requirements, grid size, locality and concrete design.

SPEED

- There does not appear to be any programme advantages in the steel structure to offset the current cost premium.
- Each structural system has advantages which may lend themselves to specific project constraints and needs. For example:
  - — Labour force to site ratio is greater in concrete structures.
  - — Steel has a longer lead time (shop drawings/ offsite fabrication).

RISK

- Steel structures have an accelerated cash flow draw down and arguably greater contract disruption and financial risk in the event of subcontractor/supplier default.
- Price volatility between locations is high for steel framed structures.
- The expertise in high-rise steel structures is viewed as more limited than in concrete high-rise structures.

Other points of interest

- **Acoustics:** The greater mass of the concrete structure provides better acoustic performance for both impact and transmitted noise when compared to the steel solutions.
- **Deflection limitations and vibrations:** Long-term deflections have been limited to 1/300th of the span of element (slab or beam).
- **The suspended upper floors** for steel framed structures have an 11%–85% (for 10-storey buildings) and 6%–45% (for 30-storey buildings) cost premium when compared to a concrete structure with PT floors. The variance depends on grid size and locality.
- **Floor-to-floor height:** The steel framed option adds between 100 mm and 200 mm (for 10-storey buildings) and between 200 mm and 300 mm (for 30-storey buildings) to the floor-to-floor height when compared to the concrete framed structure with PT floors. This would increase the cost of other vertical elements which are not accounted for in this study. The cost of facades would increase by approximately:
  - — 2.4% for a 100 mm increase in floor-to-floor height (based on the 16.20 x 8.40 m grid option for 10-storey buildings) and
  - — 5.4% for a 200 mm increase in floor-to-floor height (based on the 16.80 x 7.20 m grid option for 30-storey buildings).
- **Substructure:** Savings in footing cost for the lighter steel structure amounted to between 1% and 5% on total cost of the structure when compared with concrete framed structures.
- **Columns:** Concrete columns are more cost effective than steel columns. Steel columns account for 5% to 15% (for 10-storey buildings) and 5% to 11% (for 30-storey buildings) of the cost premium for a steel structure when compared to a concrete structure with PT floors.

Conclusions

In their report, WT Partnership have noted that pricing levels in the construction market are volatile, with costs varying greatly between the five mainland capital cities surveyed, particularly in relation to the steel design options. Over time, these pricing levels will vary with each city being driven by the supply-and-demand factors of the market. However, each project has its own commercial drivers which can see large shifts in the pricing structure.

Nevertheless, within the parameters of this report, WT Partnership note that alternative designs or price fluctuations would need to be considerable to alter the fact that, for commercial construction in Australia, concrete framed construction utilising post tensioned floors on permanent metal formwork is a significant 26% to 85% cheaper than steel framed solutions. Combine the factors of lower cost with no construction programme disadvantages and concrete's competitive edge in Australia is undeniably confirmed.

irwinconsult

WT PARTNERSHIP

WT Partnership confirms that the findings of the article are consistent with the *High- and Medium-rise Building Structural Design Option Studies* undertaken for the Irwinconsult engineering solutions.

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