Built to last

The global weather forecast is daunting, and earthquakes are a regular event. With insurance costs already climbing, we badly need buildings that can stand up to the forces of nature.

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Heavy rain undermines a house in 2006.

PHOTO COURTESY OF NIWA – ALAN BLACKLOCK.

THE NUMBER AND INTENSITY of natural disasters in the last few years serve to remind us just how fragile our built environment can be when faced with the forces of nature.

In 2005, storm surge and flooding from Hurricane Katrina caused US$80 billion in damage in one of the most deadly events in US history. In 2011, the magnitude 9.0 Tōhoku earthquake off the coast of Japan generated a 40 m tsunami that severely damaged or destroyed over 1 million homes and buildings.

In just the last few months, unprecedented storm activity in the UK has caused severe coastal erosion and flooding and displaced thousands of people. Here at home, the 2010 and 2011 Canterbury earthquakes highlighted our own vulnerability.

While these are all undoubtedly extraordinary events, much of New Zealand's built environment is vulnerable to hazards such as earthquakes, tsunamis, volcanic activity, flooding, heavy snowfall, windstorms, droughts, landslides, fire and a range of manmade hazards. Lack of resilience can carry a high price tag.

Big losses highlight need to mitigate

According to the Insurance Council of New Zealand, 2013 is likely to become the second most expensive year on record for weather-related damage, with over $174 million of insured costs arising from weather-related events. Nearly half this cost was created by damage to commercial and residential property during a single storm in September. And this is becoming a trend.

The Council believes that climate change is likely to cause stronger winds and higher levels of rain in parts of the country already prone to flooding, underlining the need for New Zealand to focus on strategies to mitigate the effects of disaster in order to minimise economic losses and social disruption.

Designing in resilience

A way to successfully mitigate loss of life, property and amenity is to design buildings that are resilient to disaster, says Dr Suzanne Wilkinson, Professor of Construction Management at the University of Auckland.

Dr Wilkinson says a resilient building has the ability to absorb change and disturbances in a time of crisis, quickly recover functionality after a disaster or sudden shock and continue to operate even when some components of the building fail. The degree of resilience, she adds, can be measured using eight key characteristics – robustness, redundancy, resourcefulness, rapidity, capacity, flexibility, tolerance and cohesiveness.

The resilient design process

For both commercial and residential projects, a resilient design process begins with a careful investigation into how the building will be used. The designer should consider how the occupants will interact with the building's systems each day and understand their expectations in terms of the level of service the building provides during and after disaster.

Hazard assessment

It's also important to accurately assess the hazards that the building will be exposed to now and in the future and the effects they will have on the building's structure, occupants, functionality and surrounding infrastructure.

Much of New Zealand is prone to earthquakes, so designers should consider the relative seismicity of the building's location – indeed, this is a requirement of the Building Code, which governs minimum levels of mitigation for some hazards – but there may be less obvious hazards to consider.

For example, a coastal location may be susceptible to tsunamis, sea-level rise and coastal erosion, while a high-altitude location may experience higher winds and excessive snow load and extended periods isolated from roads and the national electricity grid.

As climate change advances and the severity and frequency of extreme weather events increases, all New Zealand locations are likely to be exposed to quite different conditions by the time the building reaches the end of its useful life in 50 or 100 years or more.

Sustainable doesn't mean resilient

It is also important not to confuse resilient design with sustainability, although the two are complementary in many ways. Even the most advanced green building that is designed, constructed and operated according to sustainable principles is not necessarily resilient to disaster.

A low carbon footprint, high-efficiency light bulbs and recycled rainwater don't count for much if the building collapses in an earthquake, power is cut or the ground floor floods in a bad storm.

Standing up to shakes, gales and surges

Traditionally, structural components such as bracing, shear walls and moment-resisting frames have been used to resist earthquake shaking in a 'strength up to a limit' approach. They are resilient to minor seismic events, but in a design level event, they are designed to fail slowly in the interests of preserving life.

Strengthened against shakes

Many modern earthquake resilience systems suffer no such limitations. Base isolation, post-tensioned frames and vibration damping systems have all been proven to greatly enhance a building's capacity to withstand extreme seismic events.

Take Christchurch Women's Hospital – a 10-storey base-isolated building that remained fully operational immediately after both the September 2010 and February 2011 earthquakes.

Standing up to gales

In order to create a building resilient to excessive wind loads generated by strong storms, hurricanes and tornadoes, designers should try to ensure the building envelope is robust and well sealed and strengthen the superstructure to withstand higher lateral loads and vertical lifting forces.

In parts of the US where extreme winds are common, for example, the National Institute of Building Sciences recommends additional bracing of roof trusses and gable ends, installing hurricane straps to strengthen the roof-to-wall and wall-to-foundation connections and placing coverings over doors, windows and other penetrations in the building envelope.

Holding back the surges

Other effects of extreme weather, such as ground flooding or storm surge, are often best dealt with at an urban design level or by avoiding obvious high flood-risk areas such as river floodplains, estuaries and other low-lying coastal areas.

If this is not possible, the designer can boost the building's resilience by creating adequate draining and waterflow systems for underground car parks, basements, ground floor levels, roofs and any other areas where water may collect. Critical systems, such as generators and heating systems can be placed as high above ground in the building as possible to avoid failure. Some aspects of tsunami hazards can be mitigated in the same way.

A broader picture

These are just a few simple strategies to design a more resilient building. Of course, disaster resilience is not limited to buildings – to be effective, it must also encourage a long-term commitment to resilience in our communities, infrastructure and people.