The Design of Suspended Ceilings in accordance with AS 1170.4 and AS/NZS 2785 for Australia

SA AWCI 11/2/2020

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Introduction

- I am a Fellows of Engineers Australia, the American Society of Civil Engineers, the Institution of the Civil Engineers and the Institution of Structural Engineers and I have been practicing for about 50 years.
- I am also a past winner of the John Connell Medal which is the highest award of the Structural College of Engineers Australia.
- I was on AS 3600 Concrete Standard committee for about 12 years
- I have been involved in seismic design in Australia for the past 35 years and I am a past chairman of Australia Standard AS 1170.4 for earthquake loads for the design for buildings for seismic loads.
- I have designed ceilings for seismic loads for the last 10 years
- I am Chairperson of the Ceiling Standard AS/NZS 2785 to be published later this year

Failure of ceilings

- I have personally inspected two ceiling failures in Adelaide over the past 35 years or so.
- I am also aware of a number of failures through professional contacts around Australia
- CROSS In the UK as a long list of failures of ceilings https://www.structural-safety.org/publications/view-newsletter/?newsletter=2701
- Significant failure of ceilings in the Christchurch earthquake
- I'm aware of least 2 ceilings in Australia which have failed under seismic conditions
  - The John Hunter Hospital in Newcastle which had to be substantially rebuilt
  - Tennant Creek Hospital which also had to be rebuilt

Failure of ceilings

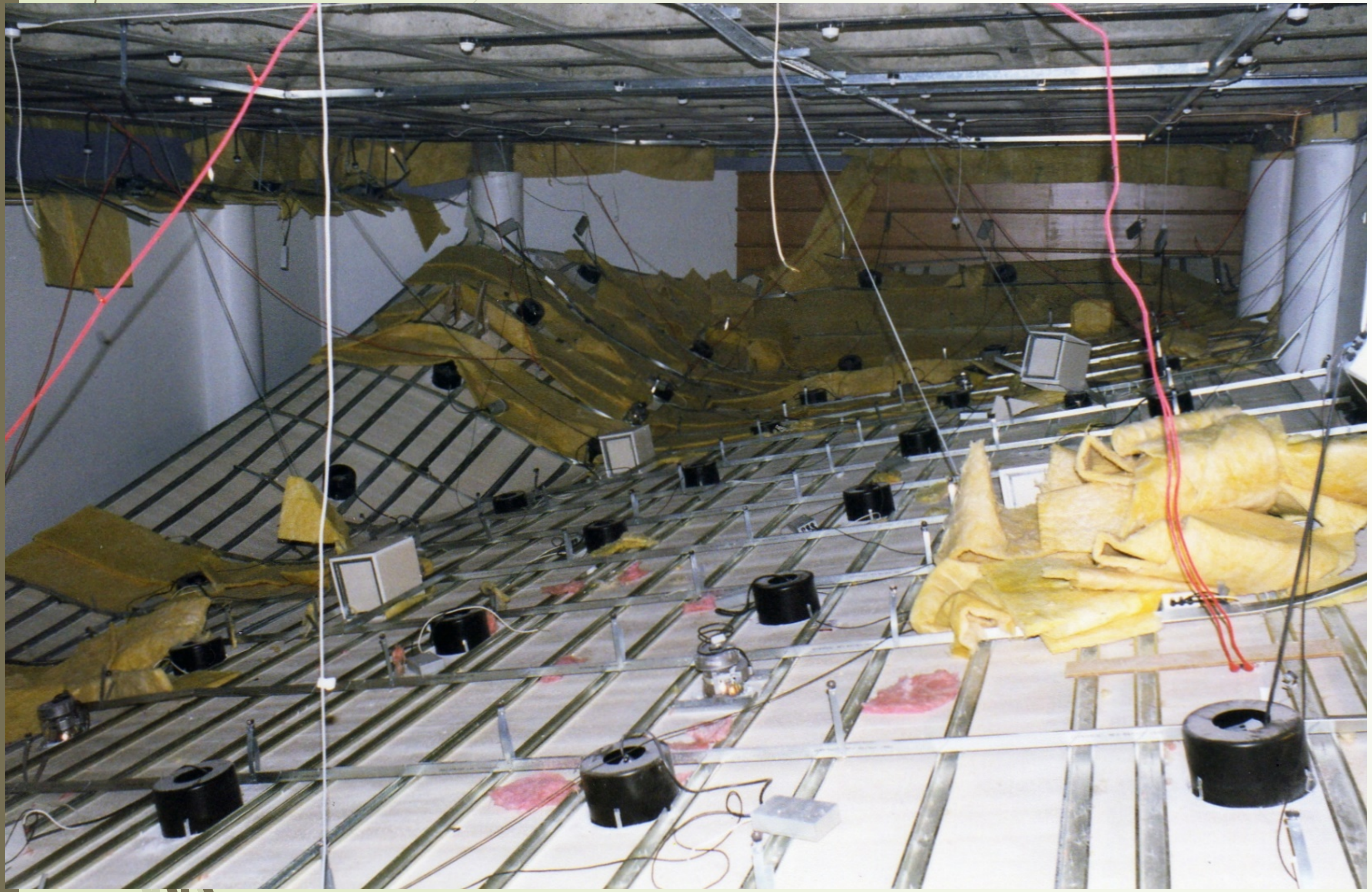
Ceilings fail for a variety of reasons including:-

- Failure of structure above e.g. gang nail trusses or old framing
- Inadequate fasteners into structure above or failure of hangers/fasteners leading to progressive collapse
- Failures in seismic condition
- Failures under wind
- Indoor swimming pools

Progressive Collapse

- A simple concept
- Can occurs in many systems with multiple and similar members
- A member is overloaded and close to failure
- Something marginally increases in the load and the member then fails
- The system then sheds its load to adjoining members which in turn are overloaded and close to failure
- The adjoining members then accept the additional load
- The adjoining members then fail
- Collapse then progressively occurs
- That is why hangers have to be designed for a minimum of 50kg or 1.5 times the design load i.e. redundancy

