Seismic effects on Heritage Buildings

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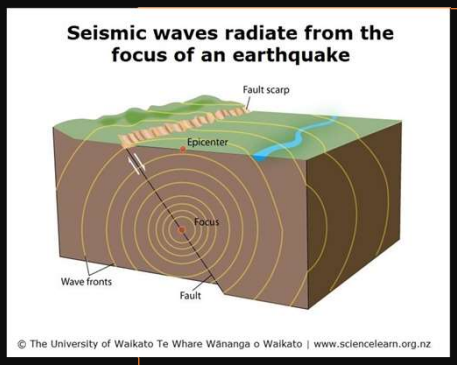
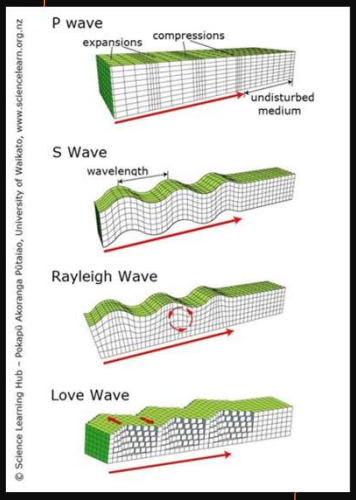
Earthquakes are ground waves

These waves have vertical and horizontal movement





It may be trite to say but earthquakes are essentially ground waves.

The ground wave emanates from the movement of large elements of the tectonic plate and the location from which the earthquake emanates is termed the epicentre.

The wave has both vertical and horizontal components and is very visible. Depending on the source, the scale of movement can vary substantially. The intensity of earthquakes is measured by a scale developed by a man called Richter in 1935.

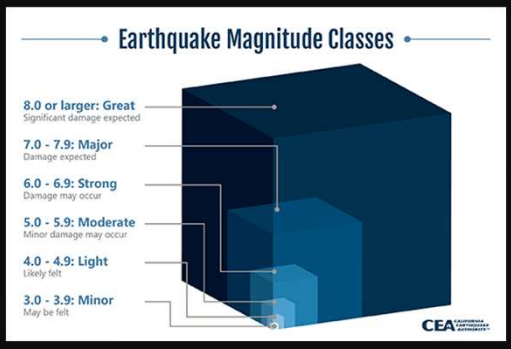
Australia records 700 earthquakes a year; with the majority in WA

Most are between 2 to 3 on the Richter scale

Above magnitude 4; minor damage to plates, windows and plaster is experience

Above magnitude 5; property damage recorded

Above 5.5 + is where serious damage occurs



On average, Australia records 700 earthquakes a year, occurring all over the country. WA is the most active both in the size and number of earthquakes.

Fortunately, most of Australia's earthquakes are magnitude 2 and 3 events, which will cause light shaking but no damage.

It's not until events are magnitude 4 and above that you start to see minor damage to property, like dishes and windows breaking; and plaster cracking.

Above magnitude 5 on the Richter scale you start to see damage to houses and buildings.

