Seismic Design of Suspended Ceilings

What you need to know about the National Construction Code, AS 1170.4 and AS/NZS 2785

siniat

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INTRODUCTION

Earthquakes can have a sizable financial impact when it comes to repairing building damage or, worse, requiring structures to be torn down and rebuilt. However, the greatest risk is to the lives and wellbeing of building occupants, which is why the key focus of seismic design is about saving lives and preventing injury.

In most buildings and building types, walls, ceilings and facades need to be designed to resist seismic loads during earthquakes. The failure of ceilings is one of the most frequently reported types of non-structural damage to buildings as they are vulnerable to damage from seismic activity, sustaining panel loss and grid failure even in the absence of major structural damage. During an earthquake, debris from a failing ceiling can cause injury or death and block off exits, preventing people from safely escaping the building.

There are numerous examples of ceiling failures under seismic conditions. In 1989, the John Hunter Hospital in Newcastle had to be substantially rebuilt due to earthquake damage to the structure as well as the ceiling system. The Tennant Creek Hospital in the Northern Territory also sustained damage to its ceiling system during a series of three large earthquakes in 1988. In New Zealand, many commercial buildings in Christchurch suffered damage to their suspended ceiling systems during the 2011 earthquake with observers noting a range of issues including dislodged and broken ceiling tiles, separated grid members, broken connections, and failed perimeter angles.[1]

In Australia, seismic design is not a choice—it is a requirement of the National Construction Code and governed by a range of Australian standards and regulations. In this respect, the design of non-structural building components for seismic loads is equally important as the structure itself, and also a regulatory requirement. Below we take a closer look at the seismic design requirements for suspended ceilings.

"Earthquakes don't occur in Australian often, but when they hit they can cause extensive damage. This photo was taken after the 2021 earthquake in Melbourne."

EFFECTS OF EARTHQUAKES ON STRUCTURES AND NON-STRUCTURAL BUILDING COMPONENTS

One of the seismic effects that negatively affect a building is the generation of inertia forces within the structure. An earthquake causes the ground to shake. While the ground is shaking, the base of the building starts to move. As the building's base moves with the ground, the roof tends to hold in its initial position. The roof, however, is dragged along with the movement of the building because it is attached to walls and columns that are joined to the structure.

In this example, the tendency for the roof to remain in its initial position is called "inertia".[2] Since the building's walls and columns are flexible, the movement of the roof will differ from that of the ground. Inertia forces put extreme stress on a building's supporting frame as a result of the difference in movement between the bottom and top of the structure, which can eventually lead to the collapse of the entire building.

Earthquakes generate forces in horizontal and vertical directions. The building's mass, size, and shape partially determine the strength of these forces and the structure's ability to resist them. Commonly, structures are designed to withstand vertical loads, but the greater the horizontal earthquake forces during an earthquake, the greater the possibility of columns and other loadbearing components weakening to the point of failure.[3]

Non-structural elements are not a part of the structural loadbearing system of a building, but they are still subject to the same dynamic forces during an earthquake.[4] If a non-structural element, such as a suspended ceiling, is hung from a structural element, it may swing during an earthquake. If the horizontal or vertical forces are too much, the suspended ceiling may fail and fall out of the structural ceiling slab.[5] Damage to non-structural components occurs at seismic intensities much lower than those required to result in structural damage.[6]

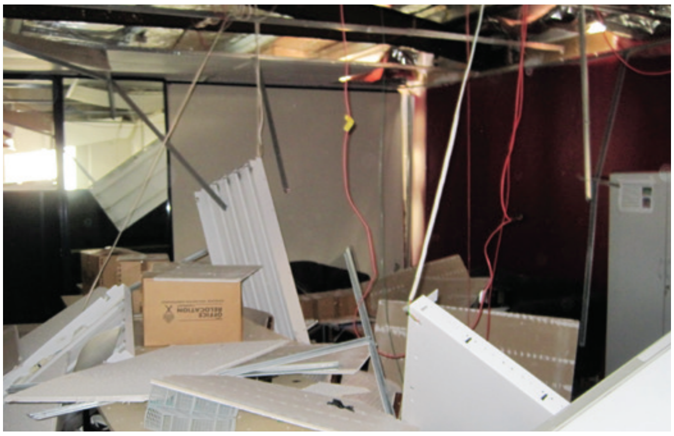


Photo by Charlene Hails of MRP Engineering while on ASCE-sponsored assessment team in Christchurch, New Zealand in 2011.