Failure of ceilings UK and USA



UK

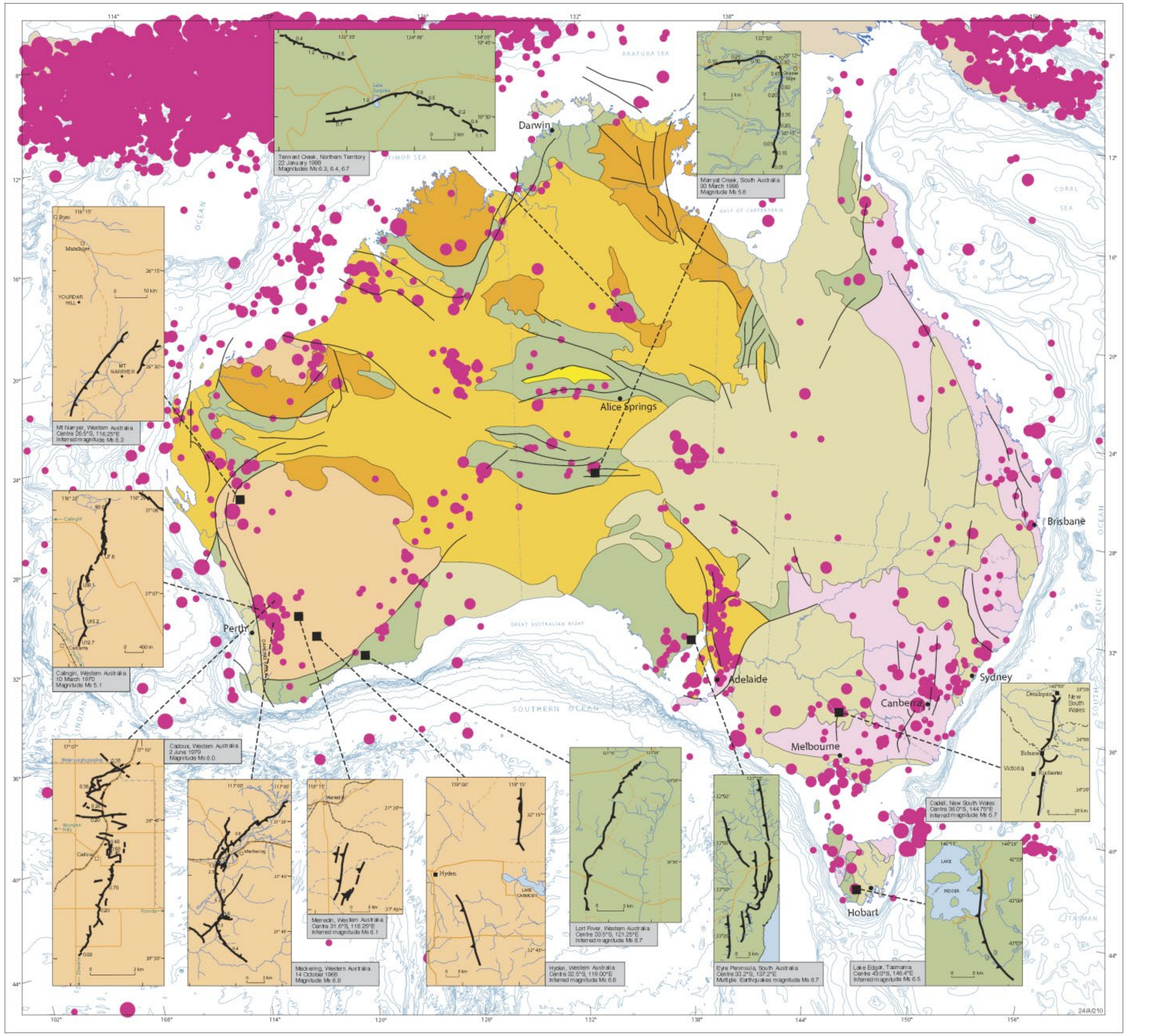
USA

Failure of ceilings Australia Wind

AUS

AUS

Seismic activity in Australia 1841-2000



Earthquake epicentres in Australia 1841-2000 and Recent fault scarps

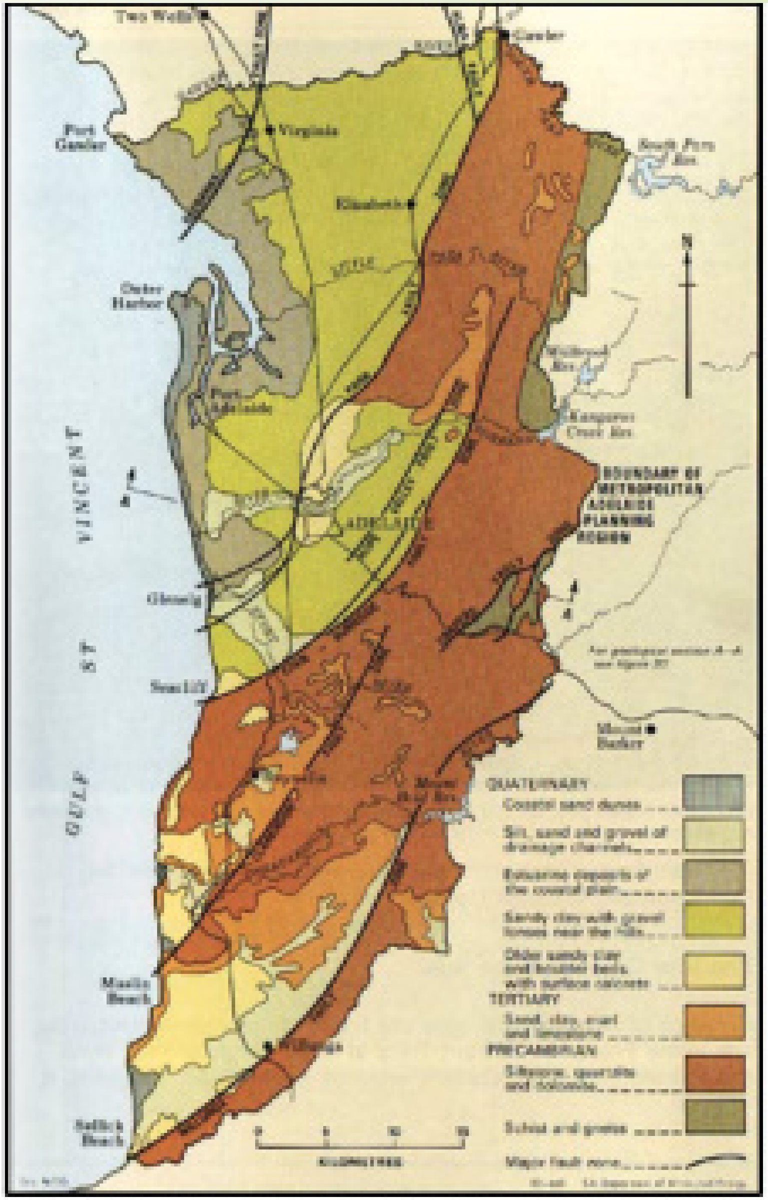
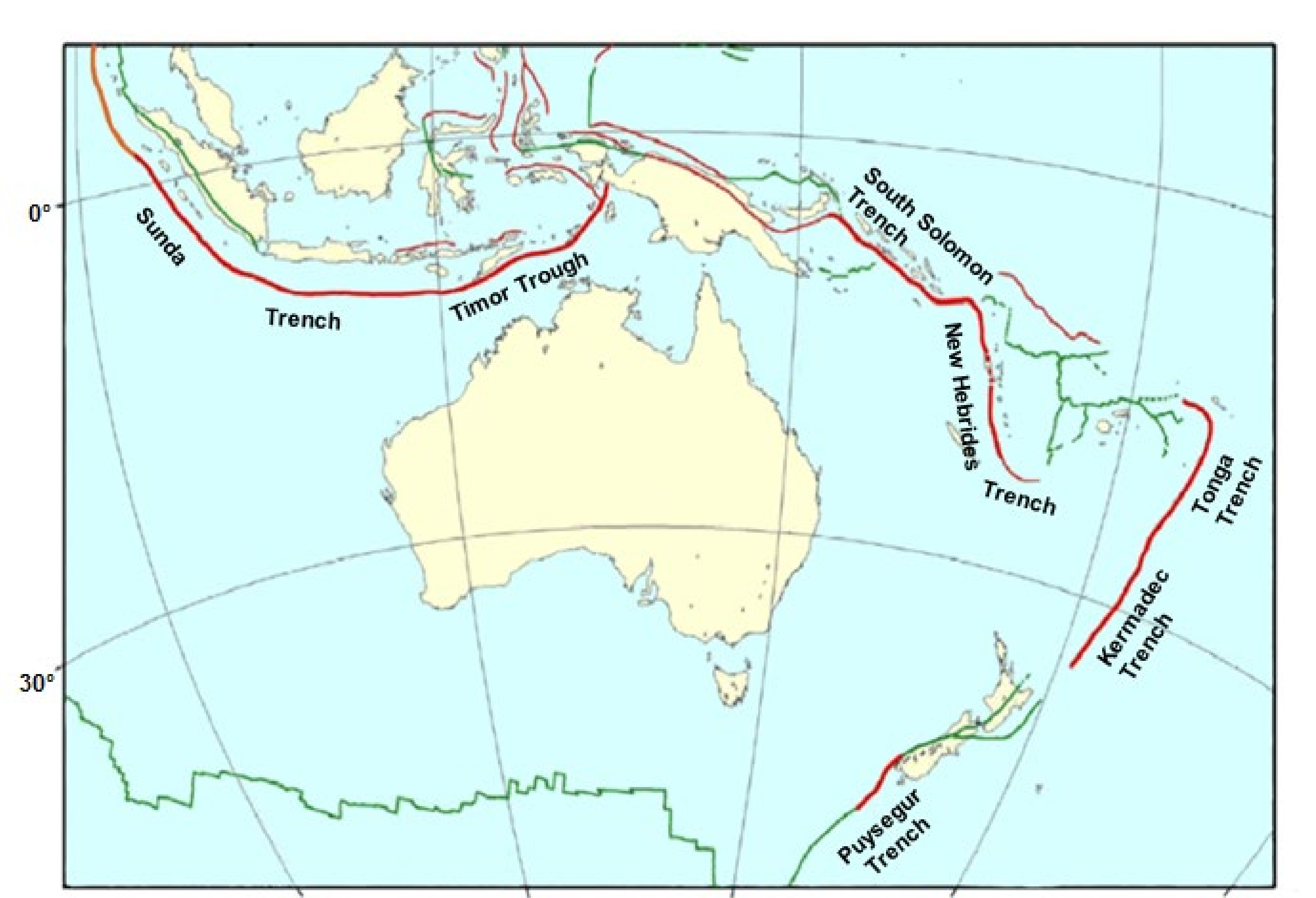


Figure 3.0 - Fault Map of Adelaide region with ground comosition.

Seismic activity in Australia

- In Australia, significant intra-plate earthquakes have been recorded since 1788.
- **Unfortunately in Australia there is a generation of engineers, architects, contractors, sub-contractors, developers and clients who do not believe that earthquakes occur in Australia, despite the long history of earthquakes in Australia and the 1989 Newcastle EQ.**
- **Fortunately I would like to believe there are none of the non believers are in the room this afternoon!**
- Significant earthquakes in Australia are rare and probably will not occur during the average lifetime of a building.
- A major earthquake however will generate the most severe demands ever experienced by a building.
- Given the rare and extreme nature of earthquakes, for economic reasons, designers are largely concerned about preserving life and preventing collapse ie **LIFE SAFETY repeat LIFE SAFETY**.

