In Sydney, Australia, the new Latitude at World Square building steals the show.

Star Attraction

By Chris Chaseling

At the southern end of the Sydney central business district, a major steel high-rise building reaches skyward in steel—Latitude at World Square (Ernst & Young Centre).

Designed by architects Crone Nation, with structural engineers Hyder Consulting, the project was completed at the end of December 2004, five months ahead of schedule. Multiplex Ltd. helped develop and construct the 55-story Latitude Tower, which provides 62,000 m^2 (667,000 sq. ft) of net rentable area. A separate four-level building covers an additional 5,500 m^2 (59,000 sq. ft) of premium office space located over a three-level retail podium, a seven-level parking garage, and a loading dock level.

Initially designed in concrete, Latitude Tower was redesigned as a composite steel and concrete structure. Andrew Merriel, construction manager with Multiplex, explained, "We asked Hyder to investigate the viability of constructing the building in steel. While that investigation found the cost of the steel option was slightly higher than the original concrete design, the use of steel addressed the risks that had been identified in the design development." Those risks included the limited working hours on-site due to city constraints, the increased time and cost to construct a transfer structure capable of carrying the much heavier concrete structure, and the risk of differential settlement with heavier concrete structure compared to steel.

In the Spotlight

The building features composite steel and concrete floors which clear-span 14 m (46′) from the concrete core to the perimeter tower columns, creating column-free space for open office planning. The perimeter columns are twin steel tubes filled with high strength concrete. The system was designed for rapid construction and was fire-safety engineered to extensively eliminate sprayed fire protection.

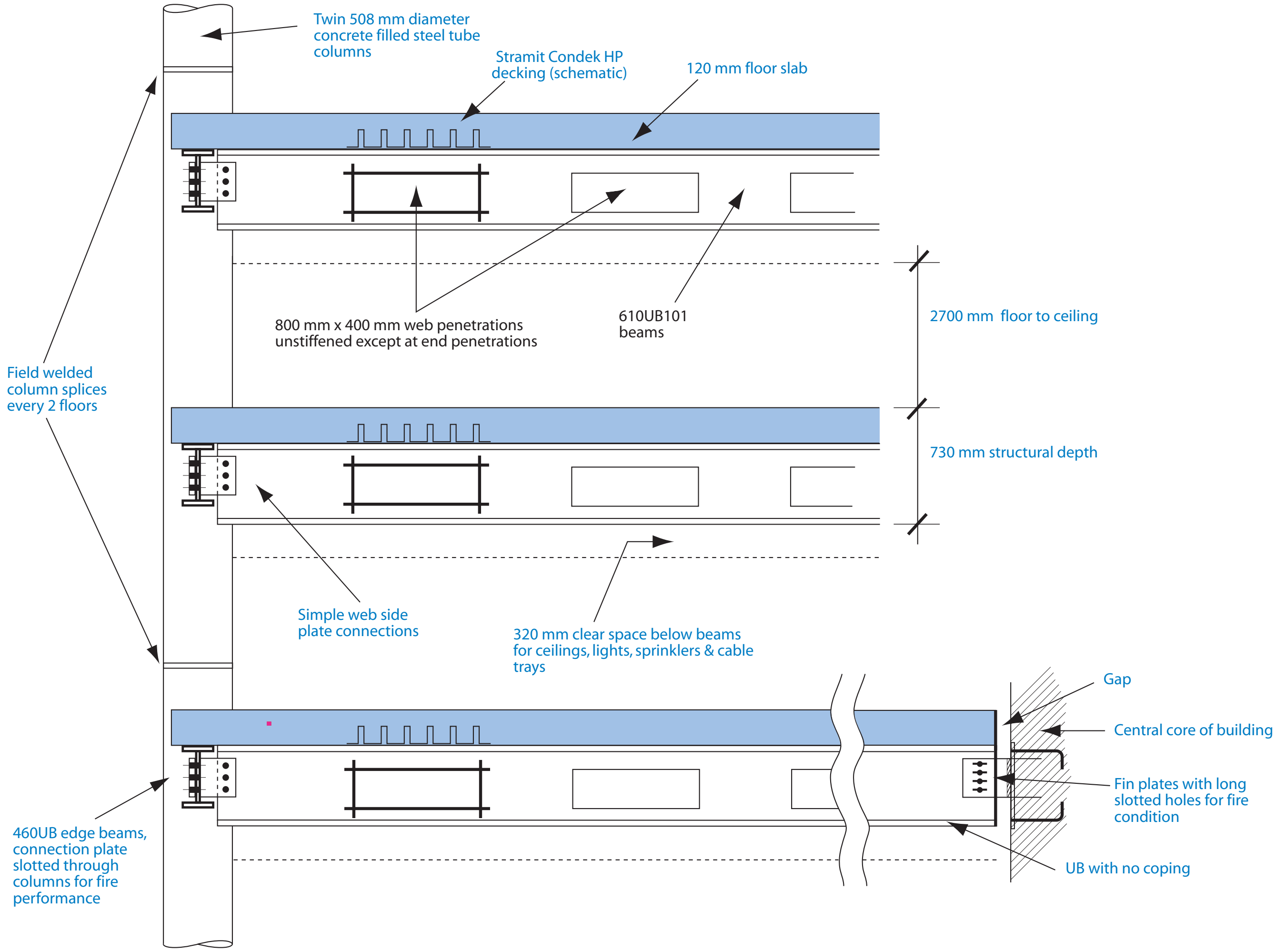
The parking garage and parts of the retail structure up to level 14 were completed in concrete 15 years ago and lay dormant until tower construction began late in 2002. However, the elevations of the existing slabs at levels 13 and 14 did not suit the new project design, so the slabs had to be demolished and rebuilt. Also, the column locations for the new steel tower did not align with the existing columns, requiring an extensive transfer structure.

