A DECADE OF STEEL

New Zealand's structural steel industry has come a long way in the past 10 years. Advances in steel design and fabrication technologies have led to more innovative solutions and, combined with the material's resilience and the local industry's proactive approach to quality, compliance and sustainability, structural steel is now the go-to material for the design and construction of multistorey buildings.

But it wasn't always this way. The tipping point was the devastating Canterbury earthquake of 2011.

Pre-earthquake, Christchurch was a concrete city built using aggregate that was readily sourced from the nearby Waimakariri River and its surrounds. With the exception of a few 'radical' structural steel buildings, most high-rises were based on a concrete moment frame structure.

"The earthquake, when it struck, was about double the intensity that was designed for. Yet, aside from some minor issues, steel-framed buildings generally performed very well," says Professor Gregory MacRae, Civil & Natural Resources Engineering, University of Canterbury. "Concrete structures, on the other hand, while they generally safeguarded lives, many later had to be demolished."

It was steel's strength and ductility that helped it to withstand the primary shockwave and the series of more than 11,000 aftershocks that shook Canterbury.

By the time of the earthquakes, research had concluded that steel buildings, when carefully designed and detailed, functioned well and delivered resilient structures. This was confirmed post-earthquake as part of the Canterbury Earthquakes Royal Commission into the performance of all construction. It became clear that structural steel offers one of the best structural solutions – it performs well both in service as part of its day-to-day operations and in strong earthquakes.

It set the stage for the material going forward and led to a massive uptake of structural steel technology in the Canterbury rebuild, to the point where its market share rose from virtually nil to more than 80 percent of building area today.

Structural steel has dominated the Christchurch rebuild. Clockwise from top left: 151 Cambridge Terrace (Deloitte); The Crossings Retail Precinct; Spark Building, Cathedral Square; Rutherford Regional Science & Innovation Centre, University of Canterbury; Christchurch Bus Interchange; PwC Centre.

In its wake, much of central Christchurch was demolished and a new, more resilient city has since emerged. The event and its aftermath changed the culture of construction, not just in Christchurch but nationwide.

"If you include gravity systems, which feature steel, the figure is closer to 95 percent," says MacRae.

A city once dominated by concrete has been rebuilt in structural steel.

WHY STEEL?

Multiple factors worked together to put steel in pole position to respond to the Christchurch rebuild. As well as steel's proven seismic performance, there were advances in low-damage seismic technology that connect easily to steel structures, the advent of compatible and lightweight flooring systems, and economical new fire design methods. Other factors included steel's low price, light weight and speed of erection.