Plate Boundaries around Australia

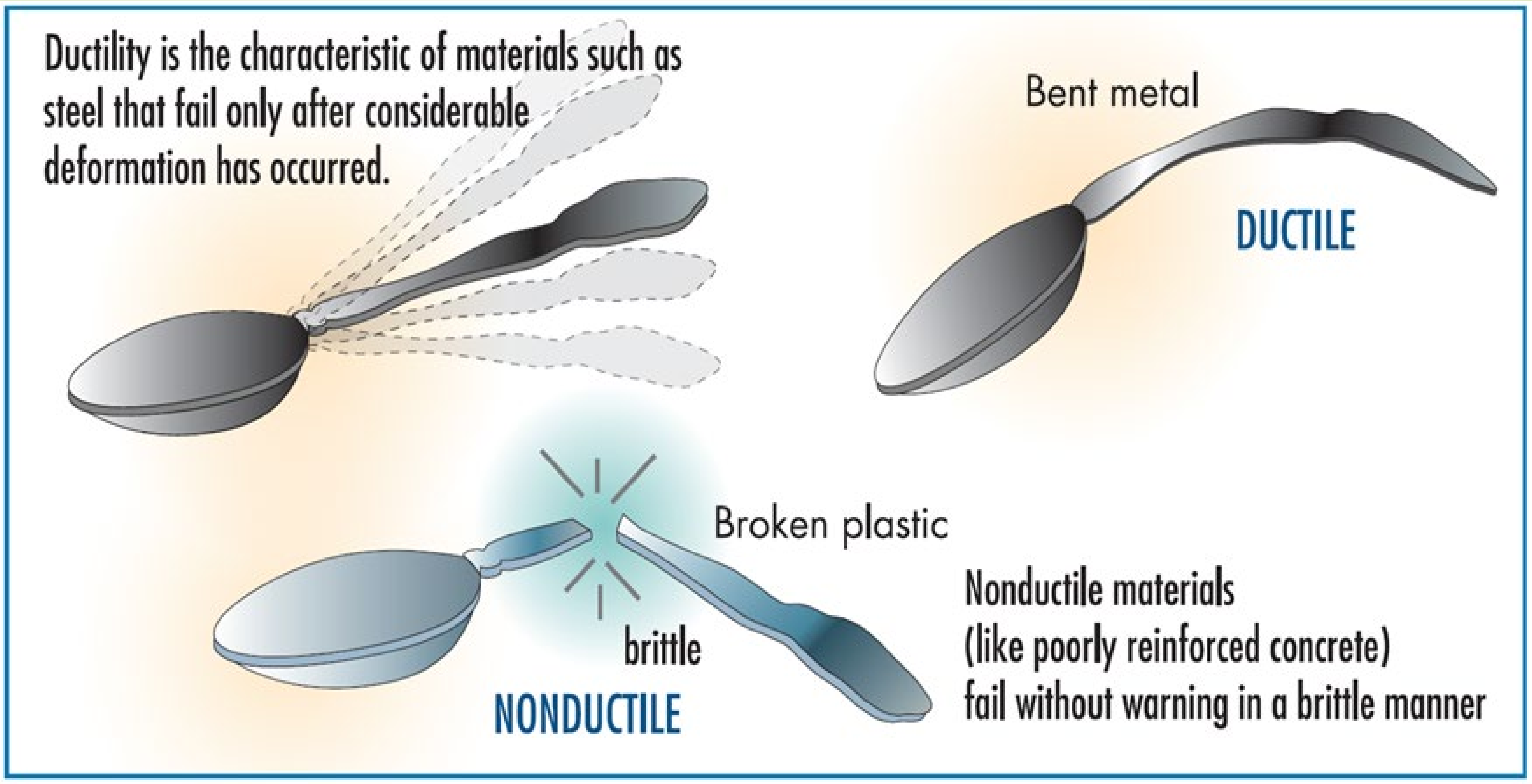


Past Earthquakes

Top 10 Worst Australian Onshore Earthquakes in Modern Times – Ranked by Cost, Magnitude and Damage (source Australian Geographic July 10, 2012)

Newcastle NSW	28 Dec 1989	(Magnitude 5.6) Public Holiday
Beachport SA	10 May 1897	(Magnitude 6.5)
Meckering WA	14 Oct 1968	(Magnitude 6.9) Public Holiday
Ellalong NSW	6 Aug 1994	(Magnitude 5.4)
Adelaide SA	1 Mar 1954	(Magnitude 5.5)
Warooka SA	19 Sept 1902	(Magnitude 6.0)
Meeberrie WA	29 Apr 1941	(Magnitude 7.2)
Tennant Creek NT	22 Jan 1988	(Magnitude 6.3-6.7)
Kalgoorlie-Boulder WA	20 Apr 2010	(Magnitude 5.0)
Cadoux WA	2 June 1979	(Magnitude 6.1)

Ductility



Ductility is the characteristic of materials such as steel that fail only after considerable deformation has occurred.
Bent metal
DUCTILE
Broken plastic
brittle
NONDUCTILE
Nonductile materials
(like poorly reinforced concrete)
fail without warning in a brittle manner

Australian EQs – Less Frequent

- The main difference between Australian and NZ earthquakes is that in Australia they are less frequent.
- Also Australia is vast, and many EQ occur in isolated areas.
- When they occur in Australia they are just as severe as in NZ.
- Australia has an Mw 6.0 earthquake about once per decade.
- The February 2011 Christchurch earthquake had Mw 6.2.

Design of buildings incl components to AS 1170.4

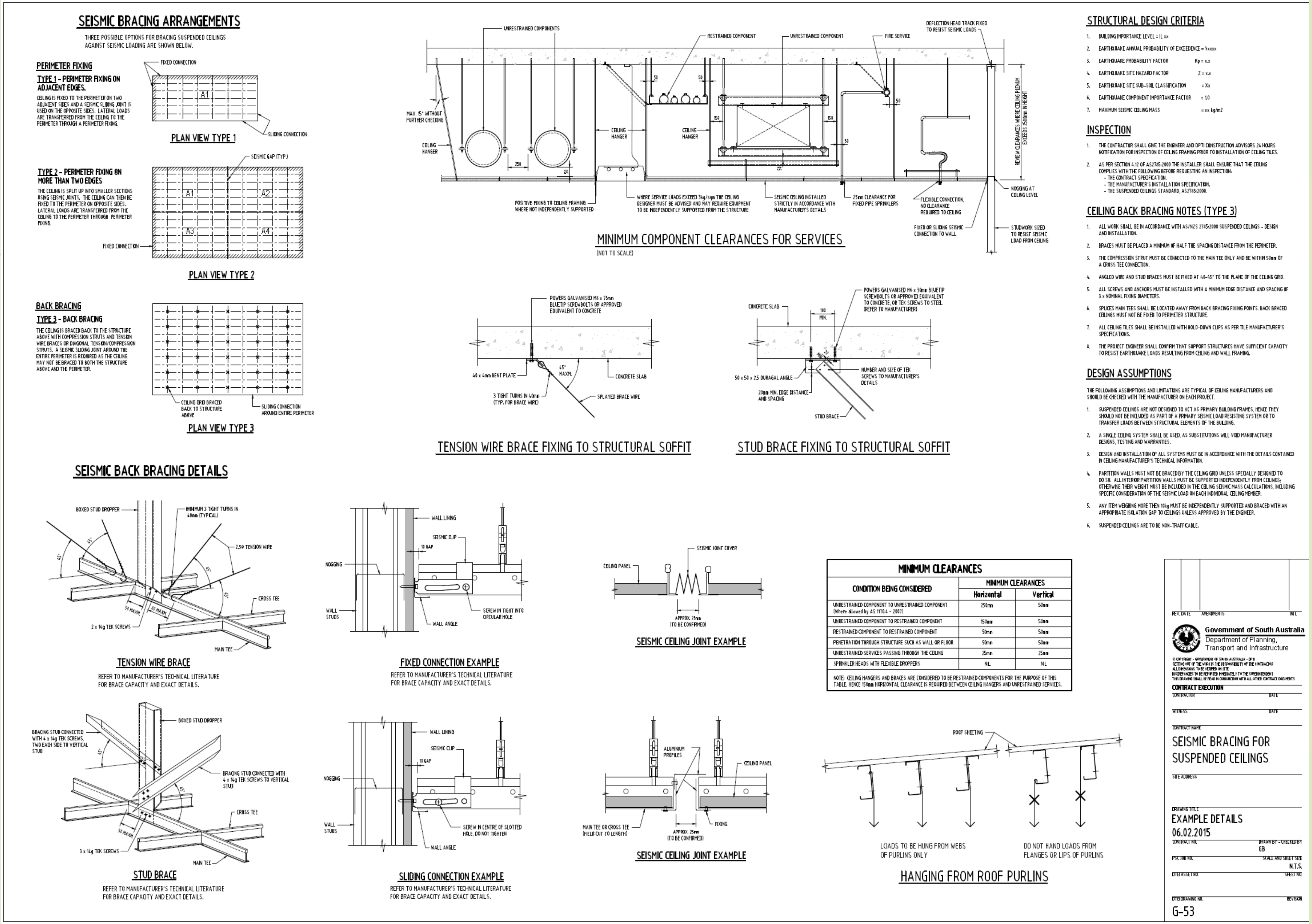
- Design for EQ is therefore about **life safety,** not about preventing damage.
- We therefore design ceilings for about 30% of the seismic load that might occur and we use the ductility of the ceilings to resist the remaining forces/actions with **some damage but not failure**.
- Client/building owners have a different view on what earthquake design means for their building. They **mistakenly** assume that their building will survive a major earthquake without damage.

That is wrong!