On many projects, Multiplex uses what is termed a "jump-start," where the construction of the vertical structural elements is accelerated up to the point where the "typical" structural floor plates begin. Construction can then proceed simultaneously on typical levels above as well as on non-typical levels below, providing significant savings in construction time.

Changing to a steel solution for the typical floors was essential for the jump-start process. The first level of the jump-start was a structural deck installed at level 16 (six levels above street level) supported on concrete-filled steel tube columns supported on existing columns at level 14. The existing concrete columns and foundations were strengthened prior to beginning jump-start work. From level 16, the two-story transfer structure at levels 18 to 20 was constructed. Then construction of the upper tower's typical floors started concurrently with the demolition and reconstruction of levels 13 and 14 below.

The transfer system employs two-story, 7 m deep (23′) trusses comprised of high strength steel, box-shaped concrete-filled chords, and tension diagonals. Bisplate 80 Grade 700 (100 ksi steel) plates were cut to size and studs were welded onto the inner faces before fabricating the plates into box members. The box members for the top chords were left open for concrete placement and fitted with stirrups to provide shear connections to the floor slab.

Compression diagonals consisted of steel tubes filled with high strength 80 MPa (12,000 psi) concrete. A number of the larger diagonals were twin tubes as large as 1100 mm (43″) diameter. A second set of outrigger steel trusses at the towers' mid-height provided additional



Typical tower floors use composite slabs. Steel beams have web penetrations for building services, but by design, only the end-most web penetrations require reinforcing. Slotted connections are used at beam-to-concrete core connections to allow the floor framing to expand and contract in a fire condition.

stiffening against wind-induced motions. These trusses were constructed from 16 mm (0.62″) thick Bisplate 80 Grade 700 quenched and tempered steel plate; highly loaded compression diagonals used large diameter concrete-filled steel tubes.

Center Stage

The typical composite floor slabs are 120 mm (4.7″) thick supported on hot rolled 610UB101s (approximately W24x68s), spaced at 4.2 m (14′) centers. On the southern side, these span 12 m (39′) from the core to the perimeter columns, while on the east, the main beams span 14 m (46′). The steel tube columns are typically filled with 80 MPa concrete, and slabs are typically 25 MPa (3,600 psi).