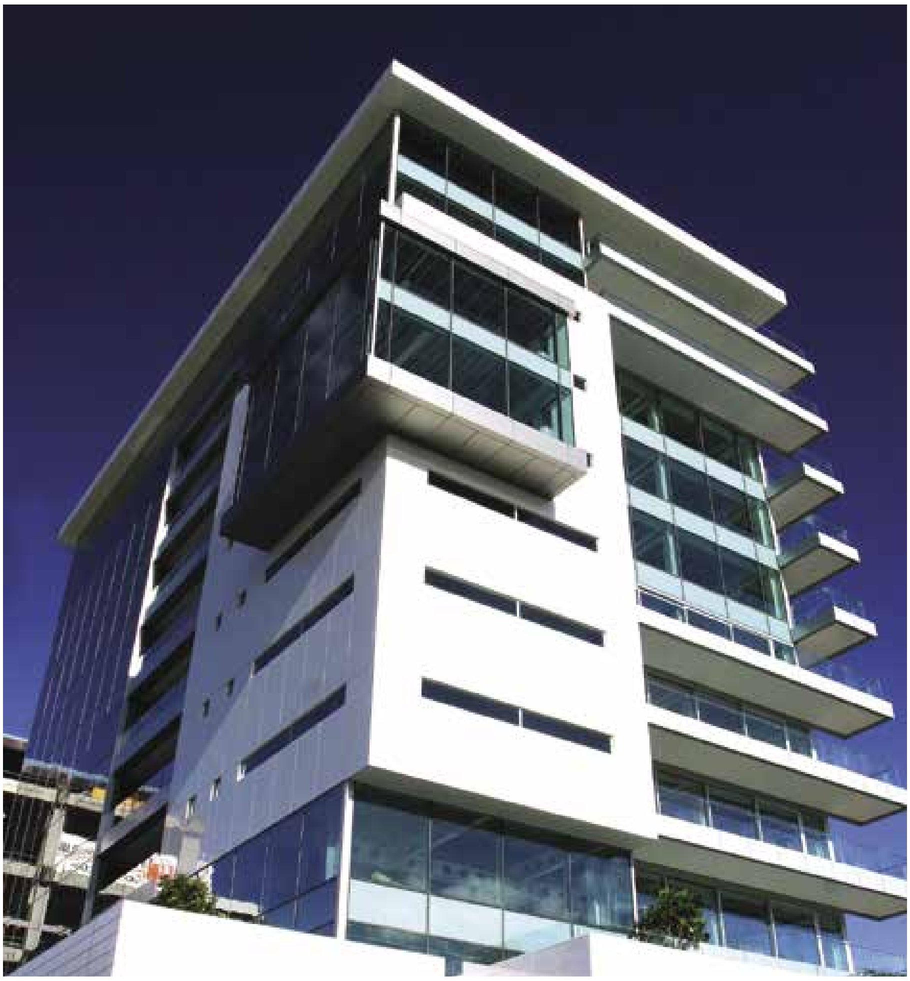
What's more, says Beca Technical Director Sean Gledhill, structural steel was consistently able to satisfy client design brief requirements for resilience, performance and functionality.

"Its ability to provide clear spans and deliver clear unobstructed space meant it could respond to the form and function of an architectural brief, and it could be used more sparingly due to its strength and stiffness than concrete or timber."

At the time, it allowed buildings to be more rapidly designed and delivered than other materials that were available.

"Steel had a mature supply chain, and fabrication and QA processes. It enabled engineers to quickly and effectively develop and cost solutions for clients," says Gledhill.

Learnings from Christchurch have been applied nationwide. In the past 10 years, other New Zealand centres have seen substantial redevelopment, and much of it has been conceived in structural steel to the point where the material now accounts for 50 percent of the market share nationwide.



Above: It was steel's strength and ductility that helped the 12-storey HSBC Tower withstand the primary shockwave and the series of more than 11,000 aftershocks that shook Canterbury. It has been described as the safest multilevel building in Christchurch, having incurred no structural damage during the earthquakes, and reoccupation began just three months after the February 22nd 'quake.

Below: Steel has the ability to deliver wide spans and clear unobstructed space. Auckland International Airport's original 1970's terminal was futureproofed with structural steel, allowing the structure to be repurposed and expanded. The new terminal has double the dwelling space without increasing the overall footprint. (Pictured, Auckland International Airport expansion.)

"STEEL IS INHERENTLY LIGHTWEIGHT, ALLOWING REDUCED FOUNDATIONS, AND IT PROVIDES A PRACTICAL SEISMIC SOLUTION. AS A RESULT, THERE WAS A CLEAR SHIFT TOWARDS STRUCTURAL STEEL AND THE CHRISTCHURCH CBD IS NOW DOMINATED BY THE RESILIENT MATERIAL ."

SHAWN CUNNINGHAM, NATIONAL ENGINEERING MANAGER, SOUTHBASE CONSTRUCTION

RESILIENCE

"Resilience became the buzz word in the wake of the Canterbury earthquakes," says Mitchel Cantlon, Associate Principal, Warren and Mahoney.

Organisations across the board – institutional, public and private – want design-led outcomes that are enduring, sustainable and resilient.

"They want structural solutions that can withstand earthquakes, protecting the building's occupants and ensuring business continuity by minimising major damage and allowing rapid repair and reoccupation," says Cantlon.