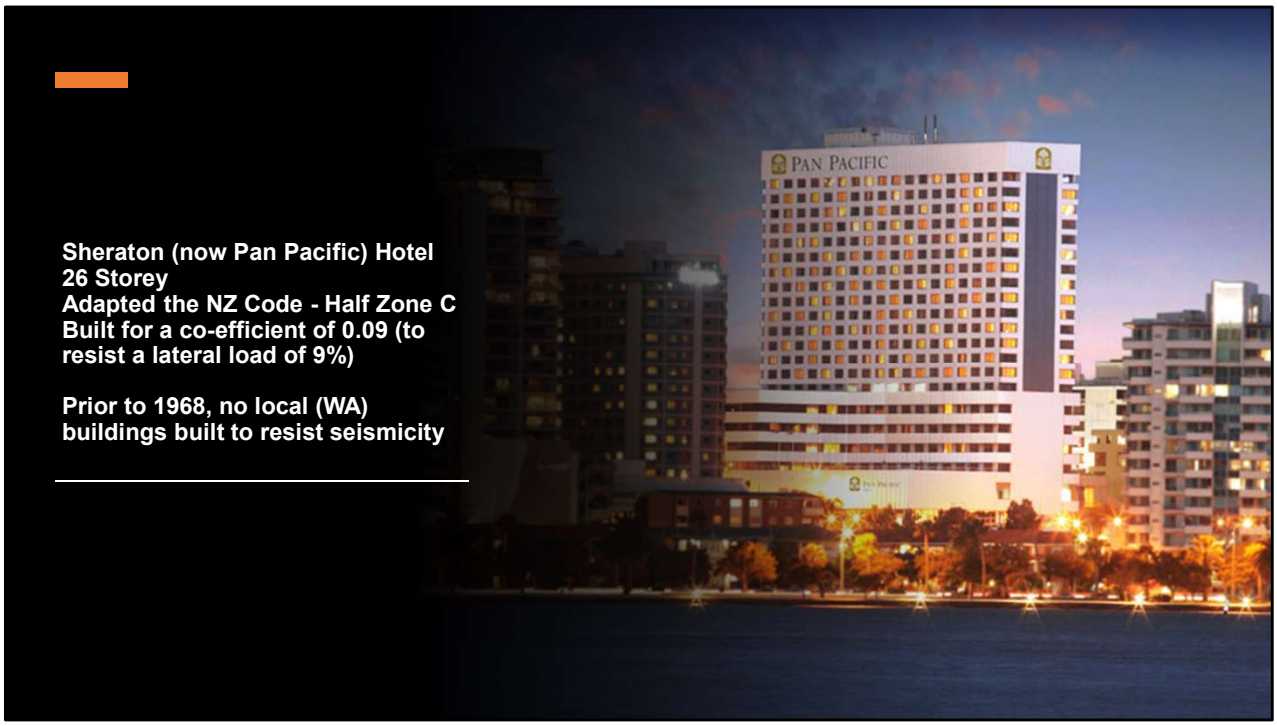
Earthquakes are significantly damaging in the scale of 5.5 and 8.9 in Magnitude. At the upper end of this scale they are devastating and often take lives.

Meckering Earthquake (1968)

To put this scale into a real-world context, the 1968 Meckering Earthquake, which is the most damaging Earthquake in the recorded history in Western Australia, was 6.5 on the Richter scale. This was pretty devastating as these images show.

Prior to 1968 the incidence of seismicity in Australia in the 5.5 to 8.9 magnitude range was so small, designing buildings to resist earthquakes was not a concern for Architects or Engineers.

This all changed in 1968. In Western Australia, we realised that there was the potential for a problem that needed to be addressed in our designs.



At the time of the Meckering Quake, I was designing the Perth Sheraton Hotel, which is now known as the Pan Pacific hotel. It is a 26 storey building.

I looked for guidance as to how to design the building for earthquakes. While there was no local Code, the answer seemed obvious.

I consulted our Kiwi Cousins who live on what a set of shakey Isles on a tectonic plate. We used the forces for their “Half Zone C” in their Code, which in New Zealand would be laughably small. This gives an acceleration coefficient to the building of 0.09, or, in effect, 9 percent of the mass of the building moving horizontally as a force.

Newcastle Earthquake (1989)

