Moving to low-damage design

Is Christchurch about to repeat the same old mistakes? Simple and cost-effective low-damage design could save the city in another disaster.

BY STEPHEN HOGG, TECHNICAL DIRECTOR - BUILDINGS, AURECON

UFP plate energy dissipator.

FOLLOWING THE CANTERBURY earthquakes, many commercial building owners were dismayed by the extent of damage to their supposedly earthquake-proof properties.

The problem was the industry's fundamental approach to building design. Since the 1970s, it has been widely understood that it's not feasible to design a rigid building to resist earthquake forces.

Instead, buildings were designed not to resist, rather to yield and break in a controlled manner. So failure mechanisms were engineered, and in 99% of the demolished buildings in Christchurch, those failure mechanisms worked perfectly. However, it also rendered most of the city's commercial buildings completely unusable and irreparable.

Design philosophy rethink

Low-damage design is a new building philosophy. It enables engineers and structural designers to design earthquake-resilient buildings that not only preserve life but also leave the primary structure intact and, importantly, usable following a major event. This has obvious advantages for both owners and occupiers in terms of business continuity, insurance costs and commercial property income.

The technology to achieve this ideal has been around for several years. The first leap forward was the development of base isolation.

Base isolators

Base isolation removes the building's rigid connection to the ground, which prevents damaging seismic accelerations from transferring upwards into the structure. Base isolator design has not changed much in 40 years, and most are still fundamentally a rubber bearing with a lead core. The technique is still one of the best options for low-damage design, offering a great deal of protection to everything above the base isolation plane.

Think of it like a gearbox - the base isolator is a step down in gearing between the ground and the building. The ground might shake in first gear at very high acceleration, but the building only responds in fourth gear.

They are relatively cheap to add to a new build, but there are a few issues with the design of base isolation systems in Christchurch due to the composition of the


Ringfeder spring.

soil in the region. The Canterbury earthquakes demonstrated a shaking anomaly that disrupts base isolation systems, and there's a lot of research to engineer alternative technologies to address the problem.

Structures under tension

Some newer technologies suffer no such limitations. Precast seismic structural system or PRESSS (Pres-Lam is a similar system using laminated veneer lumber components) uses high-strength post-tensioning cables within the precast concrete components of a building to pull the whole structure into a state of tight rigidity.

During a seismic event, the ductile cables allow the joints between members to open and the building sways in a controlled manner, returning to a centred position without structural damage when the shaking stops.

The building's oscillation must be dampened quickly – one or two oscillations are acceptable, but any more can cause problems.

Energy dissipaters, which may look like curved U-shaped steel plates, are bolted into the spaces between each wall section. As the walls rock, the plates yield and roll up and down the walls, absorbing seismic energy and slowing down the rocking motion. The dissipaters are destroyed, but can easily be unbolted and replaced after the quake.

Sitting on springs

Steel-framed buildings, which typically perform well in seismic events, often use sacrificial seismic braces called link beams, which run diagonally between the beams and columns in the frame.

During a quake, they're designed to yield and absorb energy as the building sways, destroying themselves in the process. They must be replaced to restore the structural integrity of the building but, unlike PRESSS dissipaters, this is a difficult, time consuming and expensive process.

As an alternative, designers can opt to use concentric braces held down with large springs called ringfeder springs. As soon as the column foot starts to lift in an earthquake, the spring compresses and applies an enormous restorative and damping force that replaces the sacrificial yield of the link beam. The spring is undamaged.

Sliding friction

Steel structures can also be braced using sliding hinge joints. These beam-to-column joints allow the beam to rotate around the top flange and, as the frame moves, allow the bottom flange to slip and act as a sliding friction plate. By sliding, it limits the amount of destructive force transferred to the beam and column, so the primary structure doesn't yield or sustain damage.

However, the technique is only 90% self-centring, due to the inherent friction that remains in the system. Research is under way to overcome this problem by combining them with spring-loaded viscous dampers.

Right for Christchurch

Any of these low-damage techniques are ideally suited to Christchurch and other parts of New Zealand, and can lend themselves to 3, 5 or 7 storeys or more.

The additional cost is insignificant – a couple of percent – and owners and occupiers can feel comfortable knowing their building and business will ride out the next earthquake trouble-free.