STANDARDS AND REGULATIONS

There are several standards and regulations that govern the seismic design of suspended ceilings in Australia. The three key regulatory instruments are:

- the National Construction Code (NCC),
- AS 1170.4:2007 "Structural design actions, Part 4: Earthquake actions in Australia"; and
- AS/NZS 2785:2020 "Suspended ceilings - Design and installation".

The NCC 2022 Volume One contains Performance Requirement B1P1 that requires Class 2–9 buildings to perform adequately under all reasonably expected design actions, including earthquakes. For Class 1 buildings, provisions for seismic design are contained in Appendix A of AS 1170.4 (see below). Generally, Class 1 buildings designed and detailed for lateral wind forces in accordance with the relevant material standards (e.g. AS 1684 or AS 3700) are considered able to also resist earthquake forces.

For Class 2-9 buildings, the corresponding Deemed-to-Satisfy (DTS) Provision for earthquake actions is Clause B1D3 in NCC 2022.

In accordance with Table B1D3a in NCC 2022, buildings are assessed according to their 'Importance Level'. The Importance Level determines the seismic design requirements of a building depending on its occupancy levels, hazard to life and the function of the building within the community or broader.

In relation to Australian standards, AS 1170.4 governs the seismic design of buildings and is referenced in the NCC earthquake provisions. AS/NZS 2785 was updated in 2020 and provides the minimum specifications covering the manufacture and performance of suspended ceilings systems for use in residential, commercial and industrial applications.

AS 1170.4—THE LOADING STANDARD

AS 1170.4 provides the method of assessing the seismic actions applicable to walls and ceilings in the building. Every building constructed in Australia must take AS 1170.4 into account, but the design action differs for every building. When determining the design loading that applies, several factors must be considered:[7]

- location of the site to determine the Hazard Design Factor (see Figure 3.2(F) of AS 1170.4);
- Importance Level of the building (see Table B1D3a of the NCC 2022);
- site sub-soil classification (see Section 4 of AS 1170.4); and
- structure height.

These variables allow for the determination of the Earthquake Design Category (EDC). Australia has three EDCs that cover everything from single-storey, low-risk commercial buildings to multi-storey, higher-risk structures housing a large number of people. The relevant EDC is determined by referring to Table 2.1 of AS 1170.4.

Section 8 of AS 1170.4 details specific non-structural building parts and components that must be designed to withstand horizontal and vertical earthquake forces for Class 2–9 buildings. The following non-structural components are listed in detail in Clause 8.1.4 as needing to consider earthquake loads:

- walls that are not part of the seismic-force-resisting system;
- appendages, including parapets, gables, verandas, awnings, canopies, chimneys, roofing components (tiles, metal panels) containers and miscellaneous components;
- connections (fasteners) for wall attachments, curtain walls, exterior non-loadbearing walls;
- partitions;
- floors (including access floor systems);
- ceilings; and
- architectural equipment including storage racks and library shelves with a height over 2.0m.

AS 1170.4 also requires that mechanical and electrical components and their fastenings commonly found in high-rise buildings must be considered for earthquake loads, including lighting fixtures, ducts, sprinkler systems, and more.