13 dead, 160 injured

Building Code modified

No Building Code for quakes prior to 1989

This is an issue for Heritage buildings

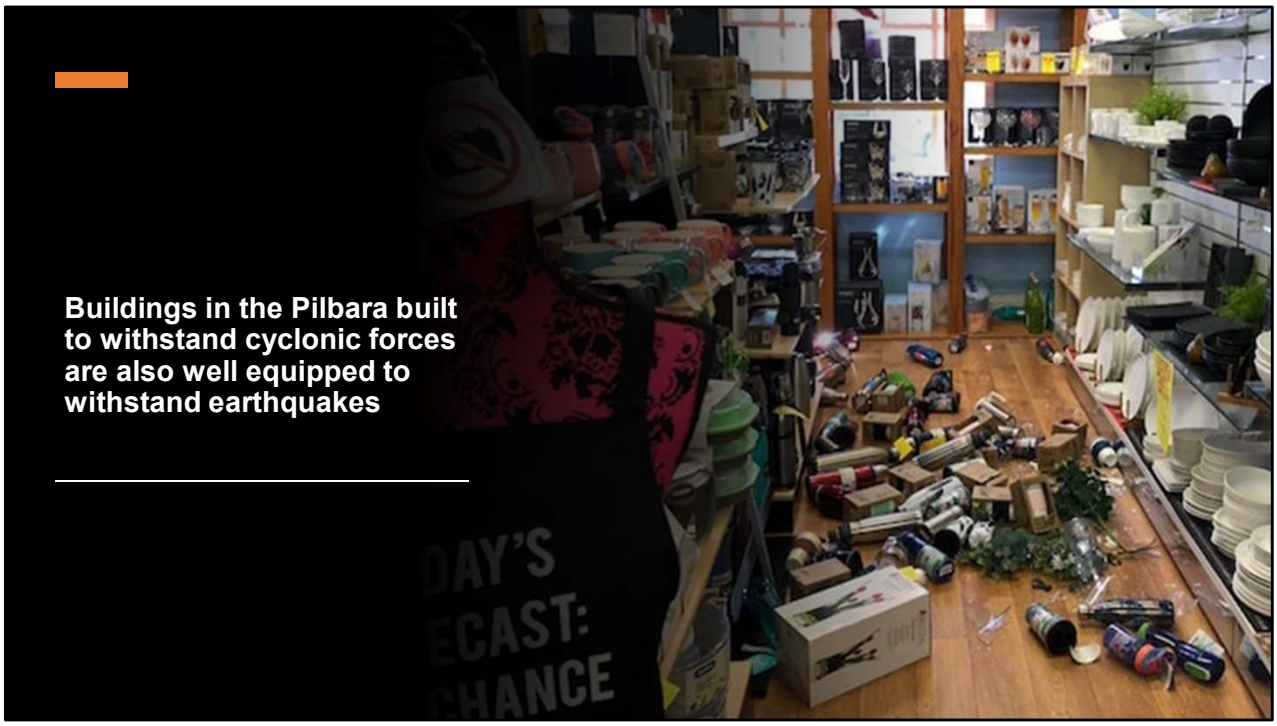
In 1989 there was an earthquake which occurred in Newcastle in NSW which measured 5.6 on the Richter Scale that resulted in deaths. 13 people were killed and 160 were injured.

After the Meckering and Newcastle events, the Australian Code was formulated for the design of buildings subject to seismic loads.

This is all very well for new buildings, but, as you would be aware, most Heritage buildings were designed before 1968 – when there was no formal code or general practice to design buildings effectively for quake events.

Heritage buildings vary enormously in scale and texture.
What you see presented is one of the most famous Heritage buildings on Earth. It is the Parthenon in Athens, Greece. It has been in position for 2000 years and properly designed for seismic events. It is in an area where seismicity is a real design factor. The designers at the time thought about seismicity and came up with a unique answer that really worked. What they discerned was the ground wave of an earthquake has a lateral component and a vertical component which needed to be dealt with if a building the scale of the Parthenon was to be placed safely on the site. What they concluded was that the lateral shearing forces of the earth needed to be prevented from causing the columns to bend; and that vertical forces needed to be abated as much as possible.

