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PLANNING AND ARCHITECTURE

The Citigroup Centre At No. 2 Park Street, Sydney

Mike Haysler and Robert Facioni

INTRODUCTION

The Citigroup Centre rises 250m above street level and is one of the tallest buildings in Australia. It consists of 4 levels of underground parking, and a 6-level retail podium with a 45-level office tower over.

Hyder worked with architect Crone & Associates and contractor Multiplex Constructions from concept design through to completion ensuring an optimum structure that could be built to suit a tight construction program and meet the target budget.

This paper covers the history of this site, a notorious black hole for many years, features achieved working on a design and construct basis and some of the technical challenges facing the structural engineer.

The successful completion of this prestigious project prior to the arrival of international visitors to the Sydney Olympics is a testament to the success of design and construct delivery method.

HISTORY OF THE SITE

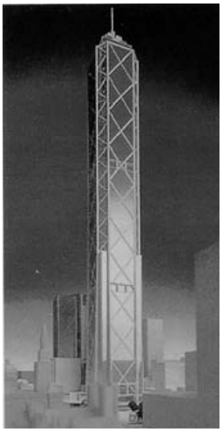
The Citibank Centre is located where the Waltons Department Store once stood. The site was notorious as Sydney's biggest remaining hole in the ground at the centre of the city opposite the restored Queen Victoria Building and Town Hall.

Hyder under its former name of Wargon Chapman Partners had a long association with the site working on various schemes with architects Crone and Associates.

The original development proposal for the site prepared in 1982 consisted of a 33-storey building constructed over a 6-storey retail centre. In 1984 with further consolidation of the site a design for a 45-storey office tower was developed.

In 1987 following the purchase of the adjacent Hilton Hotel and consolidation of all the properties between the hotel and Park Street, the Bond Corporation proposed the landmark 102 level 'Skytower' development. The wind resisting structure for this scheme comprised an externally braced steel frame with the structural system highlighted in the curtain wall façade. The structural steel core played no part in the wind-resisting frame.

There were some perceived urban planning issues with Skytower and in 1988 the design was changed to an 85-storey tower with podium level retail. The structural system for this scheme was similar to Skytower but the external steel bracing frame was no longer expressed in the façade. This scheme did not progress due to the decline of the Bond Corporation and in 1989 Kumagi Gumi purchased the site. Japanese architect Kisho Kurokawa worked with the Crone team to develop the Park Plaza scheme with a 210 metre high 48-storey tower over 9-level retail centre for international retailer Sogo. This scheme included a concrete core and composite steel frame



1984

1987

1989

Contractor Multiplex started on this scheme with excavation and shoring substantially completed and foundations started. The School of Arts was underpinned and a tunnel constructed underneath which was to be a link to the proposed Park Street Tunnel. Work also included the temporary support of the Park Plaza monorail station. This scheme again stalled with the economic downturn.

Multiplex continued their interest in the site and looked to progress the development. The current scheme was in its infancy in 1992. Hyder worked closely with Multiplex and the Architects Crone & Associates in fits and starts until the scheme finally got the green light in 1998.

DESIGN AND CONSTRUCT FEATURES

Working from early concept with the Developer and Contractor, Multiplex Constructions, Architect and Services Consultants led to the incorporation of features to improve buildability and speed of construction, to minimise the intrusion of structure and maximise lettable area. The structure was also developed to integrate with the building services requirements.

The primary structural feature to develop from co-operation between the design team was the minimisation of column transfers. This obviously simplified the structure and made the construction quicker and easier. The only significant column transfers are at the corners of the tower.

As there was a high level of repetition a lot of time was spent optimising the typical tower floor plate. To tie in with the façade and achieve the maximum lettable area the column sizes were kept to a minimum. This was achieved by using 90 Mpa concrete and 8% reinforcement at the lower tower levels immediately above the podium. As the columns were relatively large through the podium (1200mm square) prototypes were made and temperature differentials checked to ensure there would be no problems associated with curing. Various curing methods were tested on the prototypes with the most effective, leaving the formwork in place for a minimum of 7 days, being adopted. Cost studies showed that the high strength concrete was cheaper than using high reinforcement ratios so the 90 Mpa concrete was used up to the 34th level with the reinforcement ratio dropping to 1%.

A column free space was considered essential for a premium grade office in the centre of Sydney. The use of post-tensioned band beams spanning up to 14.5 metres was found to be the optimum. Band beams at relatively close centres ranging from 4.0 to 5.6 metres were adopted to minimise the slab weight with typical slabs being only 120mm thick. This is the minimum practical depth to meet fire resistance and acoustic criteria.

Changes to the requirements for formwork caused an increase in the cost of conventional systems such as table forms that would have normally been adopted for this type of floor. Various alternatives were considered before adopting a metal decking system as permanent formwork for the slabs. This reduction in conventional formwork meant that a 4-day floor cycle could be achieved with resulting benefits in construction time.

