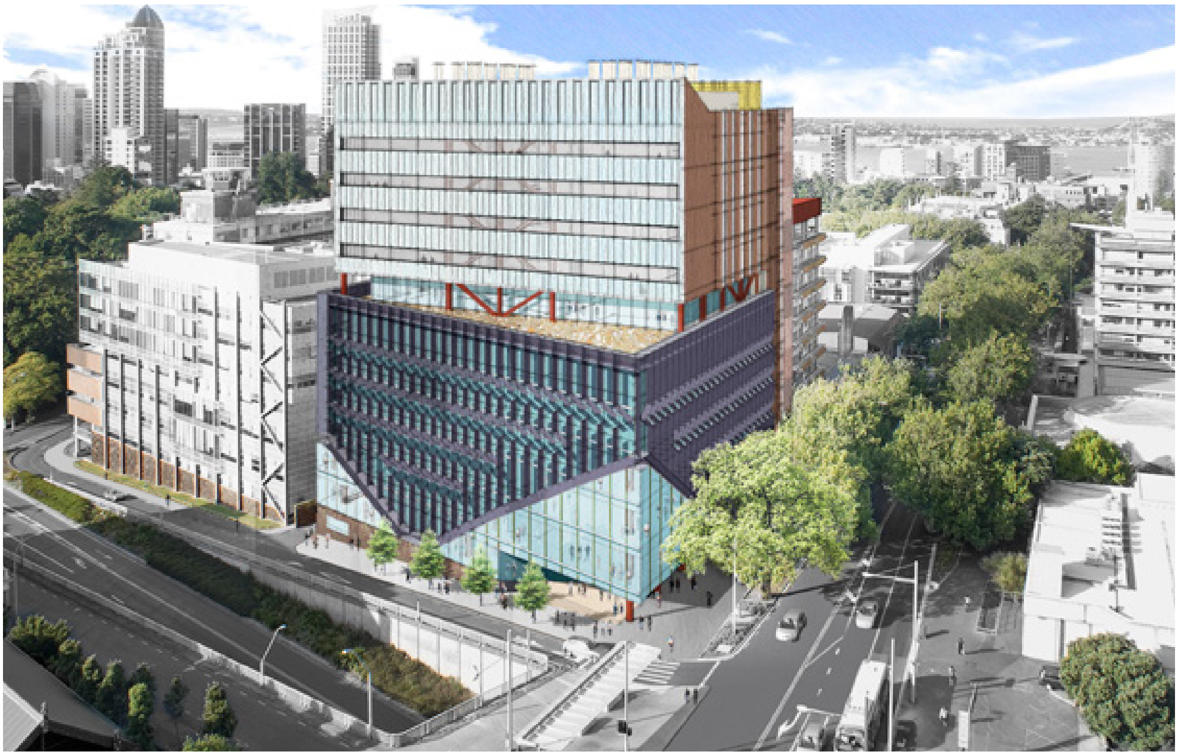
SCNZ STEEL CONSTRUCTION NEW ZEALAND

CASE STUDY: UNIVERSITY OF AUCKLAND SCIENCE TOWER

THE SCIENCE OF STEEL



In 2010 the University of Auckland embarked on a five-year project to upgrade its Faculty of Science buildings. The $290 million redevelopment consisted of the refurbishment and seismic strengthening of two existing buildings, construction of a new link structure, and demolition of two buildings to make way for the new Science Centre Tower.

The result: a state-of-the-art research and teaching facility, and a new entranceway to the University.

The existing three-storey south podium Chemistry building on the corner of Symonds and Wellesley streets was demolished and a new 13-storey tower erected using the original structure's column grid and foundations. The new 23,500m^2 building, coupled with the revamp of the adjacent tower building, brings the total floor area to almost 38,000m^2.

A staged construction programme was rolled out to ensure the Faculty's operational continuity; decanting and enabling works were completed under tight timeframes that revolved around the academic calendar year.

Engineering

The structural skeleton consists of cellular beams and welded columns to optimise the use of steel. Structural steel was chosen for two primary reasons. First, the University of Auckland wanted to avoid any disruption to its post-graduate lab operation in the event of an earthquake. As a result, the new Science Tower is a steel-braced frame structure featuring buckling restrained braces (BRBs). To retain the Science Centre's open plan structure, the BRBs were mounted on the perimeter of the building.

The significance of BRBs is that they behave consistently in both compression and tension. They are manufactured with two main components that perform distinct functions while remaining decoupled: the load-resisting element is a steel core that is restrained against buckling by an outer casing filled with grout. If damaged in a severe earthquake, BRBs can be easily removed and replaced, providing crucial business continuity.