- The design of **non-structural parts and components** for seismic loads **are equally important** as the structure. Failure of non-structural elements and components can result in people being unable to exit the building. **Compromises life safety**

SA Government Requires seismic design for ceilings and services for all new ceiling work in all their buildings

Now mandatory for all their projects in SA



Response to a Major EQ

1. 0-1 minute Panic
2. 1 minute -1 week Fear, rescue and survival
3. 1 week to 1 month Short term repairs and allocation of blame to officials, consultants and contractors
4. 1 month to 2 years Long term repairs and demands for higher standards with possibly a Royal Commission
5. 2 years to 10 years Diminishing interest
6. 10 years to next EQ **Why the hell are we doing this and reluctance to spend money on such a low risk items – This is where we are at present in Australia.**
7. The next time!! **Start over again**

Design of buildings for seismic loads

- National Construction Code (NCC formerly the BCA) requires either deemed-to-satisfy solution (DTS) or alternative solutions for the design of buildings.
- **It is a mandatory requirement of the NCC (for DTS) that all buildings including architectural and services components including suspended ceilings be designed for earthquake loads to AS 1170.4.**
- However in the past the design of ceilings for seismic loads was often ignored.
- This is because it is was all too difficult, as there had been insufficient information available on how to design and detail ceilings for seismic loads.
- **<u>That has changed with the design information now available.</u>**
- **<u>It is not difficult to design and construct ceilings for seismic actions !!!</u>**

Design Dilemma – Non Structural Parts

- The architect designs the suspended ceilings, the services engineer designs the services above the ceiling and the structural engineer designs the structure above that **and never shall they meet !**
- The structural engineer is not involved in the ceiling design, even though they have most of the **EQ design knowledge**.
- Often, the design responsibility for ceilings is then either the builder, the ceiling supplier or the ceiling subcontractor, **who have no idea!** and most ceiling suppliers struggle with the design requirements for seismic loads, as they are not structural engineers.
- As a result of this dilemma, the **statutory requirement of the NCC** have been largely ignored in the past except on very large projects where it was specified and sufficient pressure was brought to bear on the supplier to rectify this situation.
- **<u>A most unsatisfactory situation all round.</u>**
- **<u>The new earthquake standard requires all of this information to be provided at the time of tender or pricing. If it is not provided, you should ask for it!</u>**

Earthquake actions

Earthquakes know nothing about

- The NCC
- The Loading Standards
- The Ceiling Standard
- Or the building you are designing or the ceiling you are installing
- We simulate dynamic loads of earthquakes with a pseudo static loads and they are ill-defined and approximate, ie a guess or fudge but it is the best we have at present

Olive View Hospital, California, USA

- The original hospital opened December 1970. The hospital was severely damaged in the San Fernando earthquake (Feb 9, 1971) and demolished in 1973. **(Strike 1)**
- The hospital was then rebuilt and the structure performed well during the 1994 Northridge earthquake, but the hospital was unusable because of the failure of building services and non-structural items including ceilings.

  (Strike 2)
- The ceilings and services were rebuilt, but to date there has been no major earthquake to test whether they have got it right finally, but using American baseball terminology, **With three strikes it will be out.**

Ceilings and EQ

- Major earthquakes around the world have shown repeatedly that suspended ceilings are prone to failure in EQs.
- Failures of ceilings were observed in Newcastle earthquake in 1989 and Tennant Creek earthquake in 1988.
- Significant failures of ceilings occurred in the Christchurch earthquakes in 2011.
- The next major EQ in Australia in a large city will result in many ceilings collapsing.

Failure of ceilings in an EQ in Christchurch

Installation Requirements for Suspended Ceilings for Seismic Loads

- What level of damage is acceptable, minor and major and is it just life safety?
- Need to provide a ceiling system, robust enough to resist lateral forces imposed upon it without failing.
- Do not support heavy services off the ceiling. Eg TV monitors
- Need to prevent border panels from falling from the ceiling onto the floor below and the collapse of the ceiling system.
- Need to prevent light fittings and the like supported by the ceiling from falling to the floor below.

Seismic design of buildings

- The needs of a client or owner may require more stringent requirements than those set out in the relevant earthquake and ceilings standards. Standards only set minimum requirements
- Early in the preliminary design phase of a building, designers should ascertain the client or owner's expectations of the building in the event of a severe earthquake.
- Should the designers be considering life safety or alternatively low-damage design, and whether a cost-benefit analysis of a more robust design is appropriate.
- Commonly, clients/building owners have a different view on what earthquake design means for their building. They mistakenly assume that their building will survive a major earthquake without damage, which is not the intent of the earthquake standards or design to this ceiling standard.
- Non-structural parts and components including ceilings are equally important as the structure, and designers of ceilings must be involved in the discussion on whether they are designing for life safety or low-damage design.
- The failure of ceilings can cause harm to occupants and the public, prevent evacuation, and often result in an inoperative building. Designing of ceilings to the new standard is about life safety, accepting some damage and hopefully preventing collapse, **and it only provide the minimum requirements.**

The Design of Suspended Ceilings in Australia to AS/NZS 2785

- Currently the design of suspended ceilings in Australia and New Zealand is covered by AS/NZS 2785:2000.
- The standard is 20 years old and badly out of date
- Has incorrect load factors and limited detailing.
- It is **inadequate** for both Australia & New Zealand for the design and detailing of ceilings for seismic design.
- **A complete revision will be published later this year hopefully by April 2020**

The Design of Parts and Components to AS 1170.4

Clause 8.1.2 Earthquake actions

Design of parts and components shall be carried out for earthquake actions by one of the following methods:

- (a) Using established principles of structural dynamics.

  (Dynamic testing in a shaking table)

- (b) Using the general method given in Clause 8.2.

  (Used for connections to walls etc. by structural engineer but need the floor accelerations a_s This is the preferred method

- (c) Using the forces determined by the simplified method given in Clause 8.3.

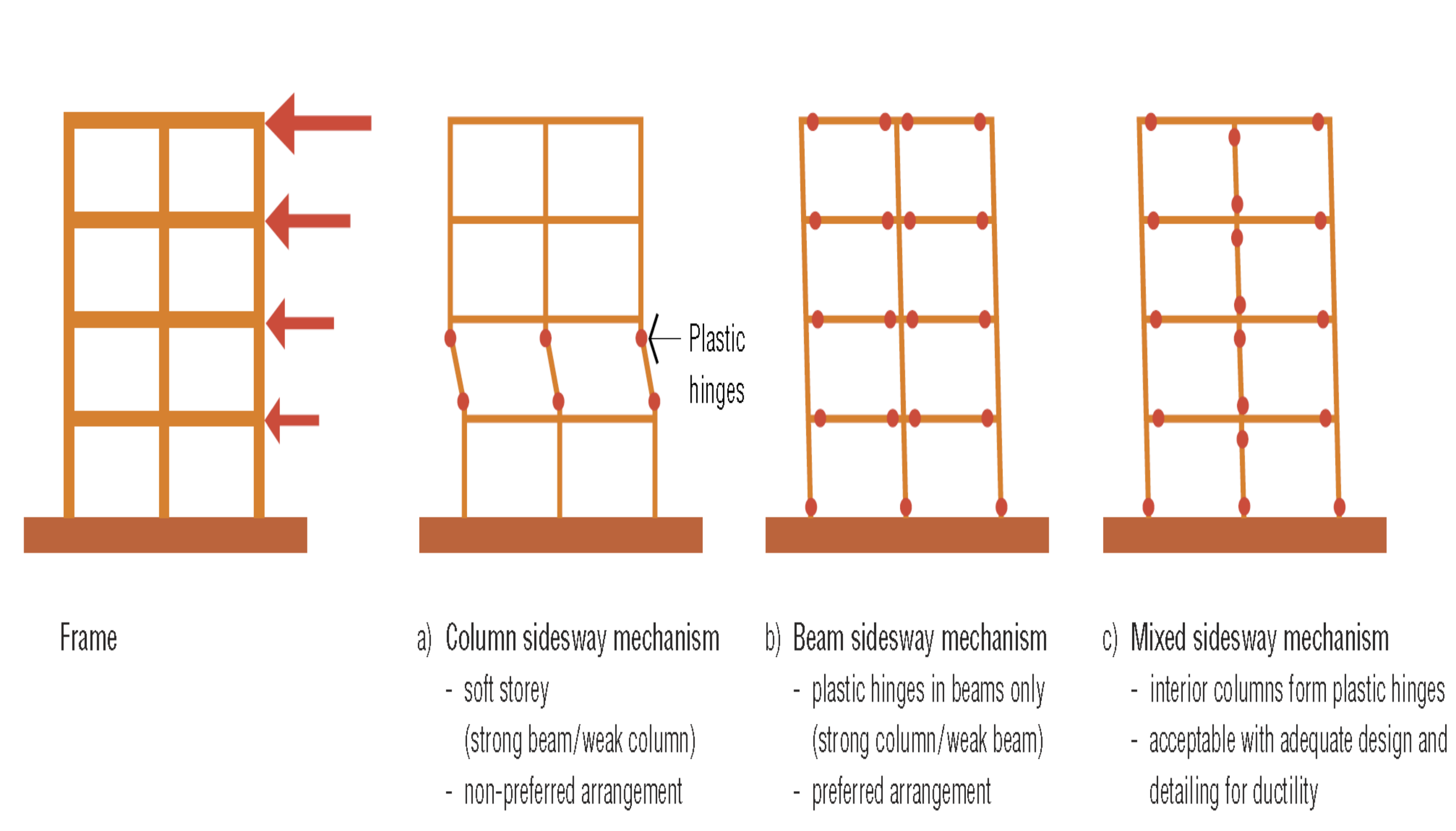
  (Do not use where possible as conservative)