The design of building components must be carried out for earthquake actions by one of the methods provided in Section 8 of AS 1170.4. These methods include the use of established principles of structural dynamics, or the general or simplified methods expressed in Clauses 8.2 or 8.3 of Section 8.[8]

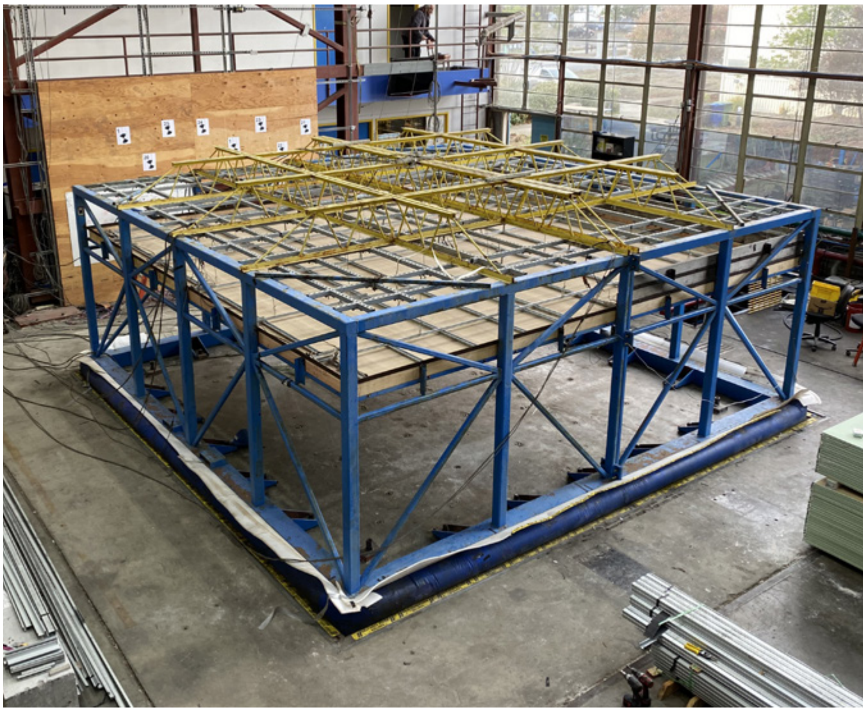
“Non-structural elements are not a part of the structural loadbearing system of a building, but they are still subject to the same dynamic forces during an earthquake.”

AS/NZS 2785—THE SUSPENDED CEILING STANDARD

The design of suspended ceilings in Australia and New Zealand is covered by AS/NZS 2785. The 2000 version of this Standard included guidance on complying with building code requirements in general, but there were several aspects of seismic design that were not covered. These aspects included the interactions and required clearances with other components; the methods of achieving adequate seismic restraint; and interstorey drift and clearance requirements.

The updated 2020 version of AS/NZS 2785 clarifies several areas of seismic design for suspended ceilings, including the following:

- consideration of the primary structure to support ceiling loads;
- clarification on the scope of imposed actions;
- seismic clearance requirements for adjacent elements and penetrations;
- serviceability requirements of square set joints and cornices;
- partition wall restraint methods and requirements, including when it is appropriate to have ceilings fixed to partition walls; and
- examples of edge connections and seismic bracing.

Photos taken during testing of Siniat products at the Pacific Earthquake Engineering Research (PEER) Centre at the University of California at Berkeley, USA.

TESTING FOR SEISMIC COMPLIANCE

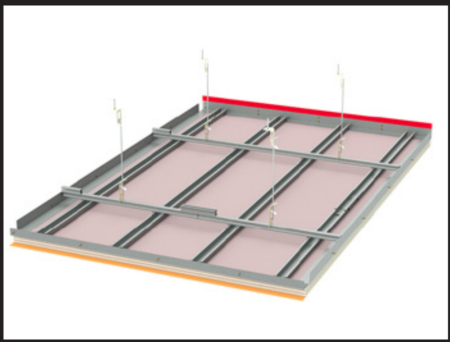
Testing for seismic compliance is complicated as there are many forces at play during an earthquake. One of the most widely accepted methods for evaluating the seismic performance of building components and systems is the shake table test. A shake table is a testing facility that realistically simulates earthquake forces that are imposed onto a test model. Building components and systems are typically tested on a shake table to the point of failure.