The Science Tower is one of the first buildings in New Zealand to be designed using BRBs, and the first to procure them from the USA. Structural engineering firm Beca undertook a significant pre-qualification process to provide assurance that what it was specifying could be built. As part of this exercise, Beca drew on the collective knowledge of six New Zealand fabricators relating to techniques such as welding, bolting and erection.

Key Facts

- **2,600 tonnes of structural steel**
- **600 tonnes of cellular beams**
- **13-storey building**
- **58m-high structure**
- **110 buckling restrained braces**
- **23,500m^2 gross floor area**
- **4,900m^3 of concrete and 960km of rebar**
- **$140 million budget for the Science Tower**
- **$290 million budget for the entire Science Faculty upgrade**

The Team

Owner: The University of Auckland
Structural Engineer: Beca
Architect: Architectus
Builder: Fletcher Construction
Structural Steel Fabricator: Grayson Engineering

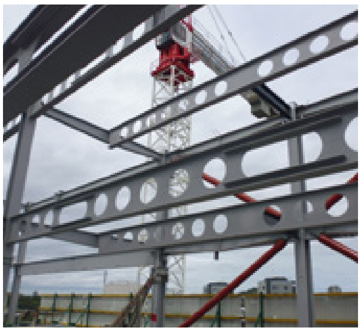
The second driver to use structural steel was to enable the tower to be erected using the former building's grid system – the architect was keen to retain the open space it allowed. So the old column locations matched those of the new columns. It meant working with the existing bell-shaped foundations of the demolished three-storey, reinforced-concrete building – removing them would simply be too difficult.

Designing the support structure for a 13-storey tower on foundations designed for just three storeys was no easy feat. Steel's light weight made it possible. The foundations had to be strengthened to accommodate the additional weight – the strengthening required is proportional to the increase in weight. Less strengthening of the foundations was necessary because lightweight structural steel was used.

And because the existing 1960's foundations didn't comply with today's codes, they had to be strengthened with piles on either side – pile caps were created to join them all. A delayed settlement joint – made from a structural steel cap – was employed so that the existing pile wasn't exposed to the additional weight before it was adequately supported by new piles.

"THE COMPLEXITY OF THIS PROJECT REALLY LENT ITSELF TO USING LOCALLY FABRICATED STRUCTURAL STEEL. THEIR EARLY INPUT WAS INVALUABLE, AND BEING ABLE TO SIT DOWN ONE-ON-ONE GAVE US CONFIDENCE THAT THE LOCAL FABRICATOR WAS GOING TO PROVIDE PRODUCT OF A HIGH SPECIFICATION AND HIGH QUALITY."

VIJAY PATEL, ASSOCIATE – STRUCTURAL ENGINEERING, BECA



Fabrication

Steel fabricator Grayson Engineering was first introduced to the project when the company was invited to consult on the use of BRBs in the tower's construction. The team coordinated closely with structural engineer Beca and head contractor Fletcher Construction; sequencing and methodologies were discussed and established early on.

From a fabrication perspective, the project offered plenty of complexity, including innovative seismic technology with multiple grades, multiple connections and strict quality assurance processes. The BRBs were installed on site and, to begin, were bolted at just one end; the other end was only fixed in its final position after the rest of the building was complete. This allowed for the braces to be installed without attracting gravity loads, which would have increased the size of the braces dramatically. Allowing the gravity load to be taken by the gravity steel frame enables the BRBs to resist lateral loads only.

Additionally, the structure had to accommodate a significant amount of services and allow for flexibility, without compromising the structural integrity. To maximise the building floor area, an integrated structure-services solution was developed using cellular beams.

The high strength-to-weight ratio of cellular beams allows for the design of lighter, more cost-efficient steel structures. Importantly, the major dimensions of a cellular beam are flexible and are commonly used for long-span secondary beams in larger buildings for services. For this project, cellular beams allowed the multitude of services to be networked through them. To maximise the structural depth available, services were reticulated through 800mm-deep cellular beams with 500mm-diameter penetrations at regular centres. The beams span either 13.4m or 14.8m to provide column-free spaces below. The design ensures services can be reconfigured at any time to meet the Faculty of Science's future needs.

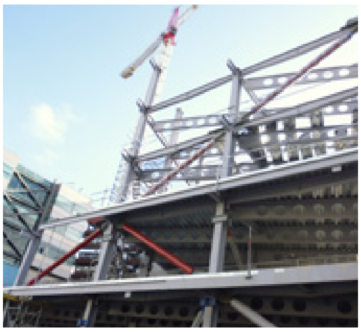
Cellular beams are a UK technology. In New Zealand, Grayson Engineering is the sole licence holder for the technology, therefore, the only local provider of cellular beams.