Unsurprisingly, the earthquake had a huge impact on the uptake of low-damage technology. According to MacRae, it provided an impetus to design structures that behave better than the nominal provisions in the Building Code.

"The term 'low damage' was coined in New Zealand yet the industry has struggled to clearly articulate what the term means. In its formative years it was a structure that had almost no damage and could be used soon after a major shaking event. This could also be achieved with easily replaceable devices that acted in a reliable way and protected the structure. Post-Canterbury, the need to have a low-damage building as a whole was emphasised. It relates not just to the structural framing, but also to the floor slab, foundation and the non-skeletal elements within the system such as internal partitions, ceilings, piping and façade components," says MacRae.

Importantly, he says, engineers are only required to design buildings for life safety, otherwise known as a 'code-minimum approach'. A low-damage design goes beyond that to satisfy a client's desire for economical and dependable buildings that can be quickly repaired post-earthquake and allow owners and tenants to reoccupy a building soon after.

Part of the attraction of structural steel is the low-damage solutions it offers. "This is thanks to steel's ability to undergo large earthquake-induced deformations in a controlled and predictable manner," says MacRae.

It's quite a task for engineers to consider the range of earthquakes that might occur within a 40km radius that are understood to substantially affect buildings, says Gledhill. "The Building Code helps engineers to design for this but to conceive a building that can be quickly and easily returned to service is not a straightforward task."

Gledhill says it's pleasing to see engineers improve their knowledge and the uptake of low-damage technology has continued to grow. The Ministry of Business, Innovation and Employment (MBIE) is working with industry to produce a low-damage design guide to assist engineers to understand how to appropriately deploy the technology.

Structural steel solutions have come to the fore with new low-damage technologies.

"Whether it's the primary component or part of a hybrid structure, steel is always able to play a key role by being more reliable and dependable than other materials. It offers more certainty to engineers and is used in locations where earthquakes are known to generate damage and it's desirable to dissipate energy," says Gledhill.

"The rebuild offered the opportunity to try new things," says MacRae, adding that clients wanted a point of difference, so various systems were installed in different buildings. New steel buildings boast a range of lateral load-resisting systems, including buckling restrained braced (BRB) frames, moment-resisting frames, eccentrically braced frames, concentrically braced frames and rocking steel frames. Most new base-isolated buildings are supporting steel superstructures, while BRB frames feature in nearly 40 percent of the total new constructed floor area of non-base-isolated buildings.

"THE LOW-DAMAGE APPROACH WILL HAVE HUGE SOCIETAL BENEFITS AND LEAD TO BUSINESS CONTINUITY, LOWER REPAIR COSTS AND THE ABSENCE OF RELOCATION COSTS."

PROFESSOR GREGORY MACRAE, CIVIL & NATURAL RESOURCES ENGINEERING, UNIVERSITY OF CANTERBURY

Above: Investment in fabrication technology and workshops, and the modern approach of simple bolted connections, has improved productivity in New Zealand's structural steel industry.

Right: Rather than viewing visible structural elements as an unwanted intrusion, exposed structural steel can lead to expressive design outcomes and provide visible reassurance to building occupants that they are in a safe and robust building.

In terms of the architecture, Cantlon says New Zealand's more rigorous seismic requirements haven't radically changed how architects design buildings, but it's sharpened architects' understanding of the structural intent and made them more attuned to what engineers want to achieve.

"A direct result is that we have to accommodate more visible structural elements when using steel," says Cantlon. "Rather than viewing the structure as an unwanted intrusion, it can lead to expressive design outcomes and, at the same time, provide visible reassurance to building occupants that they are in a safe and robust building."

Another big change in the last 10 years is the advent of retrofitting structures for earthquake strengthening purposes.

Many hundreds of buildings were lost to the earthquakes – they either collapsed as a result or were deemed unsafe and had to be demolished. But thousands of buildings that fall far short of current standards remain standing around the country. These buildings must be upgraded to be safer and more resilient, in line with the stringent new National Building Standards.