The Design of Suspended Ceilings in Australia to AS/NZS 2785-2020

Cl 2.3.6 Earthquake

- *In Australia*, earthquake actions shall be determined in accordance with AS 1170.4. Vertical actions arising from earthquakes need not be considered unless otherwise determined by a special study or where required by AS 1170.4.
- The mass of the ceiling *(G)* considered under earthquake actions shall include, but shall not be limited to, the following:
  - The mass of the ceiling tile or ceiling coverings and grid system *(G)*. **Partitions connected to the underside of the ceiling *(G)* (see Notes 1 and 2).** Recessed or surface-mounted luminaires *(G)* or similar. Services such as air conditioning registers *(G)* that are attached to and supported and/or restrained by the ceiling. Insulation *(G)*.
- The design earthquake action shall be applied through the centre of mass of the ceiling which can be taken as either the centre of the ceiling tile or lining boards.
- Ceiling systems shall be designed to resist earthquake actions without —
  - Causing suspension components to dislodge; the ceiling impacting the building structure, services, or non-structural components, including allowance for inter-storey drift of the structure; allowing parts weighing 7.5 kg or more to dislodge and fall more than 3 m.

INTERSTOREY SWAY/DRIFT



INTERSTOREY SWAY

- A.S. 1170.4 allows 1.5% sway
- For a 3 m floor to floor height that represents 45 mm sway between adjacent floors.
- If the ceiling is attached to the walls and hung from the floor above then the ceiling is going to sway of the order of 30 mm and the design has to allow for that movement!! I.e. movement joint on the other free side
- Trend in New Zealand is to brace to the structure over and this reduces the sway to about 15 mm maximum

Ceiling NRAH Bedroom with services above

Ceiling NRAH Corridor with services above

New Ceiling Standard AS 2785

- Joint Australian and New Zealand Standard.
- My comments are based on the draft standard reviewed by Industry to date.
- Has been through 3 public comment reviews.
- Hopefully it will be published late February/early March 2020.
- Will incorporates many major changes.

Changes in the Ceiling Standard AS 2785

- The word *“Load”* has been replaced by the word *“Action*”
- The definitions have been substantially upgraded.
- The word *“fastener”* has replaced the word *“fixing”*.
- The concept of Seismic Grade (SG) of the ceiling has been introduced.
- Design Producers Certification (PS) has been introduced.
- Construction Monitoring (CM) has been added.
- The concept of Significant Engineering Design (SED) has been introduced.
- Section 4 on Design and Installation requirements have been substantially revised including earthquake and wind design.
- Restraint of luminaires has been added
- The design of fasteners into concrete has been revised .
- The acoustic requirements have been modified
- Detailing, ceiling restraints and services interaction has been included in Section 5
- Testing and verification methods have been upgraded in Section 6.
- The Appendices have been upgraded.

Design Actions for Ceilings

The following apply, as a minimum:

- Permanent *(G)*, imposed *(Q)*, wind *(W)* and earthquake *(E)* actions shall be determined in accordance with AS/NZS 1170.1, AS/NZS 1170.2, AS 1170.4 and NZS 1170.5, as applicable.
- Load combinations shall be considered in accordance with AS/NZS 1170.0 as applicable.
- Allowance shall be made for an additional imposed live action *(Q)* of not less than 0.03 kPa (3 kg/m^2) in all ceilings, to account for incidental loading. This action shall be included in the earthquake mass, and shall be additional to all permanent actions including insulation, light fittings and the like. Pattern loading need not be considered with this action, unless applicable.
- All ceiling hangers shall be designed to withstand worst-case scenarios and combinations potentially resulting from positive and negative actions.

How do you design for Seismic Actions

The basic design documents:

- Sufficient drawings to show the scope of works relating to the ceilings and their support.
- The height of the suspended ceiling above the finished floor level.
- Either the level of the structural soffit above the ceiling or the depth of suspension.
- Details of the structure from which the ceiling is to be suspended and any limitations
- Details and size of any items projecting into the ceiling void (e.g. beams).
- Details of any other items contained within the ceiling void
- Details of any removable panels for access to services, controls, and the like,
- Details of any roof lights, blind boxes, and soffits to window heads.
- Siting of sprinklers, fire detectors, access to fire dampers, air distribution outlets or other terminal equipment,
- Position and detail of partition head members and facility to be provided by the
- Position and nature of cavity barriers.
- Details of edge treatments and abutments.
- Position and type of any luminaires, including weights supported by the ceiling.
- Details of integral and applied finishes.
- Details of any acoustic specification requirements, including anti-vibration components.
- Details of passive fire specification requirements.
- Details for seismic design and performance criteria, as specified in Clause B.2.
- Details for wind design and performance criteria, as specified in Clause B.3 .
- Any other relevant design details.
- The seismic grade (SG) for the ceiling. NZ
- The level of Construction Monitoring (CM). NZ
- Where Specific Engineering Design (SED) is required together with the extent of documentation required including computations, standard details, and drawings of layouts with bracing and the like.

1.For Australia

Table B.2.2(A) — Requirements for Australia

Seismic design and performance criteria

Building description	Seismic design of ceiling required?
Domestic dwellings with height ≤ 8.5 m, using conventional materials and methods of construction and $k_pZ \leq 0.11$	No
Domestic dwellings with height ≤ 8.5 m, using non-conventional materials and/or methods of construction	Yes
Domestic dwellings with height > 8.5 m (Class 1a or 1b)	Yes
Importance Level 1 buildings	No
Importance Level 2 and 3 buildings	Yes
Importance Level 4 buildings	Yes — with a special study required for serviceability, often taken as 1 in 500-year return.

Clause 8.3

Project **RAAF TINDAL CONTROL TOWER**

Importance Level = **4**

Seismic Weight

1. *Weight of grid system kg/m2*	=	3	kg/m2
2. *Weight of tile or plaster board kg/m2*	=	5	kg/m2
3. *Service load as required by AS/NZS 2785:2000 - 3.0 kg/m2*	=	3	kg/m2
4. *Supported weight of HVAC delivery unit – 0.0kg/m2**	=	0	kg/m2
5. *Supported weight of light fittings – 1.0kg/m2*	=	3	kg/m2
Total Seismic Weight - kg/m2	=	14	kg/m2

Adopted Seismic Weight W_c= 14 kg/m2

0.5 W_c = 7 kg/m2

0.05 W_c = 0.7 kN/m2 (Minimum)

8.3 SIMPLE METHOD

$F_c = K_p\, Z\, C_h(0)\, a_x\, I_c\, a_c\, /R_c]W_c > 0.05W_c$ . . . 8.3

k_p = probability factor = 1.7

Z = hazard factor = 0.06

$C_h(0)$ = bracketed value of the spectral shape factor for the period of zero seconds,
as given in Clause 6.4 = 1.3 Site sub-soil C_e

a_x = height amplification factor at height h_x at which the component is attached, given as follows:
= $(1 + k_c\, h_x)$

$k_c = 2/h_n$ for $h_n \geq 12$ m or = 0.17 for $h_n < 12$ m

h_x = height at which the component is attached above the structural base of the structure, in metres and assume ceiling 1.5 m below floor level

h_n = total height of the structure above the structural base, in metres
= 25 m

I_c = component importance factor, = 1.5 Assume component critical for life safety

a_c = component amplification factor = 1

R_c = component ductility factor = 2.5 Assume member design

$F_c = [K_p\, Z\, C_h(0)\, a_x\, I_c\, a_c\, /R_c]W_c > 0.05W_c$ . . . 8.3 = 0.010916 $*a_x$ kN

Poduimn

Storey	h_n m	h_x m	k_c	a_x	Force Fc Kn /m2	Force Fc Kg /m2	Horizontal Force on Brace 81m2 Kn	Horizontal Force on Brace 81m2 Kg	Horizontal Force on Brace Connections 81m2 Kn	Horizontal Force on Brace Connections 81m2 Kg
Control Floor	25	25	0.080	3.00	0.0327	3.3	2.652	265.2	6.63	676.7

Seismic Design

For Australia, where seismic design is required, the following procedure may be used:

- Determine the building Importance Level the National Construction Code (NCC).
- Determine the annual probability of exceedance for wind and earthquake, NCC.
- Determine the actions, permanent (G), imposed (Q), wind (W) and earthquake (E) in accordance with the relevant Australian Standards.
- Determine any other action, when relevant.
- Determine combination actions in accordance with AS/NZS 1170.0.
- Analyse the ceiling system and parts, in accordance with AS 1170.4. It is preferable to use the **method of floor acceleration** which requires analysis by a competent person.

