# Adequacy of Australian Standards for Non-Structural Component systems

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## Abstract

Non-Structural Components (NSCs) within a building or structure are defined as architectural, mechanical, electrical and plumbing systems supported by a structural system but are not part of it. The operational capability of NSC during and after an earthquake is critical and even more vital in highly populated buildings and post disaster function facilities. Furthermore, maintenance and repair work of NSCs interrupt the operational function of the building which carries significant downtime and costs.
The performance of NSCs under a seismic event is addressed by the Australian Standards (AS 1170.4:2007–section 8).
This paper reviews NSCs in MEP (Mechanical, Electrical and Plumbing system) standards such as medical gasses systems, fire sprinkler systems and other mechanical, plumbing, electrical systems and their seismic requirements, and propose improvements to allow for seismic design to be better incorporated into the construction industry.

**Keywords:** Non-Structural Components (NSCs), Australian Standards, MEP system (Mechanical, Electrical and Plumbing system), seismic action, adequacy of Australian Standards

## 1. Introduction

Non-structural components NSCs are attached to and supported by the primary structure but are not a part of it. They do not form a part of the load bearing system and does not possess a seismic loads resistant element.

Most common NSCs found in typical buildings are as follows:

- Architectural: partitions, ceilings, walls and cladding
- Mechanical: heating ventilation and air conditioning systems (HVAC), fans, chillers, cooling towers, pipework and ductwork.
- Electrical: cable trays, switchgear, battery racks, lighting fixtures and electrical cabinets.
- Plumbing: pipework, pumps and tanks

The serviceability of NSCs, or the capability of the NSCs to maintain functionality during and after a seismic event is critical, in particular, inside buildings that are intended for immediate occupancy. NSCs contribute an average of 75-85% of construction cost (figure 1). Failure of NSCs directly affects the serviceability and functionality of buildings, so the repair work interrupt occupancy and business efficiency.
This paper reviews the application of seismic design for NSCs in the Australian Standards.

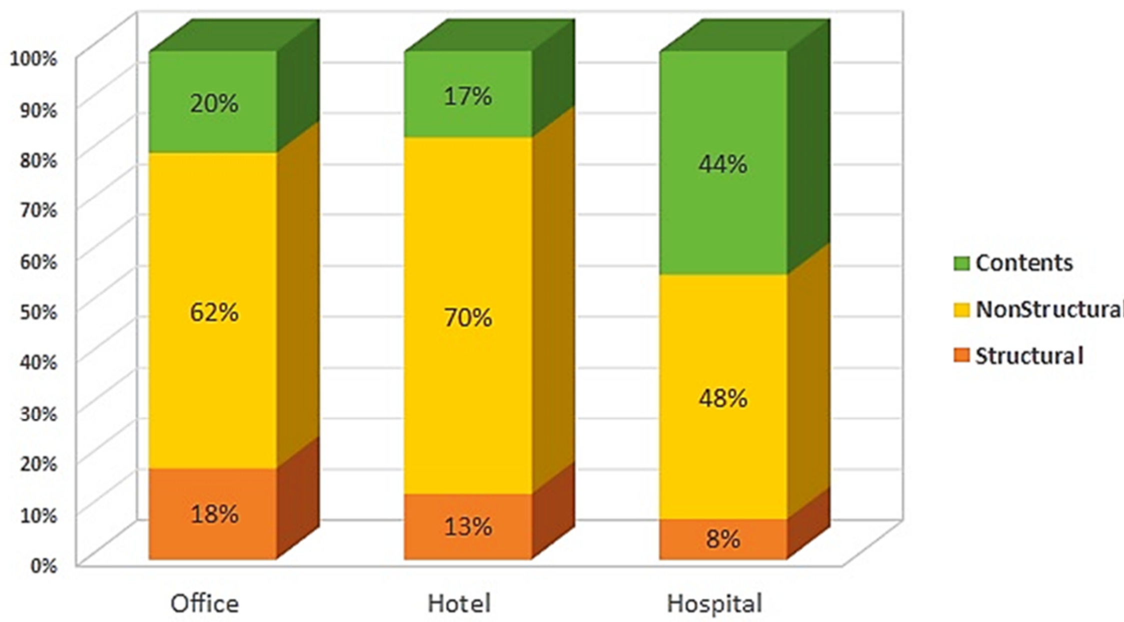



Figure 1: FEMA-74-2011

## 2. The history of seismic action in the Australian Standard

Post Meckering earthquake back in October 14th, 1968, the Standards Association of Australia has addressed the issue for the first time and published AS 2121 in 1979. This standard was commonly known as "the earthquake code".