"So, there has been a big move towards the use of steel for earthquake strengthening applications – steel is an integral part of retrofitting and upgrading existing buildings to meet the new standards, which would otherwise have to be demolished," says Cantlon. "This is especially important in preserving heritage buildings, the Christchurch Town Hall being a prime example where structural steel bracing has been sympathetically incorporated to preserve an important piece of our cultural heritage."

Adaptive reuse is another emerging trend, whereby a building's life is extended by altering, upgrading and renovating it to suit a range of new uses.

"Adaptive reuse is an exciting space and one of increasing interest to developers as they look at the development potential of existing building stock. Older commercial buildings that are no longer considered suitable as A-grade office space are being converted to residential apartments," says Cantlon. "Steel's inherent resilience, coupled with the ease with which the material is modified, makes structural steel ideally suited to this sustainable alternative to a new build."

Top Left and right: Another big change in the last 10 years is the advent of retrofitting structures for earthquake strengthening purposes. (Pictured, Chinese Embassy, Wellington.)

Below: Adaptive reuse is an emerging trend, whereby a building's life is extended by altering, upgrading and renovating it to suit a range of new uses. (Pictured, The CAB, Auckland, formerly the Civic Administration Building.)

COLLABORATION IN THE DRIVER'S SEAT

When the earthquake struck, the Christchurch construction industry was still mired by the effects of the global financial crisis. The downturn had put a damper on building projects in the commercial and industrial sectors nationwide.

"People were 'waiting and seeing'," says Frank Van Schaijik, Managing Director, John Jones Steel. "It took a couple of years post-earthquake for businesses to have the confidence to pursue their stalled growth plans. When that happened, demand in the construction industry shifted from assessment and repair work in the Garden City to new builds. By that time, however, the lull had taken its toll on local resources.

"For the steel construction market, it strengthened existing relationships and led to considerable collaboration between South and North Island structural steel contractors to deliver on Christchurch rebuild projects. It was a formula for success, which the industry has continued to adopt throughout the country."

Today, the North Island is particularly buoyant with significant growth in Auckland, Hamilton, Tauranga and Wellington, and the 127-strong network of structural steel fabricators is once again pooling resources to satisfy demand.

The structural steel industry has also embraced collaboration amongst the wider industry in the form of early contractor involvement (ECI). The approach has formalised what many in the industry were already doing. ECI allows subcontractors to add real value to the project from the get-go, by collaborating on the design with the consultants and lead contractor to explore buildability, timeframes and risk, and achieve the best outcome for the project.

"THE SCALE OF TODAY'S INDUSTRY HAS LED TO SPECIALISATION. TEN YEARS AGO THE INDUSTRY WAS CHARACTERISED BY ALL-ROUNDERS, INDIVIDUALS THAT COULD CUT THE STEEL, WELD AND ASSEMBLE IT, TAKE IT TO SITE AND ERECT IT. TODAY, WE HAVE DEDICATED STEEL FABRICATORS, WELDERS, SPRAY PAINTERS, CNC OPERATORS, DRAFTSMEN, TRUCK DRIVERS AND CRANE OPERATORS. THIS FOCUS HAS BUILT EXCELLENCE INTO OUR PROCESSES."

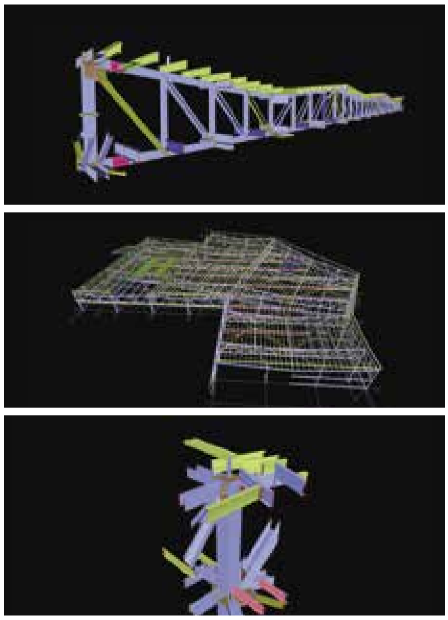
FRANK VAN SCHAIJIK, MANAGING DIRECTOR, JOHN JONES STEEL

TECH SPEAK

Another impact of the earthquakes was the momentum it provided to initiatives already underway in the structural steel industry. One was the industry's investment in workshops and cutting-edge fabrication technology, which led to a significant increase in local structural steel fabrication capacity of 120,000 tonnes.