A typical floor-to-floor height in the tower is 3750 mm (12.3′) with a 2700 mm (8.9′) floor-to-ceiling height. The overall depth of the structural floor system is 730 mm (29″). This configuration allows 320 mm (13″) of clear space below the

Two story transfer trusses transmit the tower column loads to the existing reinforced concrete structure below.

Transfer truss top-chord members were left open for concrete placement.

steel beams for ceilings, lights, sprinklers and tenant cable tray layouts.

Six large penetrations, nearly 800 mm (31″) wide by 400 mm (16″) deep, are provided in the web of each beam to allow ductwork to be located within the structural floor depth. The beams were made deeper for deflection control, as well as to avoid stiffening the majority of the web penetrations. Only the end penetrations had a top and bottom stiffening plate.

The slab was shored at mid-span during construction by a simple lightweight truss system supported from the lower flange of the 610UB101s. This allowed full access to the floor below.

With such large clear spans, calculated deflections in the order of 60 mm (2.4″) were considered problematic. To counter this, all main steel beams were cambered approximately 40 mm (1.6″). Then, concrete was placed to the finished floor level.

Supporting Cast

The tower columns consist of pairs of 508 mm (20″) diameter tubes of 6 mm (0.25″) thick Grade 250 (36 ksi) material. These tubes included a cage of reinforcing steel installed prior to arrival on site. The columns were light and easy to handle and erect. Unfilled, they were used to support several levels of tower floors prior to being pumped (from the base) with 80 MPa concrete.

The twin tube columns were two stories high, with a welded field splice located at a convenient height above the floor slab. Every alternate column was spliced at a given floor to reduce any congestion associated with having all splices on the same level. This construction system removed the columns from the critical construction path. It also separated the steelwork and concrete crews by several floors.

On the Set

Andy Davids, director of structures at Hyder Consulting, explained, "Using steel means having a much less congested construction site—it has fewer workmen and much less vehicle traffic in and out of the gates."

The use of structural steel in this high-rise office building also provided a more flexible construction sequence. This flexibility allowed more options for Multiplex to work within the parameters imposed by the City of Sydney Council to restrict construction noise.

Davids said the key to a successful steel structure is its connections. If not well understood, connections can be labor-intensive and costly—both in the fabrication shop as well as during erection. For example, it is essential that detailers consider the fabrication sequences and accessibility for assembly at complex connections.

The typical floor beams used simple single-plate connections to simplify erection. Un-coped beams and slotted holes for attachments to the core were incorporated as additional innovations for robustness under fire conditions. Recommendations from FEMA's *World Trade Center Building Preliminary Study; Data Collection, Preliminary Observations and Recommendations* were studied and incorporated in the steel detailing.

A critical step was the accurate location of the site-located "fin" plates, which were welded to steel plates cast into the main jump-formed concrete core. After one or two floors, a four-day construction cycle was achieved. "All the steelwork for a typical floor could be delivered on 13 trucks and erection occupied two of the three tower cranes—it all went together like a big [erector] set," said Jones.

Jones added that by using two tower cranes, two small steel rigging crews could work simultaneously on opposite sides of the building. The lifting capacity was restricted to 9 metric tons (10 tons), which influenced the design of the transfer truss system and was a factor in choosing the high strength Bisplate 80 steel for parts of the transfer trusses.

According to Peter Jones, project manager from Alfasi Steel Constructions, a crew of 22, including a permanent on-site surveyor, was maintained to cover the erection and site welding of tubular steel columns and main beams, the laying of structural decking, stud welding, and moving and installing the propping and perimeter safety screen systems. Stephen Boss, site manager for Multiplex, estimated that a concrete floor system, using traditional formwork, would require a team of more than 80 workers on site. "The composite floor solution allowed the concrete pours to stop at any stage, whereas for the conventional concrete slabs, it would have been necessary to finish pouring the complete floor in one continuous operation," said Boss. This, of course, was not possible given the restricted working hours. The steel solution eliminated any risk from interrupted concrete pours.

Motion Picture

The natural frequency and damping of the floor systems were measured throughout the construction sequence to reliably determine the vibration response to human excitation. Close observations were made as more services, ceilings, and fit out were installed to see if floor damping needed to be increased. Floor and tower lateral accelerations were also being measured by staff from University of Sydney and compared with current world best practices to confirm that design performance was achieved.