The earthquake code was both a loading and design code and was applicable for most general-purpose type of structures but did not include bridges or special structures. The code stipulated the followings:

- The parts of building to be designed for minimum forces.
- The detailing of reinforced concrete and steel in the commentary.
- References to assist designers in understanding the principal of seismic design

AS 2121 has been revised in 1988 by the subcommittee known as BD6/4. The committee was a part of the Standards Australian committee BD6 which was responsible for all loading standards for buildings in Australia. The subcommittee first meeting took place just a couple of weeks prior to the Newcastle earthquake in December 28th, 1989. The quake measured 5.6 in the Richter scale, resulting in 13 fatalities, over 160 injured individuals, 35,000 damaged homes, 147 damaged schools and 3,000 damaged commercial buildings. The damage was estimated to exceed A$4 billion (McCue K., 28 Dec 1989). This quake changed the attitude of the building industry towards the potential risks of seismic activity.

In 1993, AS 1170.4 (earthquake actions in Australia) was introduces by Standards Australia. In addition, AS/NZS 1170.0 (structural design actions) was also introduced in 2002. Together, they specified minimum lateral forces for all structures. Also, for the first time NSCs have been addressed in relation to seismic design

## 3. NSCs in the Australian Design Standard

Thanks to AS 1170.4, NSCs were clearly addressed and become a non-separable part of the structural design code. The design methodology has become available for all NSCs designers. The standard addresses the design requirements and exclusions for buildings with importance levels of one to three. But, importance level four buildings require a special study to be carried out. The special study is needed to make sure that the serviceability of NSCs is maintained at all time to allow for immediate occupancy of the building.

NSCs have their own standards in accordance with their discipline. In this paper we focus on MEP systems which compromise of Mechanical, Electrical and Plumbing systems. The design sequence ideally follows the below hierarchy structure:

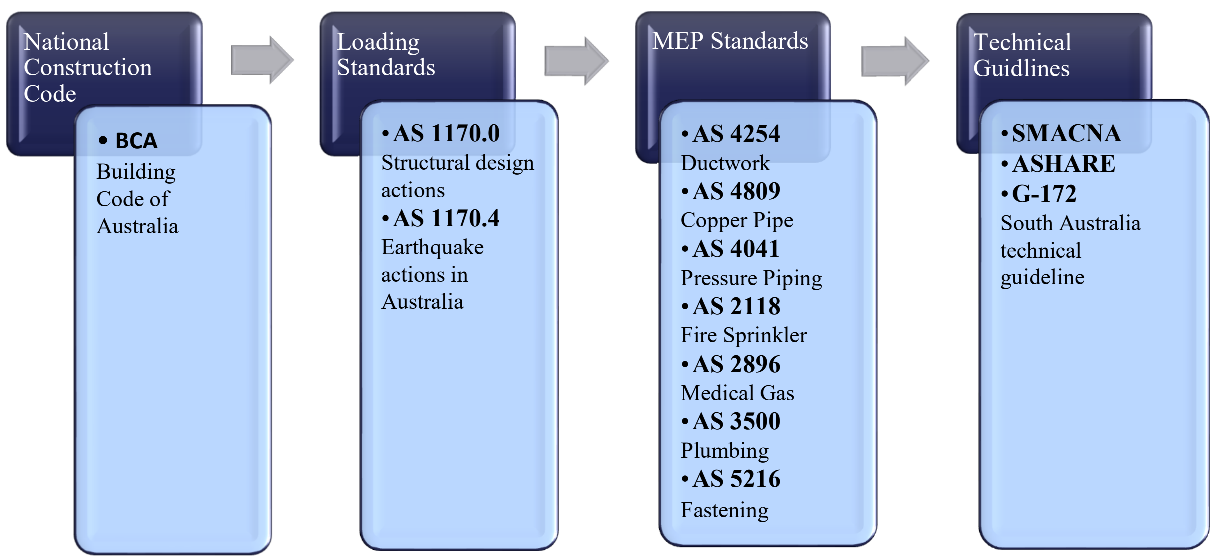



Figure 2: Hierarchy of Standard and technical guidelines in NSCs

AS/NZS 1170.0 and AS 1170.4 are used to calculate the imposed seismic loads which are applied on each component and its connections. Discipline specific standards (figure 2) set the design requirement for the use of each specific system. The standards also describe fixing methods, however, most of the discipline specific standards do not provide a seismic restraints guideline or instructions. Even worse, many of them don't even reference that this is something that should be considered during the design process. As a result, we come across many designers and contractors who are not aware of this requirement. This leads to many projects where NSCs have no ability to resist the next quake and this is a major concern.