NOTE: A competent person in this instance could be a structural engineer.

- Provide the necessary design for fixed and free edges together with any back bracing and the like.
- Confirm that the system capacity, as design, exceeds the appropriate design action effect.
- The project documentation for Australia should, as a minimum, include the information in Table B.2.2(B) to facilitate the seismic design of the ceilings.

Project documentation for Australia

Parameter	Value
Building importance level	
Earthquake design category (EDC)	
Site sub-soil class	
Structural period (T)	
Interstory drift — Ultimate (mm)	
Interstory drift — Service (mm)	
Peak floor accelerations (a_{floor})	

If it is preferred to use the design accelerations method as this results in a more economic ceiling system, for the seismic design of parts, then peak floor accelerations (a_{floor}) should be specified.

Wind design and performance criteria

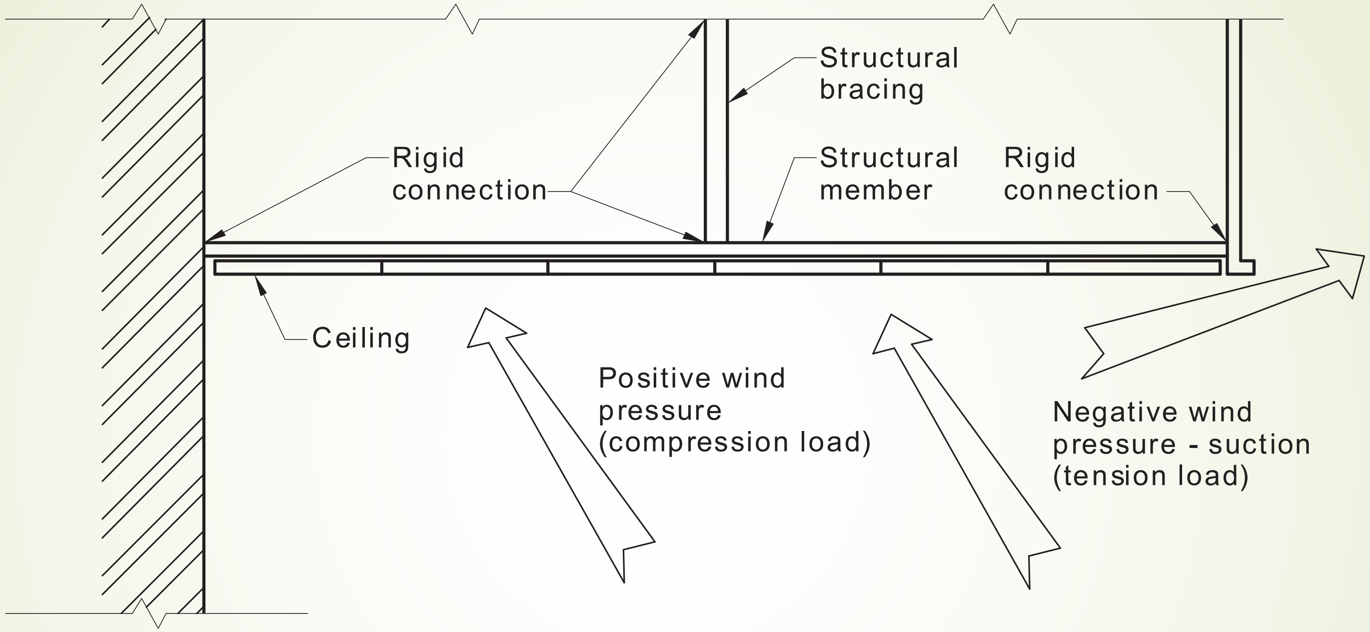
The project documentation should, as a minimum, include the information in Table B.3 to facilitate the wind design of the ceilings.

Parameter	Value
Design wind speed ($V_{des.\emptyset}$)	
Terrain category ($M_{z,cat}$)	
Shielding factor (M_s)	
Topographic multiplier (M_t)	
Hill-shape multiplier (M_h)	
Lee multiplier (M_{lee})	
Internal pressure coefficient (C_{pi})	

Design drawings and documentation for tender

- Layout drawings for tender should be provided at a minimum scale of 1:100, and be cross-referenced to drawings illustrating general details, perimeter details, changes in level and junctions between dissimilar materials and the like.
- For ceilings that are to be supported from purlins or trusses, the ceiling layout should be designed with the main rails perpendicular to the purlins.
- Where the layout of ceiling infill units is important, reflected ceiling plans should be included showing setting out points for the ceiling.
- Where recessed luminaires or ceiling registers/cushion boxes are to be used, these should be indicated on the reflected ceiling plans together with an indication as to whether the ceiling contractor is required to provide support for them. The approximate weight of recessed luminaires or ceiling registers/cushion boxes and, where known, the supplier's reference should also be given.
- The design criteria listed in Clause B.1 should be included in the drawings. Alignment with modular elements such as structural columns or window mullions should be considered.
- Where additional hangers are required for support of other services, this requirement should be stated in the tender document.
- The tender documents need to indicate whether the design of ceilings is required by a registered and experienced engineer and where Specific Engineering Design (SED) is required.

Installation of external ceilings, areas with doors to outside



The wind actions on an external ceiling, wind lobbies and the like will be the same as the wind actions applied to the adjacent wall and roof areas. Wind actions create both positive pressure (compression) and negative pressure (tension) on the face of the external ceiling and bulkheads. Consequently, the ceiling product, including tile or plaster board, as well as the structures to support it will need be designed to resist these actions by a competent person for the appropriate wind actions experienced in wind design (see Figure E.1). This design will require Specific Engineering Design (SED). The installation will also have to be consistent with the SED principles.

Safety critical fasteners

Fasteners used for the installation of both primary structural elements or non structural elements are regarded as **safety critical**, if they fail, or failure could lead to the injury of the building's occupants or possible loss of life.

Do not let others suggest they are not safety critical, **THEY ARE**

Fasteners for ceilings

- Significant failures of post installed fasteners worldwide including Australia
- Fasteners can be into concrete or steel
- A new Standard on Design of post-installed fasteners and cast-In fasteners into concrete was released in 2018, AS 5216 and called up in the 2019 NCC.
- **All ceiling fasteners into concrete are deemed to be safety critical**
- Power actuated (shot fired) fasteners (PAF) for ceiling hangers into concrete are not acceptable fastener into concrete in tension unless they comply with AS 5216. Only one supplier has Etag approval for PAF and load capacities are low.
- All post-installed fasteners into concrete must comply with AS 5216 and with recommendations of the Australian Engineered Faster and Anchor Council (AEFAC) information for the design of safety-critical cast-in and post-installed fasteners and all operatives should have AEFAC Installer Certification
- Post installed fixings should comply with the principles as set out in the Australian Engineered Faster and Anchor Council (www.aefac.org.au) and all fixings must be tested in accordance with ETA – European Technical Assessment (formerly European Technical Approval
- Power actuated (shot fired) fasteners Into the webs of purlins in shear generally satisfactory subject to design.

Fasteners generally for seismic

Nasty clause in AS 1170.4 in Clause 8.2

- Rc = component ductility factor : = 1.0 for rigid components with non-ductile or brittle materials or connections = 2.5 for all other components and parts
- What this means is that ceilings components such as braces, framing et cetera is designed for the seismic load but the connections are designed for 2½ times that load for robustness

Hangers

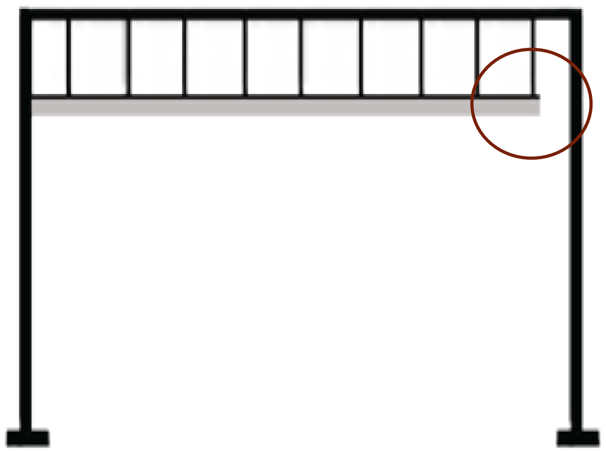
- Unlike New Zealand hangers need to be only designed for vertical loads for permanent loads down and wind up or down.
- **No requirement for seismic loads up or down for hangers.**
- However do need to check for wind load up and down which could be critical.
- There have been a number of failures due to wind particularly in high-rise buildings of ceilings in Australia, not in cyclonic areas and this is alerted in the Wind Standard AS 1170.2.
- Hangers are designed for 50 kg minimum down or 1.5 times the total load up or down.
- **Need to avoid progressive collapse**.
- Shot fired fixings for ceiling hangers into concrete not acceptable and drilled fixings into concrete must be used.
- 6 and 8mm mm screw fixings have typically now been used extensively for the last 5 years successfully for fasteners into concrete