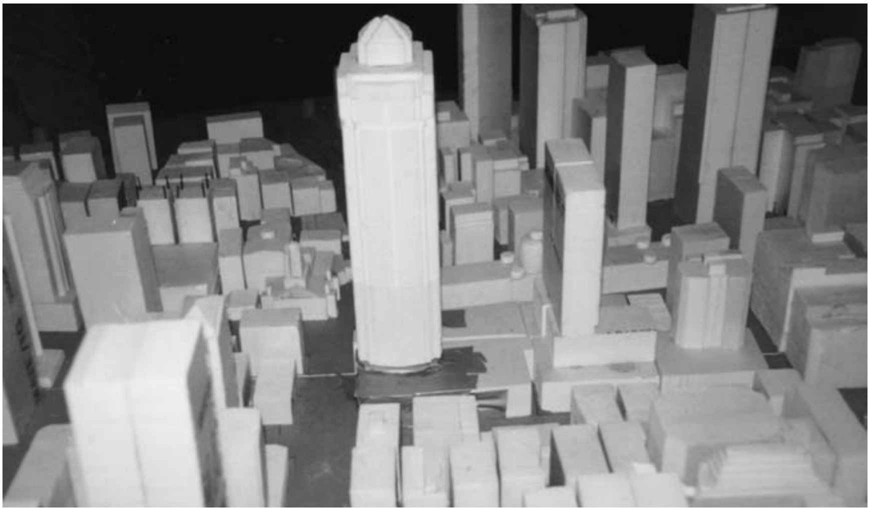
There were significant benefits to be made by minimising the floor to floor height. This would allow the maximum number of floors within the approved building height, whilst keeping FSR in line with Council approval. It would also reduce the height of curtain wall façade per floor with significant cost saving. The most significant reduction was achieved by notching the beams at the perimeter and at the connection to the core to allow air conditioning ductwork to pass under.

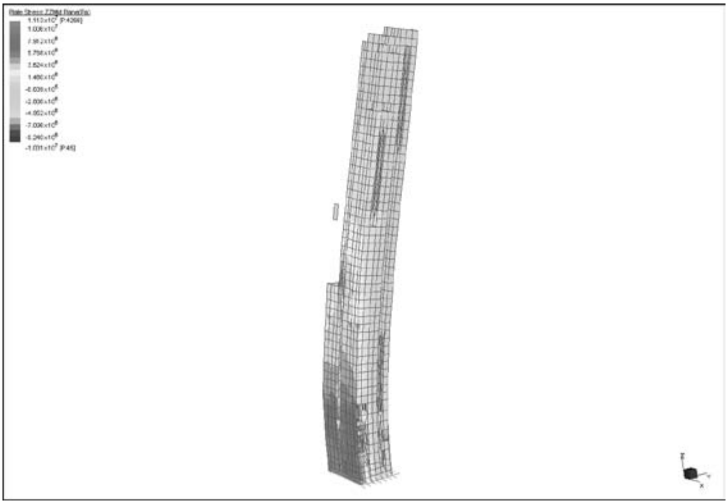
For commercial reasons and to meet City Councils requirements for substantial completion prior to the Olympics fast tracking was essential. The onus was on the design team to produce construction documents early as excavation for basement carparking had already been completed prior to the main project starting. The design progressed in stages sufficiently in advance of the construction to allow co-ordination between disciplines, optimisation of the structure and resolution of buildability issues.

STRUCTURAL FEATURES

The concept design included steel truss outriggers at the mid-level plantroom connecting the core to the perimeter columns as part of wind resisting frame.

The wind frame was optimised by utilising wind tunnel testing of an aerodynamic model in which the wind induced loads were measured using a very sensitive, high frequency Base Balance. Initial sizing of structure, core wall thickness and steel member sizes was done manually. A finite element computer model was then set up to confirm the fundamental natural frequencies at 0.152, 0.218 and 0.393 Hz.





The wind tunnel testing was carried out using these parameters and also with higher and lower natural frequencies to determine the effect of varying the stiffness and allowing optimisation of the structure. This showed that the outrigger trusses could be omitted with the consequent benefit of time and cost saving and uninterrupted space in the mid-level plantroom. The wind tunnel testing gave peak deflection of 295mm and peak acceleration of 23mg at the highest occupied floor. This was within the acceptance criteria of the International Standard ISO 6897 for the response of occupants to low frequency motion.

Three railway tunnels run through the site. The podium area over these tunnels was separated from the rest of the structure. Elastomeric bearings were used to reduce the transmission of noise and vibration from the trains. The podium columns over the tunnels were on large spread footings so as not to overload the tunnels. Special care was taken with excavation and construction in the vicinity of the tunnels.

The site included the heritage-listed School of Arts. This was restored to its original splendour working in conjunction with specialist heritage architect Howard Tanner and Associates.

The existing Monorail station was incorporated into the new structure. It was necessary to move one of the monorail columns without disruption to the running of the system.

Computer modelling of the 37-metre high structural steel spire at the top of the building showed it to be potentially responsive to wind excitation, with resultant fatigue problems. Specialist advice was sought from Professor Bill Melbourne. Chain dampers were installed in the spire. These dampers have been tested after construction and shown to be effective.

CONCLUSION

The involvement of the Contractor from the early stages of design is an essential part of a successful fast track project. A condition of the development approval from the City of Sydney required that the building be substantially completed prior to the Olympics. The Citigroup Centre, one of the tallest office buildings in Sydney, was completed 2 months ahead of the planned 26-month construction program. This is a testimony to successful co-operation between the designers and builders.