## 4. Seismic design of MEP in the Australian Standards

Many of the MEP standard contain limited or no information at all in relation to seismic design. A short list of the common MEP standards is listed below:

### 4.1 No seismic design references

The below list of standards does not address seismic action as a design requirement

- AS 4254.1-2012 Part:1 (Flexible duct).
- AS 4254.2-2012 Part:2 (Rigid duct).
- AS 4809-2017 (Copper pipe and fitting)
- AS 3500.1-20018 (Plumbing and drainage – water services)
- AS 2118.1-2017 (Automatic fire sprinkler system)
- AS 2896-2011 (Medical Gas system)

### 4.2 Limited seismic design reference

This standard mentions seismic as a design load, but doesn't provide design instructions

- AS 4041-2006 (Pressure piping)

### 4.3 Seismic design of fasteners

AS 5216:2018 is the new version of SA TS 101:2015. This standard provides information about post-installed and cast-in fasteners and is referenced in the NCC. However, the design provisions do not allow for seismic actions for fasteners. This is excluded from the scope of this standard: "the design engineer should seek technical advice from the fastener supplier in relation to the suitability of the selected fastener for the intended application". Under clause 1.1.2 we find: "The design parameters and product specifications required for use with this Standard may also be obtained from a current European Technical Approval/Assessment for the relevant fastener."

European technical Approval Guideline (ETAG)-001 introduced Annex E in 2013. Annex E assess anchors under seismic loading. The selection of anchors for structural and NSCs' usage in two seismic performance categories C1 and C2 depends on low or high seismic level and importance class based on EN 1998-1:2004, 4.2.5. This provides a two-tier selection process for anchors and this must be considered in any design that includes seismic loading as a part of its process. In this context it is noted, that the implementation of the standard and the definition of the parameters therein are the responsibility of each individual European member state and the selection parameters for C1 versus C2 are still debated in Europe. (P. Mahrenholtz, 2016) Therefore, it is not clear when category C1 and C2 have to be used for seismic action.

## 5. Additional technical documents and guidelines

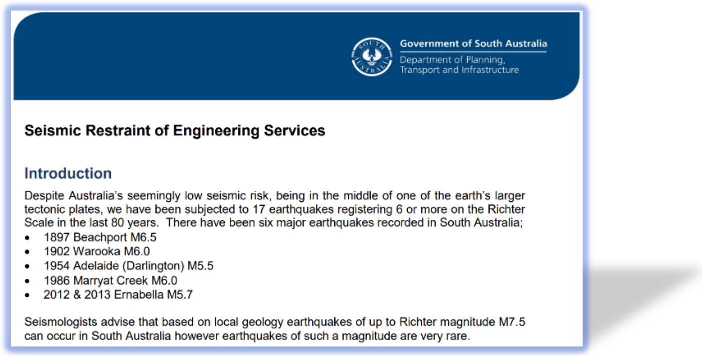
Due to the limited information in the Australian Standards listed above, designers can refer to international standards and guidelines.

### 5.1 G-172 Seismic Restraint of Engineering Services

The South Australian Government is taking proactive actions in relation to design, standards and guideline. The aim of this guide notes is to make the designer aware of:

- Requirements of seismic restraints in accordance with section 8 of AS 1170.4
- Requirements of engineering services and details that needs to be documented and co-ordinate across all discipline.
- Technical information available to assist in designing and detailing.

Although the document provides excellent information about seismic restraints and the requirements of AS 1170.4:2007 section 8, the restraint of engineering services in importance level 4 buildings is excluded from the scope of this guide notes.



Government of South Australia
Department of Planning, Transport and Infrastructure

**Seismic Restraint of Engineering Services**

**Introduction**

Despite Australia's seemingly low seismic risk, being in the middle of one of the earth's larger tectonic plates, we have been subjected to 17 earthquakes registering 6 or more on the Richter Scale in the last 80 years. There have been six major earthquakes recorded in South Australia;

- 1897 Beachport M6.5
- 1902 Warooka M6.0
- 1954 Adelaide (Darlington) M5.5
- 1986 Marryat Creek M6.0
- 2012 & 2013 Ernabella M5.7

Seismologists advise that based on local geology earthquakes of up to Richter magnitude M7.5 can occur in South Australia however earthquakes of such a magnitude are very rare.