Post Installed Fixings NRAH

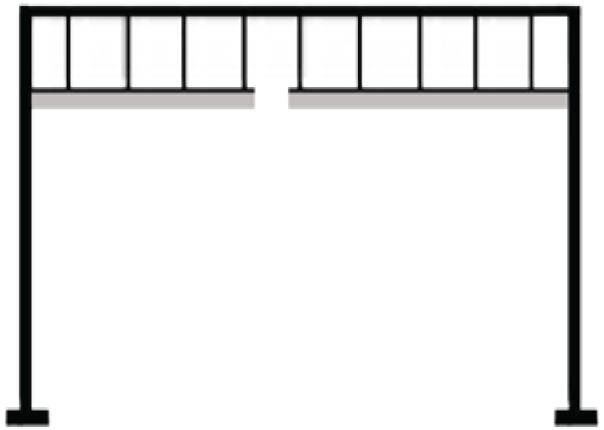
- The NRAH project some years ago shook up the fixing industry in SA as all fixings had to be designed for actions incl EQ **(by engineers).**
- Anchors had to be suitable for use in cracked concrete and rated for seismic conditions.
- Shot fired fixings for ceiling hangers into concrete were not acceptable and drilled fixings into concrete were used.
- Recommend all fixings comply with the Australian Engineered Faster and Anchor Council (AEFAC) Standard for the design of safety-critical cast-in and post-installed fasteners and all operatives to have AEFAC Installer Certification
- A new Standard on Post Installed Fixing was released in 2018 and is now called up in the NCC, AS 5216
- Post installed fixings must comply with the principles as set out in the Australian Engineered Faster and Anchor Council (www.aefac.org.au) and all fixings to be tested in accordance with ETA – European Technical Assessment (formerly European Technical Approval)

Restraint and Bracing for Seismic Actions

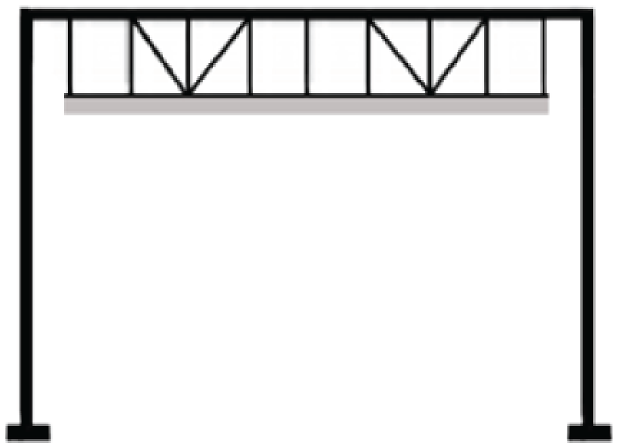
- Ceilings can be restrained against seismic or other horizontal actions using one of several methods. The method of restraint will depend upon the site conditions, structure type, seismic action and other conditions. The more common restraint solutions are as follows:



1. Perimeter fixing



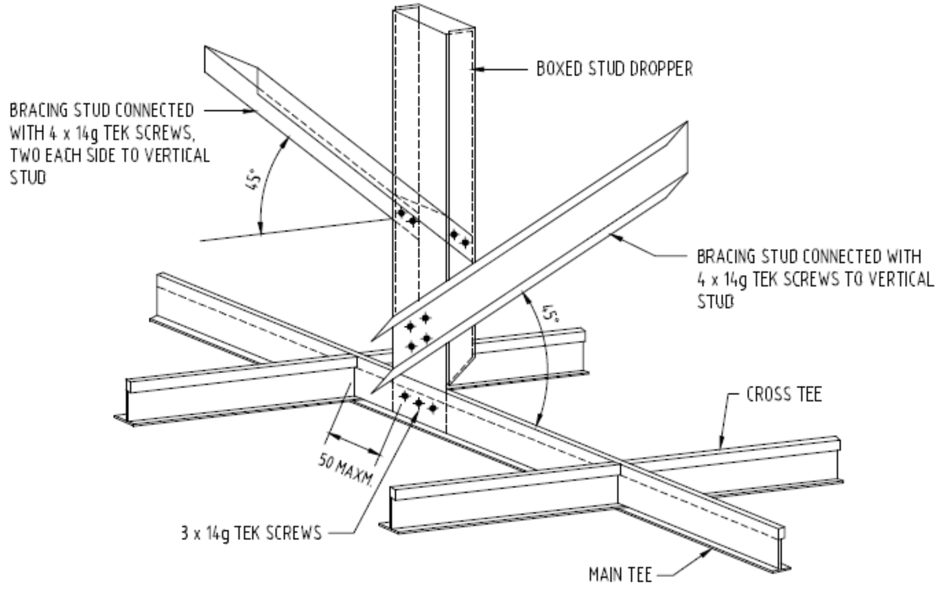
2. Perimeter fixing with seismic separation break



3. Floating on all sides, braced to the structure

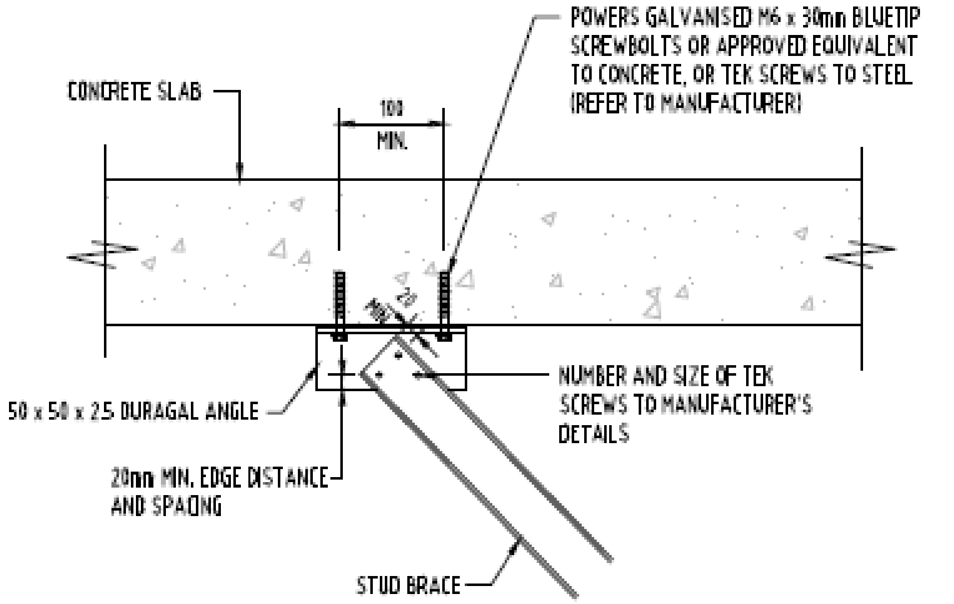
System 3 is almost universally used in NZ

Bracing



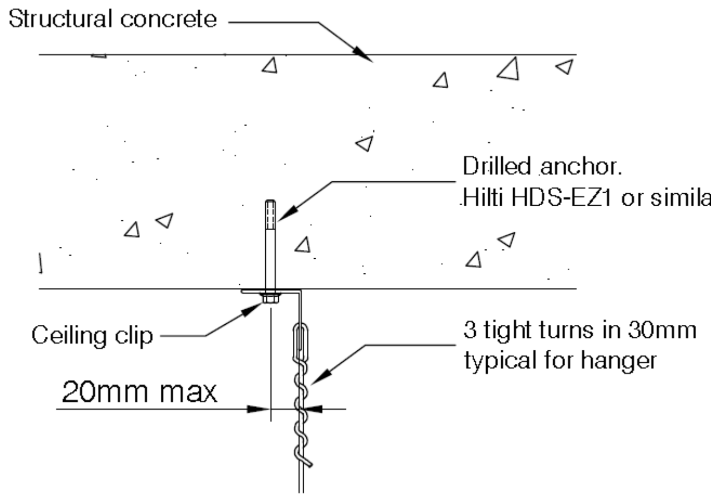
STUD BRACE

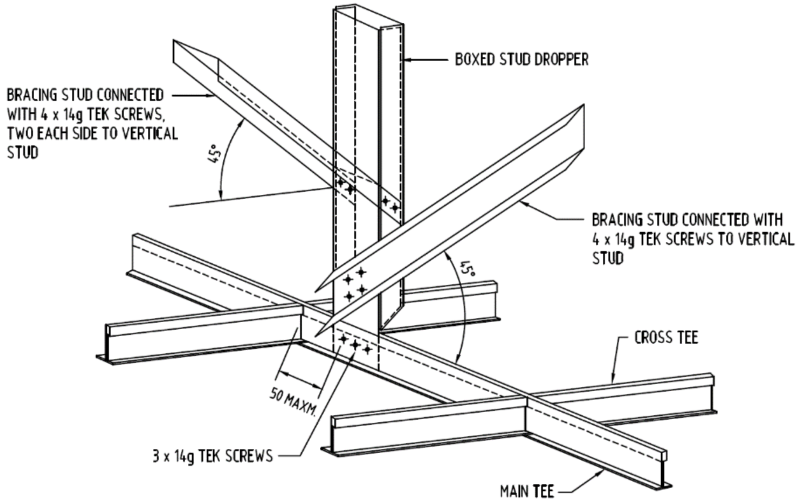
REFER TO MANUFACTURER'S TECHNICAL LITERATURE
FOR BRACE CAPACITY AND EXACT DETAILS.