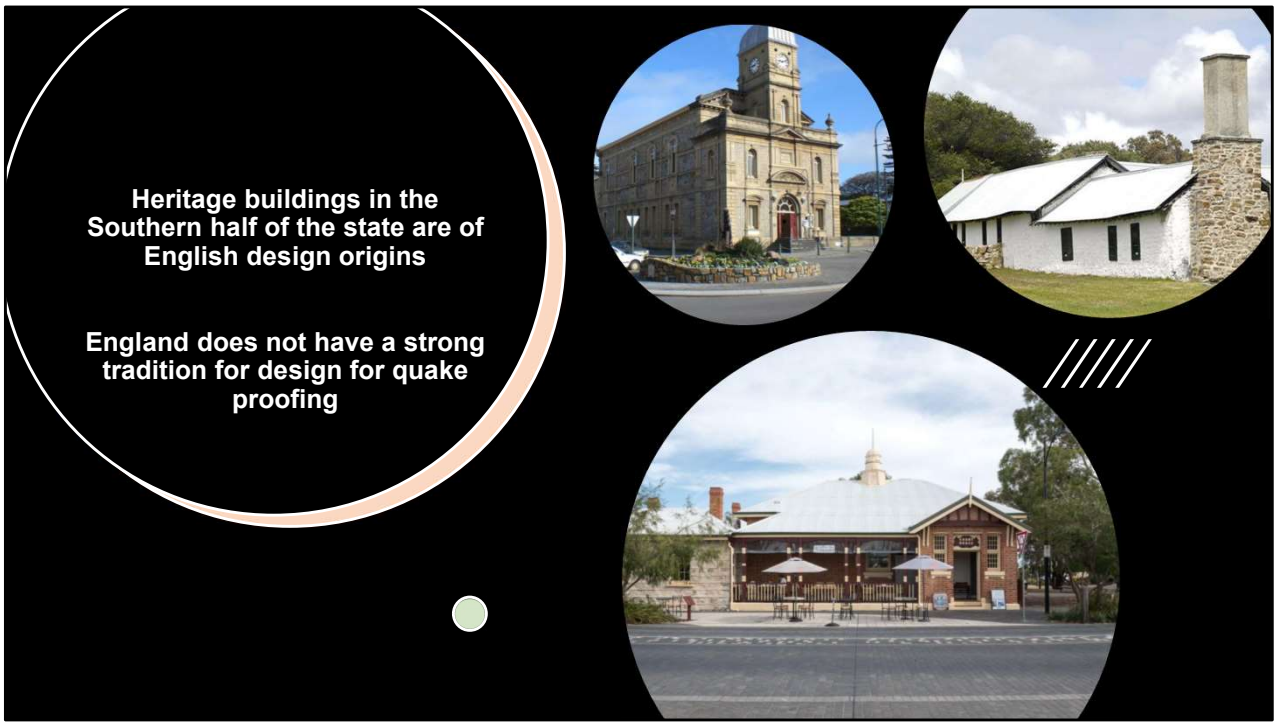
What they did was unique and effective. They placed large, stacked beds of animal hides separated by brush underneath each of the columns. The animal hides allowed the translational impetus of the earthquake to be avoided and the vertical forces were nullified by the stack of energy absorbent material.
Ladies and gentlemen, this was 2000 years ago and was great thinking. The damage you see to the Parthenon is not due to seismic events, but due to the actions of man during war.



Locally we need to understand how to design buildings for the forces generated by earthquakes.

While the forces involved in earthquakes are different to cyclones, if buildings are designed for cyclonic windloads, our seismic loads are comparatively small and the buildings are able to accept them without damage. This applies to many of the buildings in the Pilbara area and the north of the State, particularly near the coast.

A good recent example is the aftermath of a Magnitude 6.6 earthquake that hit 200 kilometres off the coast from Broome. The worst damage experienced was to freestanding cabinets overturning, as you can see in the picture on screen, that occurred in shopping centres. The buildings themselves have remained intact and were undamaged.



The Heritage buildings in the south of this state are of different construction. Their designs drew on English experience, much of which did not include a necessary provision for earthquakes.

Nevertheless, addressing significant basic Engineering issues such as the centre of stiffness being aligned with the centre of mass greatly assists any building to avoid seismic damage.

If the centre of stiffness and centre of mass are not aligned, the building tends to spin around the centre of stiffness during a seismic event, causing damage at the corners of the building.

Suggestions for quake resistance

Check the roof membranes are properly engaged with the walls

This can be easily corrected if absent

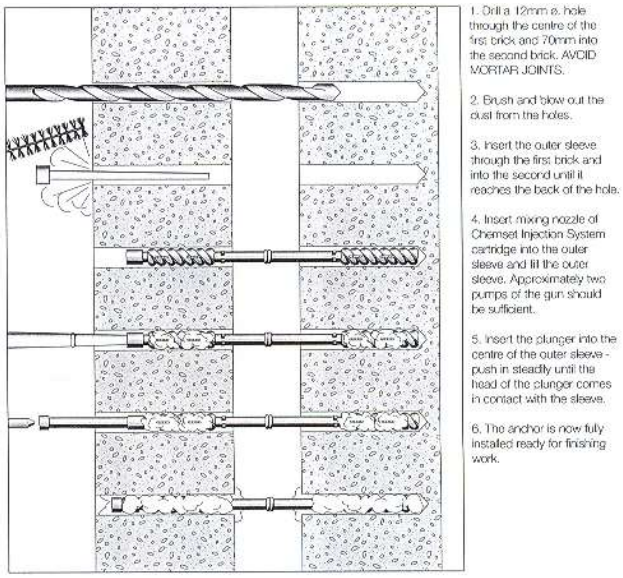
To give existing buildings good resistance to minor seismic action, ensuring that the roof membrane is properly engaged to the walls of the building is an important facet of design, even if engaged retroactively.

