Restoration of Quay Quarter Tower, Sydney, Australia

Overall winner of the 2023 ACI Excellence in Concrete Construction Awards

Located in the Central Business District of Sydney, NSW, Australia, the 50-story Quay Quarter Tower (QQT) is believed to be the world's largest and tallest adaptive reuse project. The design expanded the tower's size and extended its service life by 50 years—all while saving time and money and reducing the project's carbon footprint.

Quay Quarter Tower is a landmark building in the heart of Sydney, Australia, that offers new work, retail, and social experiences. The project achieved a 6 Star Green Star – Office Design v3 and is targeting a 5.5 Star NABERS Energy rating

"The Quay Quarter Tower is an excellent example of how we can reuse an existing building and save natural resources," said awards judge Roberto Stark, President of Stark + Ortiz, S.C., a consulting firm based in Mexico City, Mexico.

Built in 1976, the skyscraper was reaching the end of its life span by 2020. Rather than demolish and rebuild, the project team chose to upcycle it. They retained 90% of the existing core structure and 65% of the beams, columns, and slabs, which resulted in a savings of 12,000 metric tons (13,230 tons) of embodied carbon. When compared with conventional demolition and rebuilding, the adaptive reuse strategy shaved construction time by 13 months and project costs by 140 million AUD.

Adaptive reuse at such a large scale comes with several engineering and construction complexities. A construction sequence that involved simultaneous demolition and construction activities added another layer of complexity to the project. Stark gave the project team high praise for identifying the important aspects to be considered when embarking on such an expansion.

Project Details

The QQT project involved the redevelopment of the 45-year-old reinforced concrete building along with the addition of new structural elements—both vertically and horizontally. The project team included developer/owner AMP Capital; engineering firms BG&E, ADG Engineers, and Kasina Consultants (peer reviewers); general contractor Multiplex Construction; architectural firms 3XN Architects and BVN Architecture; concrete contractor De Martin and Gasparini; and concrete supplier Boral Limited.

Construction work included top-down demolition of nearly one-third of each floor, which enabled the extension of concrete core walls (the main lateral stability system) and composite floor plates on the north side of the existing core walls. Every floor was lengthened by about 100 ft (30 m) to the north, which provided an additional 10,800 ft^2 (1000 m^2) of office space per level. Five stories were added on top of the building, increasing its height by approximately 100 ft.

Connecting New Concrete to Old

Concrete was the project team's building material of choice for several reasons, said Reza Hassani, Senior Associate Structural Engineer at BG&E. The material's high strength, stiffness, and durability properties met project requirements to ensure lateral stability of the high-rise. At the same time, using concrete enabled ease of construction as well as cost and time efficiencies.

However, a major concern was that shrinkage of the fresh concrete in the new construction would pull the existing core and its adjacent columns downward, affecting all facets of construction, including the elevators and the façades. To minimize these adverse effects, the team used a special concrete mixture with low shrinkage, low hydration temperature, and high elasticity.

A pour strip was introduced between the new and existing core walls to leave a temporary gap between the building's old and new portions. The pour strip was fully connected after 42 days, which allowed the new construction to substantially settle before tying the old and new together. To minimize the column shortening in the new structure, the team used concrete-filled steel tubes with low-shrinkage concrete.

Modeling and Testing

"The greatest challenge was predicting the differential horizontal and vertical movements between the old and new towers in the design process," Hassani said. "We overcame this by conducting a rigorous structural analysis along with structural monitoring throughout construction to gain more knowledge about the building behavior and design for the predicted building deformations."

The project team developed a four-dimensional (4-D) time-dependent nonlinear staged finite element model to analyze the structure from its first construction in 1976 to the end of its new life in 2070. The model considered the in-place mechanical and time-dependent material properties of the existing concrete, including strength, modulus of elasticity elements, shrinkage, creep, and aging. To assess the in-place material properties of the existing building, the team used several destructive and nondestructive test methods, including:

- Performing carbonation and chloride diffusion tests to investigate the durability of the existing concrete and ensure the structure's design life could be extended for the next 50 years;
- Installing accelerometers, strain gauges, and inclinometers to measure structural accelerations, strains, and displacements;
- Employing conventional methods like surveying; and
- Taking about 1600 core samples from the concrete elements to determine the mechanical properties of the concrete.

The data captured were used to calibrate the structural model at several milestones. The digital twin became a true representative of the structure, and the calibrated model mitigated the risks associated with existing buildings and dealing with unknown structural parameters. From the detailed structural checks, the team identified where reinforcement was needed to upgrade the structural performance of key elements and extend the overall design life.

As a result, the core walls were strengthened by using externally bonded carbon fiber-reinforced polymer (CFRP) laminates and steel plates to increase their tensile and compressive/shear strength, respectively. The coupling beams were strengthened for axial, shear, and flexural actions with an innovative hybrid system that contained CFRP and steel plates. The capacity of the reinforced concrete columns was improved through concrete jacketing.

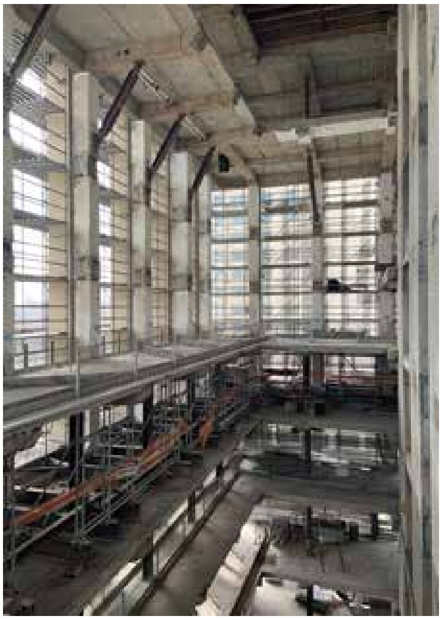
Setting a New Standard for Sustainable Design

"This project was both innovative and creative. The project team of architects, engineers, and contractors addressed many unique challenges to deliver a world-class sustainable building," said awards judge Ron Burg, former ACI Executive Vice President.

The upcycled tower was completed in 2022 and was built with future transformation in mind. Now standing 709 ft (216 m) tall with a doubled floor-plate size, the structure provides an additional 480,000 ft^2 (45,000 m^2) of new office space. The project team's use of innovative materials and solutions has set a new global standard for the conservation and service life extension of tall concrete buildings.

"This project is now a benchmark for the sustainable design of future high-rise buildings," Hassani said.

Selected for reader interest by the editors.



Quay Quarter Tower under construction