Figure 3: South AUS government guide notes G-172

Also, the document displays the hierarchy of accountabilities in relation to seismic design (figure 4) which can be very useful for designers, builders and developers when they work on their project.

*Table 1: Design responsibilities for restraint of engineering services to comply with AS1170.4-2007 (Extract from FEMA 454 table 9-3)* Note: 1 = Primary Responsibility 2 = Support Responsibility

| Engineering Service | Architect | Structural Engineer | Electrical Engineer | Mechanical Engineer | Other Design Professional |
|---|---|---|---|---|---|
| HVAC systems | 2 | 2 | | 1 | |
| Plumbing systems | 2 | | | 1 | |
| Plumbing equipment | 2 | 2 | | 1 | |
| Communication and data systems | 2 | | 1 | | May consider a specialty consultant |
| Electrical equipment | 2 | 2 | 1 | | |
| Vertical transportation systems | 2 | 1 | 2 | 2 | |
| Emergency power supply | 2 | 2 | 1 | 2 | |
| Fire protection systems | 2 | | 2 | 1 | May consider a specialty consultant |
| Kitchen systems | 1 | 2 | | | May consider a specialty consultant |
| Lighting systems | 2 | | 1 | | |
| Medical systems | 1 | 2 | 2 | 2 | May consider a specialty consultant |
| Tanks and vessels | 2 | 2 | | 1 | |
| **Other:** | | | | | |
| Suspended ceilings | 1 | 2 | | | |

Figure 4: Design responsibilities for restraints of engineering services

### 5.2 International Guideline

In addition to G – 172 by the Governments of SA. There are multiple seismic guidelines from around the world where engineers and designers can use in their designs. The most reputable ones are SMACNA (Sheet Metal & Air Conditioning Contractors' National Association), ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) and FEMA (Federal Emergency Management Agency) see figure 5. They offer design methodology for different situations and provide valuable details and connection options for NSCs. The guidelines are relevant to the Australian industry and geography and many sections in the guidelines can be incorporated into AS 1170.4 to create a more specific and clear seismic instruction for the industry.

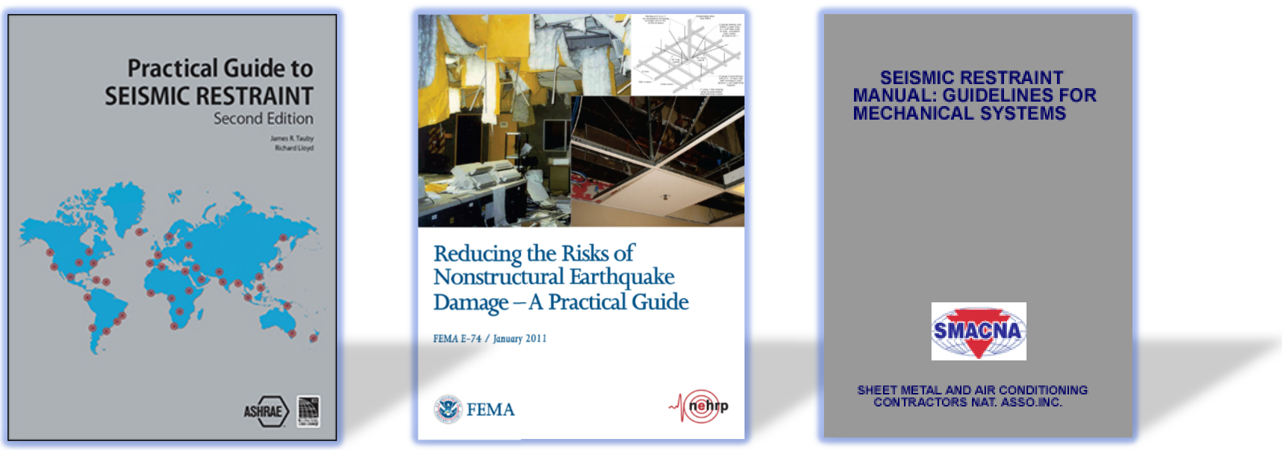



Figure 5: International guidelines

## 6. The future of seismic standards

*"The next generation of earthquake standard is focusing on performance-based design to not only protect life but also to reduce the significant economic losses"* (J.L. Wilson, EJSE 2008).

*"The new generation of seismic standard will be produced for performance base design"* (ABCB Australian Building Code Board 2016)

The current Deemed-to-Satisfy Provisions of 1170.4:2007 are based on life safety only. The provisions apply to buildings with importance levels of 1-3, while importance level 4 buildings require a special study that will provide a Performance Based Design. We believe that amendments to the standards must be introduced before we see the industry implementing them on job sites.