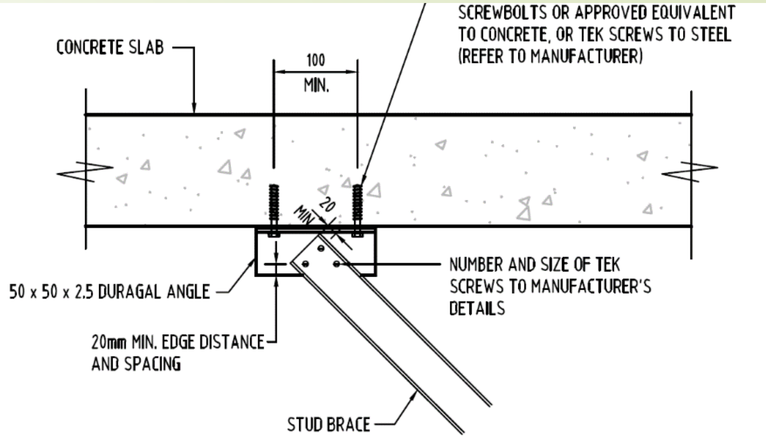
STUD BRACE FIXING TO STRUCTURAL SOFFIT

Fixings and Bracing



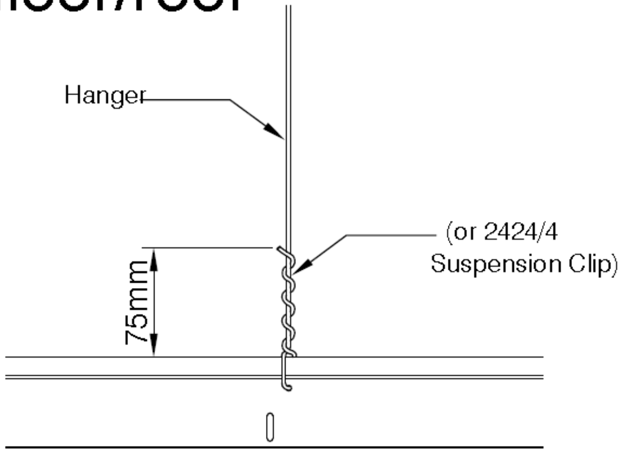


STUD BRACE

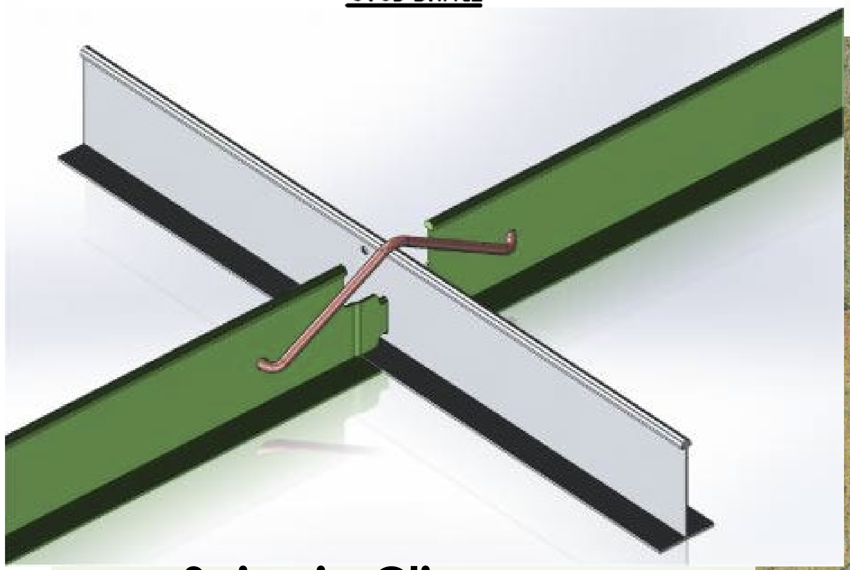


STUD BRACE FIXING TO STRUCTURAL SOFFIT

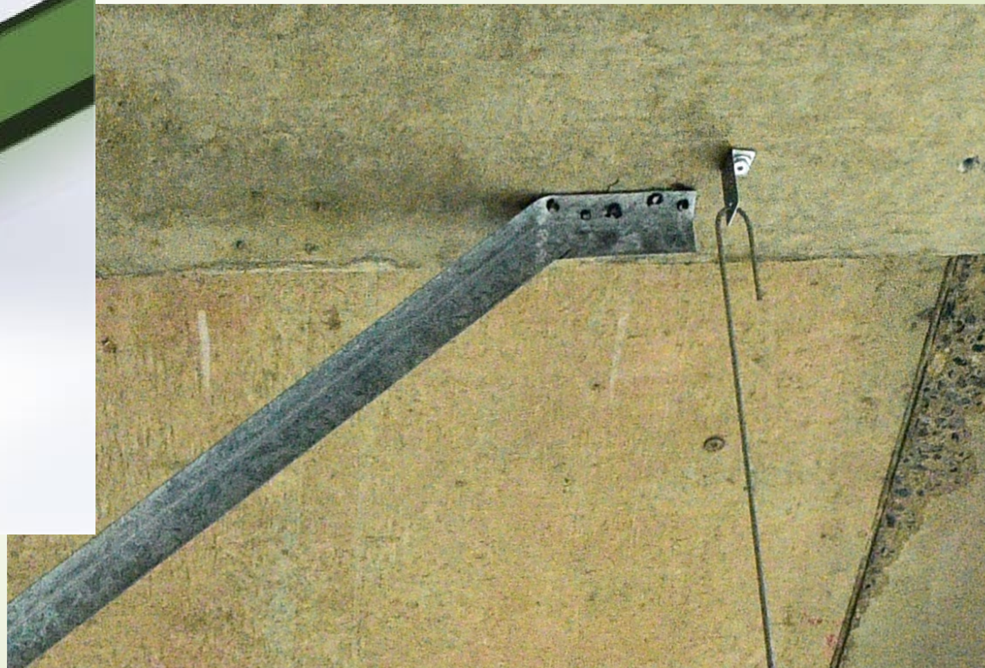
vertical hanger wire attachment at concrete floor/roof



Hanger at tee bar
section F-F



Seismic Clips



Design for wind AS 1170.2

- Combinations of openings shall be assumed to give internal pressures, which together with external pressures give the most adverse wind actions. Potential openings include doors, windows and vents. Closed doors (including roller and garage doors) and windows shall be considered to be openings unless they are capable of resisting the applied wind pressures in all regions (and impact loading from wind-borne debris in Regions C and D). This structural assessment shall include elements such as supports, frames, jambs, roller door guides, wind locks and fixings where the resistance of roller doors relies on those. This assessment shall account for any catenary actions developed and relied upon in the structure.
- In Regions C and D, internal pressure resulting from the dominant opening shall be applied unless the entire building envelope (windows, doors and cladding at heights up to 25 m) can be shown to be capable of resisting impact loading from wind borne debris determined in accordance with Clause 2.5.8.

Design for wind AS 1170.2

- External ceiling needs to be designed by a structural engineer e.g. balcony soffits etc
- Ceiling adjacent to main doors and the like are very susceptible to wind actions (loads)
- Medium and high rise buildings with external doors particularly when left open can lead to failure of ceilings
- Indeed a number of failures have already been reported around Australia

DPTI SA

DPTI now requires designers on their projects in SA to:

- Specify and install ceilings to resist seismic forces in accordance with Section 8 of AS 1170.4 – 2007 and AS/NZS 2785 - Suspended ceilings.
- Co-ordinate ceiling design and services design where the services impose any load on the ceiling or penetrate the ceiling.
- Will not allow the design team to make builders responsible for the EQ design of ceilings.
- Provide suitable seismic clearances between services and ceiling members.
- **The design team have to design and document the ceilings and partitions for tender such that the manufacturer and ceiling suppliers and installer clearly understand the seismic design criteria and seismic design requirements.**

Who designs your ceiling for seismic loads

- You need to allow for screw fasteners for ceiling hangers and bracing as required in your tender.
- You need to decide what method of bracing you are going to use.
- You need to allow for any engineering design and periodic inspection if required for the design of the ceiling.
- You need to allow the cost of this work in your tendering. Suggest you separated out as separate prices so those assessing the tenders understand the costs involved.
- There are new products out of New Zealand principally for bracing which can be used for ceilings.
- Most of the major ceiling suppliers now provide that service albeit they are struggling with the amount of work they are getting.
- There are now consultants, principally structural engineers to provide these services
- **It is no longer good enough to guess it!!**

Conclusion

- For the design of ceilings in Australia the NCC calls up the loading standard AS 1170.4 for earthquake design which in turn calls up the ceiling standard for detailing.
- The ceiling standard for Australia and New Zealand has been updated and rewritten to suit current detailing required for seismic loads.
- Building owners, architects, structural engineers, project managers, contractors and ceiling contractor's and suppliers need to understand that it is

  It is mandatory under the NCC to design ceilings for both seismic and wind actions (loads).

- **Thank you for listening**