This can be checked on Heritage buildings and corrected if absent.

Suggestions for quake resistance

Ensure wire-ties are not corroded

Replacement with stainless steel wire-ties highly recommended



In the Newcastle quake of 1989, the decay by rusting galvanised wireties restraining the external leaf of brickwalls was found to be a predominant factor in the structural damage and associated deaths.

As the external walls were effectively freestanding, they collapsed when subject to the lateral loads of the earthquake.

Salt in coastal areas cause wireties to rust out. All Codes now request that stainless steel wireties be used in areas subject to this degradation. There are many buildings in Perth and Western Australia that should have retroactive installation of stainless steel wireties. Wireties have been developed which can be fitted to existing walls by drilling into the walls and affixing them without reconstructing the entire wall.
An example of this type of refixing arrangement which is used to retrofit walls is shown on screen.

This is particularly important for Heritage buildings. Prior to 1960, stainless steel wireties were not available in Western Australia and were not used. Checking the status of the wireties in Heritage assets is sensible and retrofitting of the type described can be cost effectively done from either inside or outside the building.

Buildings with heavy roofs such as tiled roofs are more vulnerable to damage from seismic effects than those with lightweight roofs.

This is due to what is known colloquially as the “toffee apple effect” because earthquakes shake affected tiled roofs like when you shake a toffee apple! Considerable care is required to ensure the roof membrane’s action is resisted by the walls which are effectively in shear. This is a detailing and configuration issue.

Where possible when conducting maintenance on Heritage assets, thought could be given to roofing replacement with lightweight alternatives if it does not disrupt the Heritage nature of the asset.

“Boxshell” - multilevel constructions with small rooms and concrete floors with all floors repeated all the way up

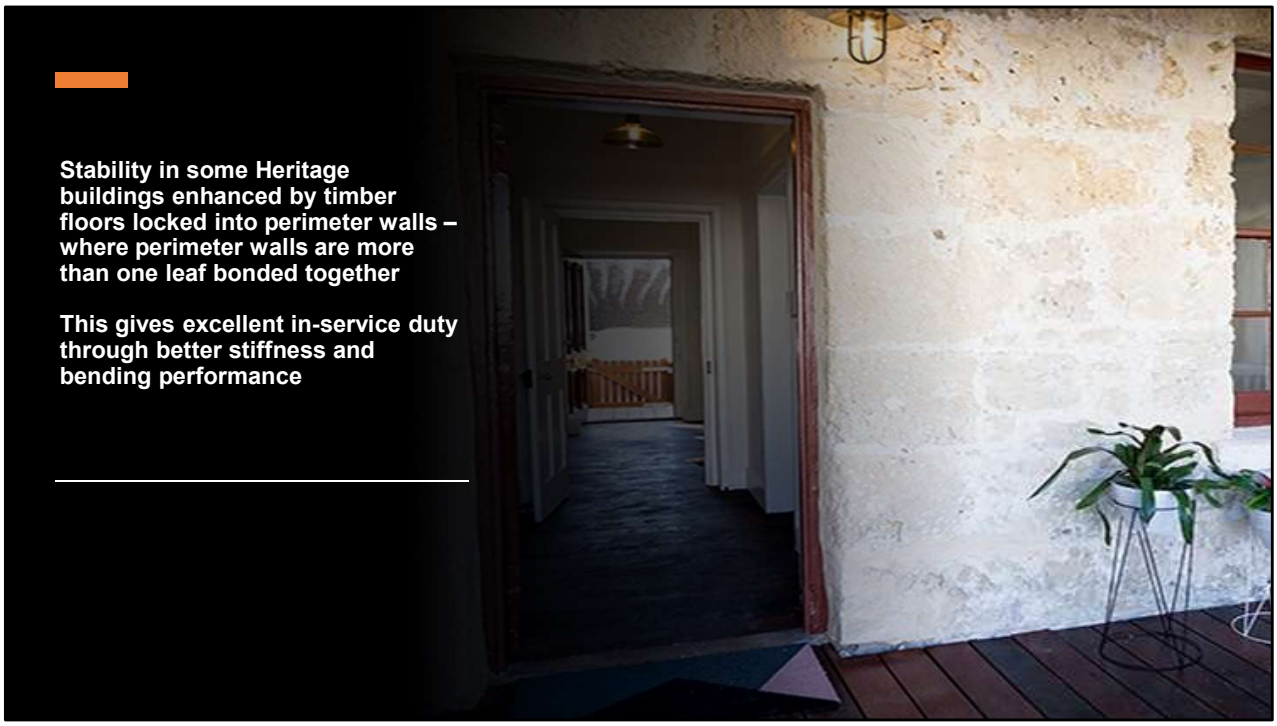
Features in Heritage listed apartments, hotels and school dormitories