### 6.1 Proposed amendments to AS 1170.4:2007

The standard in its current configuration provides limited guidance in regard to NSCs alongside a short list of exclusions. The standard needs to host deeper information and details that can be collected from the documents and guideline mentioned above. In addition, the standard must evolve from its current life safety approach into a performance-based attitude to make it more consistent with other worldwide standards.

One way to achieve this is to introduce a performance matrix to determine the performance requirement of each section of the building (figure 6). The matrix provides designers and building owners reassurance and consistency of how their building will behave under seismic loads. Demand parameters can be improved for performance-based design method for two categories of components: deformation-sensitive such as partitions and motion-sensitive like devices.

Combinations of structural and nonstructural seismic performance

| Nonstructural Performance Levels | Structural Performance Levels and Ranges | | | | | |
|---|---|---|---|---|---|---|
| | S-1 Immediate Occupancy | S-2 Damage Control Range | S-3 Life Safety | S-4 Limited Safety Range | S-5 Collapse Prevention | S-6 Not Considered |
| N-A Operational | Operational 1-A | 2-A | Not Recommended | Not Recommended | Not Recommended | Not Recommended |
| N-B Immediate Occupancy | Immediate Occupancy 1-B | 2-B | 3-B | Not Recommended | Not Recommended | Not Recommended |
| N-C Life Safety | 1-C | 2-C | Life Safety 3-C | 4-C | 5-C | 6-C |
| N-D Hazards Reduced | Not Recommended | 2-D | 3-D | 4-D | 5-D | 6-D |
| N-E Not Considered | Not Recommended | Not Recommended | Not Recommended | 4-E | Collapse Prevention 5-E | No Rehabilitation |

Figure 6: Performance matrix (FEMA)

### 6.2 Proposed amendments to MEP standards

Mechanical, Hydraulic and Electrical engineers use their own discipline specific standard to accomplish their design. Even though the BCA and NCC governs the designs and dictate seismic consideration, in many cases this is being missed. Most of these standards do contain some sort of fastening requirement for vertical (gravity) loads, but no allowance for seismic. To ensure full compliance, we would suggest each MEP standard to have an additional discipline specific section dedicated for seismic restraints requirements, performance expectations and restraints installation examples. AS 1170.4 will always be the primary loading standard, while each discipline standard to have scope specific consideration.

## 7. Conclusion

The resilience and adequacy of buildings in Australia depends on the information and requirements set by the Australian Standard. Lack of information or requirements that are open for interpretation leaves the industry vulnerable. Most builders and construction professional are putting in big efforts into every project and some areas of the standards must be refined to allow for better results. Adding seismic requirements into each MEP standards and amending AS 1170.4:2007 into a performance-based standard are small steps to make our buildings safer and allowing the industry to achieve better structures to serve the community.

## 8. References


- BCA: 2016 Building Code of Australia
- NCC: 2016 National Construction Code
- AS 1170.4: 2007 Structural design actions, Part 4, Earthquake action in Australia.
- AS/NZS 1170.0: 2002 Structural design actions, Part 0, General Principles.
- AS 2121: 1979 the design of earthquake-resistant building (earthquake code)
- AS 4254.1: 2012 Ductwork for air-handling system in buildings, Part1: Flexible duct
- AS 4254.2: 2012 Ductwork for air-handling system in buildings, Part2: Rigid duct
- AS 4041: 2006 Pressure piping
- AS 4809: 2017 Cooper pipe and fitting
- AS 3500.1: 2018 Plumbing and drainage – water services
- AS 2118.1: 2017 Automatic fire sprinkler system
- AS 2896: 2011 Medical gas system-installation and testing of non-flammable medical gas pipeline systems
- AS 5216: 2018 Design of post-installed and cast-in fastening in concrete
- SA TS 101: 2015 Technical Specification, Design of post-installed and cast-in fastenings for use in concrete
- ETAG 001: 1997 Guideline for European technical approval of metal anchors for use in concrete
- G172: 2015 Seismic restraint of engineering services – South Australia government
- SMACNA: 1991 Seismic restraint manual guideline for mechanical system Sheet metal and air conditioning contractors' national association
- ASHRAE: 2012 Practical guide to seismic restraint – American society of heating, refrigerating and air-conditioning engineers
- FEMA. Reducing the risk of non-structural earthquake damage (2011) A practical guide Federal emergency management agency of USA
- ABCB. Upgrading existing buildings handbook (2016) Non mandatory document - Australian building code board
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