Another feature of the build is the steel and composite metal deck flooring. One benefit of metal decking is that, because there is no need to prop it, it's quick to install. There are, however, challenges with pouring concrete onto metal trays across beams up to 14.8m in length: when the concrete is dry it increases the strength of the beam, but when wet it's a load that causes the beam to deflect.

Consequently, the design called for pre-cambers – beams fabricated with a curve that disappears under the full weight of the structure. The pre-cambers are created during production of the cellular beam. First, a plasma cutter is used to cut the beam into two T-sections. Next, the beams are positioned in jigs and bent to the desired deflection profile prior to being welded together. The pre-cambered beams offset deflections. The degree of curvature had to be precise to ensure accurate levels in situ. Multiple checks were completed, first in the factory then on site once the loads were applied.

Steel supports innovation

After considerable research into footfall-induced vibration, Beca imported the damping system Resotec, which was originally developed by UK firm Arup to combat 'Millennium Bridge Syndrome'. In a first for New Zealand, the thin rubber damping membrane was fitted between the soffit of the steel decking and the top flange of the steel beams. In these areas there is no mechanical link between the floor and the supporting structure, allowing the two to move independently during vibration-induced movement.



Given the high degree of seismic engineering involved, precision and verification were critical. Multiple grades of steel were employed on the job and each required a certificate of authenticity; independent weld inspections were carried out by a third party; and in the interests of transparency, and in line with all projects completed by a New Zealand fabricator, a quality manual was produced for the project. Product traceability is assured.

The project was typical of most inner-city sites where storage and laydown were extremely limited. Grayson broke the construction into phases, packages of work and, ultimately, truckloads. As a local fabricator, Grayson could work with the project team to sequence the fabrication, store product and deliver to the construction site when required.

"UNLIKE OFFSHORE FABRICATORS, WE WERE ABLE TO FABRICATE IN SEQUENCE, STORE PRODUCT ON OUR OWN SITE AND DELIVER AS REQUIRED BY THE BUILDER. EVERY ELEMENT WAS DETAILED BY OUR TEAM – EVERY COLUMN, BEAM AND CONNECTION. THEN WE SENT THE SHOP DRAWINGS TO THE CONSULTANTS FOR APPROVAL PRIOR TO FABRICATION. IT WAS LIKE A MECCANO SET OF THOUSANDS OF PIECES."

COLIN BERGER, PROJECT MANAGER, GRAYSON ENGINEERING

Construction

The Science Centre wasn't just another project for Fletcher Construction – the company built the old science centre some 50 years prior. Demolishing its own work to create a new structure was an interesting experience for the team. Fletcher replaced the heavy reinforced concrete structure with a steel frame, curtain wall and precast façade, and composite flooring.

Unlike concrete, which progresses floor by floor, steel allows multi-storey 'jumps'. Two-storey jumps are typical but this project, impressively, featured four. The steel flooring trade prepared four floors and handed over to Fletcher to pour the concrete. The process was repeated until the team reached the top of the tower. Steel allowed large floor-to-floor spans of approximately 15m, and cambers of 40-45mm.

Planning helped the build team accelerate the internal fitout. CAD-based 3D-modelling platform Revit was used extensively, allowing site clashes to be resolved during the shop drawing phase. With all trades working from the same set of as-built drawings, coordination was easy. Rather than programming the trades' time on site in waves, Fletcher had multiple subbies working in parallel without conflict. It also meant Fletcher could visit site with the drawings loaded onto a tablet, and visually inspect that the installation of services corresponded to the design intent. It offered the opportunity to identify issues early, saving time.

Fletcher worked closely on shop drawings with local fabricator Grayson Engineering and the fabricator's counterpart in the USA, CoreBrace. Grayson called on the specialist services of Cadtec to produce the shop drawings. CAD details were shared, checked and double checked. The biggest challenge for the team was retaining accuracy when swapping between metric and imperial measurements. And because the Science Centre houses laboratories, the roof features a complex array of flue stack assemblies – all prefabricated – to service the 150-odd fume cupboards. Their installation was a demonstration of the speed of erection steel offers – they went up during the course of one morning, as opposed to several weeks.

"I LIKE STEEL'S PRECISION. IT DOES TAKE A LOT OF PRE-PLANNING AND PRE-CHECKING, BUT ONCE THE SHOP DRAWING PHASE IS COMPLETE ANY ISSUES WILL HAVE BEEN RESOLVED, SO WHEN IT COMES TO SITE IT FITS REALLY WELL. WHEN YOU'VE GOT THAT MANY HOLES TO LINE UP YOU HAVE TO GET IT RIGHT; IT WAS REALLY WELL DONE, LIKE CLOCKWORK."

CHRIS TUXFORD, PROJECT MANAGER, FLETCHER CONSTRUCTION