3D-modelling technology, too, has been a gamechanger. Digital design tools have evolved considerably in the past decade, enabling design consultants and structural steel contractors to produce and erect increasingly more complex structures and geometries. Building information modelling (BIM), for example, is becoming a default tool allowing architects, engineers and contractors to work collaboratively to achieve more sophisticated building outcomes. And BIM provides superior analysis that can fine tune a building design to eliminate waste where possible and produce highly efficient structures.

"The use of digital technology has had a huge influence on quality assurance and the design process. Even before the earthquakes, the structural steel industry was well ahead of the curve in its use of 3D modelling. Now, building information modelling is widespread in the industry, to the benefit of all," says Shawn Cunningham, National Engineering Manager, Southbase Construction.



Above: Digital design tools have evolved considerably in the past decade, enabling design consultants and structural steel contractors to produce and erect increasingly more complex structures.

BIM provides clarity and certainty for all disciplines in the design and construct space by allowing the seamless transfer of design and detailing between all parties.

Another advance was the advent of off-site steel fabrication and its high degree of sequencing and programming. The steel can be designed, detailed and fabricated very early in the construction process.

"THE LOCAL STRUCTURAL STEEL INDUSTRY HAS BECOME MORE SOPHISTICATED AND INNOVATIVE IN ITS DELIVERY. WE ARE INCREASINGLY SEEING A HIGHER LEVEL OF COLLABORATION AND ENGAGEMENT DIRECTLY WITH STEEL SUBCONTRACTORS IN SEEKING EFFICIENT, HIGHLY ACCURATE DESIGN-LED OUTCOMES."

MITCHEL CANTLON, ASSOCIATE PRINCIPAL, WARREN AND MAHONEY

QUALITY AND COMPLIANCE

Crucially, the earthquake, in conjunction with the 2010 Stadium Southland roof collapse, also ignited the structural steel industry's work in the quality and compliance space.

Steel Construction New Zealand's (SCNZ's) industry-led quality scheme, Steel Fabrication Certification (SFC), is a cornerstone of the industry's quality and compliance activities. Launched by the industry body in 2014, the scheme provides independent, expert certification of New Zealand fabrication companies. Ninety percent of the sector's annual output is now delivered by SFC-qualified fabricators who manufacture structural steelwork to international best practice.

The Structural Steel Distributor Charter is the latest quality assurance initiative led by the structural steel industry. The Charter, which complements SFC, ensures that structural steel supplied to the local steel construction sector is sourced using best-practice procurement. It represents a mark of excellence for structural steel distributors in New Zealand.

These initiatives provide procurers and specifiers – such as engineers, architects and head contractors – with certainty of product quality and significantly reduced compliance risk. This is particularly important at a time when independent on-the-ground quality assurance of prefabricated structural steel sections procured from low-cost offshore sources is difficult to achieve.

"The seismic code has changed considerably post-quake, and with it there is more governance regarding quality assurance (QA), from both a central and local government perspective. Testing procedures are far more advanced and the QA documentation is more robust," says Cunningham.

"It's not just ticking a box, it's actually making sure that those QA procedures are followed through and documented correctly across all parties involved in the design, build and compliance. It ensures that there is a paper trail so that it can be traced back to its source in the event that something does go awry."

WHAT'S NEXT?