Sizzling Hot

A comprehensive fire safety engineering study was conducted on the proposed building system. The study gave a holistic view of the nature and extent of probable fires, as well as a realistic assessment of the building's fire, air, egress and structural systems' behavior during such an event.

The study concluded that the proposed structural system for the typical floors could provide the required fire resistance level without the need for additional surface fire protection to the structural steel. Concrete-filled tubular compression members create an increase in compression capacity because of the confinement stresses produced under axial loads. Concrete also gives steel a fire rating.

The collapse behavior of steel columns and beam end connections under real fire conditions was taken from work done by the Steel Construction Institute in 2000. Their findings showed that traditional wide-flange column heads collapse by severe plastic buckling under elevated temperatures. Simple beam connections fail by axial contraction during the cooling phase of the fire event.

The beam to column connections on the Latitude project featured a vertical plate inserted through the composite column, allowing the beam reaction to carry into the center of the concrete column during a fire. Also, beam connections to the central core included long-slotted holes to permit beam contractions to take place freely after a fire. To provide a second path of support for the beams, beam flanges were not coped on any connection.

Closing Scene

On top of the tower is a 50 m (160') tapering slender steel spire of circular section. Slender spires are subject to wind-induced oscillation due to vortex shedding. At low wind speeds, the vortex shedding frequency is close to the natural frequency of the spire, and large amplitude motions can result due to the very low level of damping inherent in welded steel structures. A simple "hanging chain" impact damper providing about 2% damping was connected near the top of the spire. The damper—inexpensive and free of maintenance—works for wind in all directions.

Rave Reviews

The newly opened Latitude at World Square used composite steel construction to provide a competitive advantage in delivering significant potential rental returns for its early completion. Along with Sydney's Olympic structures, this building will stand as a trophy to the efficiencies and capabilities of the Australian steel construction industry to deliver a world-class project. ★

This photo provides a sense of scale for the two-story transfer trusses. Some of the twin-tube diagonals used 1100 mm (43") tubes.

Chris Chaseling is the editor of Steel Australia*, the magazine of the Australian Steel Institute. This story draws heavily from a paper by Andy Davids of Hyder Consulting and Andrew Merriel, a construction manager with Multiplex Constructions, presented at the Seventh Pacific Structural Steel Conference in Long Beach California, March 24-27, 2004, available online with this article at* www.modernsteel.com.

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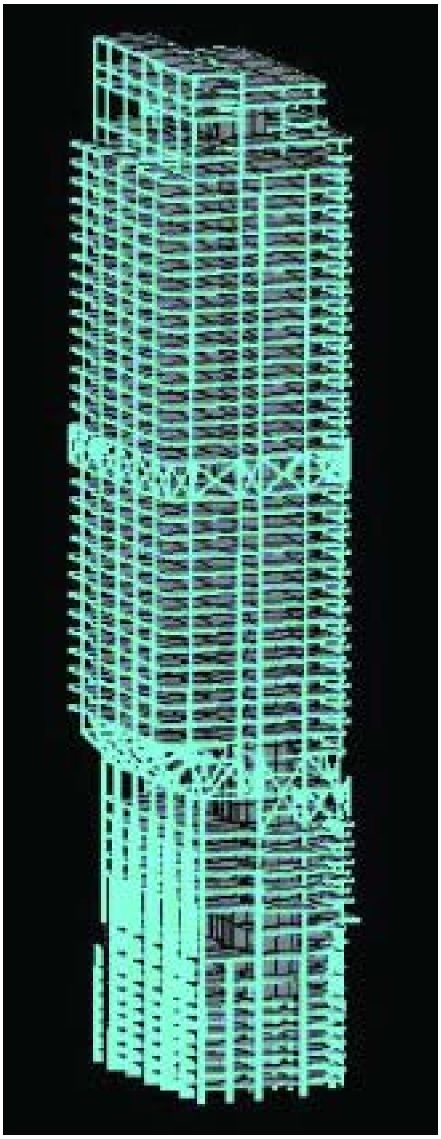

Computer model of the Latitude at World Square building.