All the parts and components in the load path of the structure must have sufficient seismic performance ratings to safely transfer the seismic loads imposed from the suspended ceiling.[9] This includes fasteners, restraints, and other connection points.

To ensure that the ceiling performs as expected, test procedures should mimic reality as close as possible. In lieu of an applicable Australian testing standard or guideline, international seismic testing standards are used for ensuring the ceiling assembly performs as expected in earthquake conditions.

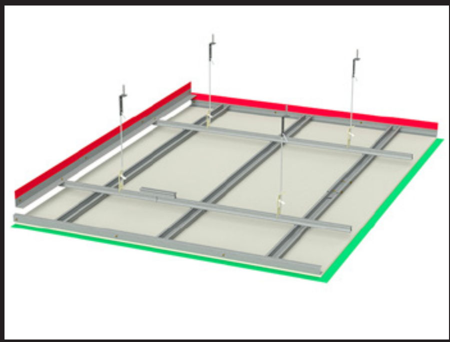
SEISMIC CEILING DESIGN SOLUTIONS BY SINIAT

Siniat offers three main design solutions for suspended ceiling systems to comply with the Australian seismic design requirements of a particular project. The three solutions are differentiated by the size of the ceiling area and seismic loads, and all three can be used in fire-rated and non-fire-rated applications.



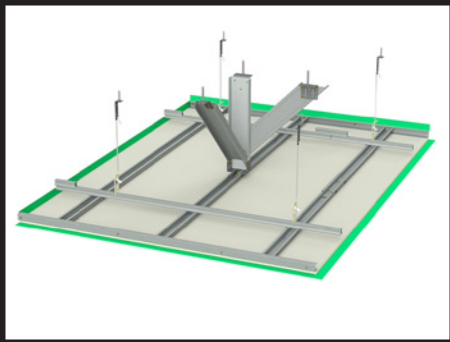
Type A (Fire-rated and Non-fire-rated): One side fixed and the opposite side sliding.

Type A can be used in small to medium rooms. It is also suitable for long corridors without the need for plenum bracing, e.g. in shopping centres or hospitals. The design can be used for fire-rated and non-fire-rated applications.



Type B (Fire-rated and Non-fire-rated): Two adjacent sides fixed and two adjacent sides free.

Type B is typically used in small to medium rooms. During an earthquake, the ceiling will move with the wall on the fixed sides but move freely on the free sides. The design can be used for fire-rated and non-fire-rated applications.



Type C (Fire-rated and Non-fire-rated): 2-way plenum brace with four sides free.

The main advantage of this installation is that it can be used in ceilings of all sizes. The Type C design solution does not rely on any perimeter fixing but rather uses a ceiling plenum bracing system to stabilise the ceiling during a seismic event.

There is no perimeter fixing, allowing for movement on all sides. The design is used for fire-rated and non-fire-rated applications.

Unique to the Type C solution is the Seismic Ceiling Bracket (SCB), 80 mm wide Universal Bracket (UB80) and the 45° Soffit Bracket (SB45), exclusively manufactured by Siniat.

How were Siniat's suspended ceiling systems tested for seismic compliance?

Siniat's suspended ceiling systems were tested for performance and compliance at the Pacific Earthquake Engineering Research (PEER) Centre at the University of California at Berkeley in the United States. This testing facility features the largest multidirectional or six-degrees-of-freedom shaking table in the US and allows for rigorous seismic testing in real-world, large-scale conditions. The results have given Siniat a better understanding of how their seismic ceiling systems perform under seismic loads.

The three types of internal suspended ceiling solutions offered by Siniat comply with seismic requirements. All three types surpassed Australian performance ratings.

Please note that compliance with the seismic standards is the combined responsibility of engineers, architects, designers, building certifiers, manufacturers, installers and builders.

Project details must be determined by structural design and the design of suspended ceilings will require a structural assessment unique to every project.

Photo by Charlene Hails of MRP Engineering while on ASCE-sponsored assessment team in Christchurch, New Zealand in 2011.

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