"Society, our economy and reducing our future carbon footprint require the industry to consider recoverable, resilient buildings that perform beyond a code-nominal approach," says Gledhill. "The starting point will be MBIE's low-damage design guideline followed by its uptake by industry, future reviews, and ongoing research, knowledge gains and refinement."

The cost of resilient construction is the same or very slightly more than traditional building, so it is actually a matter of political will, argues MacRae.

"It doesn't need to be fancy; it doesn't need to be high tech. With new technology, it is simply important that it's robust and works in practice. Standardisation and quality assurance are essential, and industry players need to remain up to date in this space so they can build the best possible structures."

Several organisations are helping to provide the tools industry needs: SCNZ is doing its part by consulting closely with engineers and providing a large amount of design guidance to assist building practitioners; the Heavy Engineering Research Association is developing sought-after design examples; the University of Canterbury offers a postgraduate course on advanced steel and composite construction, which describes new and emerging systems; and the University of Auckland and AUT are collaborating to provide resources in this space, including the delivery of a joint Structural Engineering Society New Zealand (SESOC) seminar.

Going forward, says Gledhill, it will be important that people are open minded, that they consider the benefits of any system and any material, and that they understand and adopt new technology that is fit for purpose.

"Buildings need to be developed with clearer intent around whole-of-life material use – how the structure will be designed, built, owned and operated. But more thought is needed to plan for their recycling and, importantly, recovery at the end of its life. Structural steel is a material that can be recycled and reused," says Gledhill.

"Reducing our aspirations and focusing on quality rather than quantity is part of the solution. It means doing what we do well, working smarter and using materials more efficiently. Steel has an important role to play."

"WHERE WE ARE ABLE, WE SHOULD ALWAYS TRY TO DO BETTER THAN CODE-MINIMUM SEISMIC PERFORMANCE – BEYOND LIFE SAFETY. A BUILDING IS MORE SUSTAINABLE IF IT IS RECOVERABLE AND OUR DESIGN RESPONSE SHOULD REFLECT THAT. THE BEST USE OF RESOURCES IS USING SOMETHING OVER AND OVER AGAIN. STEEL ENABLES THIS."

SEAN GLEDHILL, TECHNICAL DIRECTOR, BECA

Above: The structural steel elements of The CAB were found to be very sound. Reusing such a large portion of the building vastly reduces its carbon footprint. (Pictured, original 1950's steel in The CAB, Auckland.)

Right: Worldwide it is estimated that 90 percent of steel from demolition sites is returned to steel mills for recycling.

RESEARCH

At the time of the Canterbury earthquakes, considerable thought was being invested in what the future of new buildings might look like.

"Work was already underway to implement updated building designs in line with the seismic code of the day, and engineers were exploring the use of different materials, including structural steel. Even then, steel was gathering momentum," says Gledhill.

There were three main areas of government-funded research related to structural steel buildings before the earthquakes: new structural systems, retrofit and addressing issues with current standards. MacRae says the earthquakes proved this research to be very relevant.

Before the earthquakes, both the concrete and steel industries explored using different types of technology to dissipate earthquake energy as it gets into a structure. From dissipaters and friction devices to viscous dampers, whatever the device required to connect it to the structure.

"Because the device has steel components, it's typically easier to connect to a steel structure than to a concrete structure," says MacRae.

Another piece of research explored flooring systems for long spans. The result was an economical, composite steel floor decking system that allows large, uninterrupted interior grids to be easily created with fewer beams. Lightweight cold-rolled steel sections in a trapezoidal shape are fixed on beams and concrete is cast onto them.

The quick and effective process is ideally suited to steel buildings.

MacRae adds that a new area for research involving post-earthquake assessment and repair also became apparent.

"What happens to a building that sustains damage following an earthquake? Leave as is, demolish the structure or repair it? There is a multimillion dollar difference between pulling it down and leaving it. The new area of research is focused on how to make that decision. It involves accurately evaluating how much damage it has sustained and how much 'earthquake life' the building has remaining. It's very challenging because there are lots of variables, and design and construction uncertainties. Not everything can be measured."

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