Good service duty for quake events

Western Australia has many buildings which have “boxshell” construction - comprising relatively small rooms, load bearing (often brick) walls, concrete floors and, eventually, a roof. This configuration is typically found in apartment buildings but also seen in hotels and schools – some of which are Heritage listed.

Construction of this type has given very good in-service duty in seismic events so long as they do not have what is called a “soft storey” near the base. A soft storey is created when the lowest or lower levels have a different occupany to the occupancy of the upper floor. It is typically a commercial tenancy or car park under apartment above a transfer floor.

Many buildings now being built in Perth effectively have a “soft storey”. Heritage buildings or those built prior to 1950 of this type rarely had “soft storeys” so they are effectively more stable; and have given very good service for seismic events.



Stability is enhanced by the historic practice of using timber rather than concrete floors that are locked into the perimeter walls - particularly with perimeter walls of more than one leaf bonded together.

This arrangement gives immensely better stiffness to the walls and better resistance to bending than modern cavity wall construction.

In summary, earthquakes are a factor in Western Australia that should be considered for Heritage asset protection. Some basic measures to enhance protection are :

- Check the roof membrane is effectively engaged to the walls
- Check and augment existing wireties with stainless steel option
- Consider replacing heavy tiled roofing with lightweight alternatives
- Check that flooring locks in effectively with walls

Having a professional Structural Engineering report on your asset is always recommended, particularly if there are multiple concerns.

Thank you for your time, ladies and gentlemen.

Image Sources

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Slide 1 : State Government of WA Department of Mines and Petroleum website from https://www.dmp.wa.gov.au/Geological-Survey/Understanding-the-Meckering-28218.aspx
Slide 2 : “Seismic Waves” page at Science Learn website from https://www.sciencelearn.org.nz/resources/340-seismic-waves
Slide 3 : California Earthquake Authority website from https://www.earthquakeauthority.com/Blog/2020/Earthquake-Measurements-Magnitude-vs-Intensity
Slide 4 : Australian Institute for Disaster Resilience website from https://knowledge.aidr.org.au/resources/earthquake-meckering-region-western-australia/
Slide 5 : Airey Taylor Consulting internal marketing photos

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Slide 6 : Australian Institute for Disaster Resilience website from https://knowledge.aidr.org.au/resources/earthquake-newcastle-1989/#:~:text=Newcastle%20earthquake%2C%201989&text=On%2028%20December%201989%20at,fatalities%3B%20160%20people%20were%20injured
Slide 7 : The International Information Centre for Structural Engineers website from https://www.thestructuralengineer.info/news/parthenon-triple-anti-seismic-protection-and-brilliant-engineering
Slide 8 : Photo of Broome shops supplied by Esse Davis to ABC News at https://www.abc.net.au/news/2020-07-14/one-year-on-from-broomes-magnitude-6.6-earthquake/12450206

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Slide 9 + 16 : “Buildings Historical Sites Museums in South West” from https://scoop.com.au/scoop-guides/australias-south-west/museums/?categories=166533&type=museums&region=australias-south-west&listing=ellensbrook-heritage-site&mapType=roadmap&view=grid&mode=discover
Slide 10 : Roof Services UK from https://www.roofixservices.co.uk/flat-roofing/single-ply-epdm-rubber-roofing/
Slide 11 : from Ramset Remedial Wall Ties product information guide available at : https://ramset.com.au/product/Detail/28/Remedial-Wall-Ties
Slide 12 : Prevention Web from https://www.preventionweb.net/files/28774_eqstrengthenhouse.pdf
Slide 13 : Google Street view of 9 Parker Street, South Perth; drawing plans internal to ATC
Slide 14 : Apply for a Heritage Grant from https://www.wa.gov.au/organisation/department-of-planning-lands-and-heritage/heritage-grants-and-incentives