
Seismic implications associated with unreinforced masonry parts within timber-framed buildings

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ABSTRACT

A notable portion of New Zealand's pre-1976 building stock listed in the Earthquake-Prone Building (EPB) register consists of timber-framed structures incorporating unreinforced masonry (URM) parts. Observations from the 2010/11 Canterbury earthquake sequence reaffirmed the well-established understanding that timber-framed buildings generally demonstrate adequate seismic performance when subjected to significant ground movements. However, the presence of URM parts potentially pose a major life-safety risk and govern the seismic risk rating of such buildings according to the EPB methodology. A review of the timber-framed building stock incorporating URM parts was undertaken using data collated from the national EPB register. A typological classification was developed according to the design date, number of storeys, occupancy class, and characteristics of URM parts within timber-framed buildings. The influence that the different configurations had on the potential for injury or death to occupants and nearby pedestrians as well as damage to adjacent properties due to failing URM parts during seismic events is reported. The reported study was undertaken alongside other ongoing initiatives aimed at establishing a more proportionate and risk-based regulatory system for managing earthquake-prone buildings (EPB).

1 INTRODUCTION

Timber-framed buildings form a substantial portion of the New Zealand building stock and have generally demonstrated adequate seismic performance in past earthquakes (Miranda et al. 2023). Post-earthquake observations from the 2010–2011 Canterbury earthquake sequence indicate that timber-framed buildings have generally maintained their structural integrity (Buchanan et al. 2011). However, unreinforced masonry (URM) parts within timber-framed buildings have been shown to introduce vulnerability and generally perform poorly during earthquakes (Buchanan et al. 2011; Cooney 1979; Dizhur et al. 2017; Dizhur et al. 2013).

Under the current earthquake-prone building (EPB) methodology (MBIE 2017), the seismic classification of a building is governed by its weakest part such that even localised deficiencies can result in the entire

building being classified as earthquake-prone. Recent data indicate that 34% of buildings on the EPB register fall outside the profile categories outlined in the EPB methodology, including timber-framed buildings with URM parts (MBIE 2025). Notably, low-rise residential timber-framed buildings were also found in the EPB register despite being within the exclusion criteria under section 133AA of the Building Act 2004. Within this context, URM parts in timber-framed buildings appear to be a key factor in identifying these buildings as earthquake-prone. Therefore, it is important to closely examine timber-framed buildings with URM parts alongside other initiatives to improve future seismic assessment guidelines to be more risk-based and proportionate. A typological classification is proposed that addresses URM parts commonly present within timber-framed buildings in New Zealand, which is then used to evaluate the seismic implications of different URM parts using a qualitative framework.

2 INVENTORY OF TIMBER-FRAMED BUILDINGS WITH URM PART

The inventory of timber-framed buildings with unreinforced masonry (URM) parts was derived from Beca's building inventory dataset (Beca 2025), comprising a subset of timber-framed buildings listed on the EPB register. The buildings in the dataset fall outside the profile categories defined in the EPB methodology (MBIE 2017) and appear to have been classified under the 'at any time' pathway. According to the EPB methodology, territorial authorities identify potentially earthquake-prone buildings either within the set time frames based on three profile categories or through the 'at any time' pathway under section 133AG(3) of the Building Act 2004 when there is reason to suspect that the building may be earthquake prone (e.g. a timber-framed building of two or more storeys on a significant slope) (MBIE 2017). The dataset covers six locations spanning the three New Zealand seismic zones (Standards New Zealand 2004), namely Auckland, Christchurch, Dunedin, Feilding, Wellington, and Whanganui. The subset was further refined using the workflow shown in Figure 1.

The inventory was screened to confirm the presence of URM parts through desktop research and Google Street View (GSV), which involved removing duplicate entries and prioritising buildings for detailed review. Building documentation was requested from the relevant territorial authorities to support detailed inventory review and URM part typological classification. The level of detail in the available documentation varied between locations, resulting in inevitable differences in the amount and quality of information available for review. The screening and review process excluded buildings outside the scope of this study, as well as strengthened buildings, demolished properties, and buildings for which adequate information was unavailable. Following completion of the detailed inventory review, a final dataset of 132 buildings across six locations was compiled for the development of the URM part typology classification (Figure 2a).

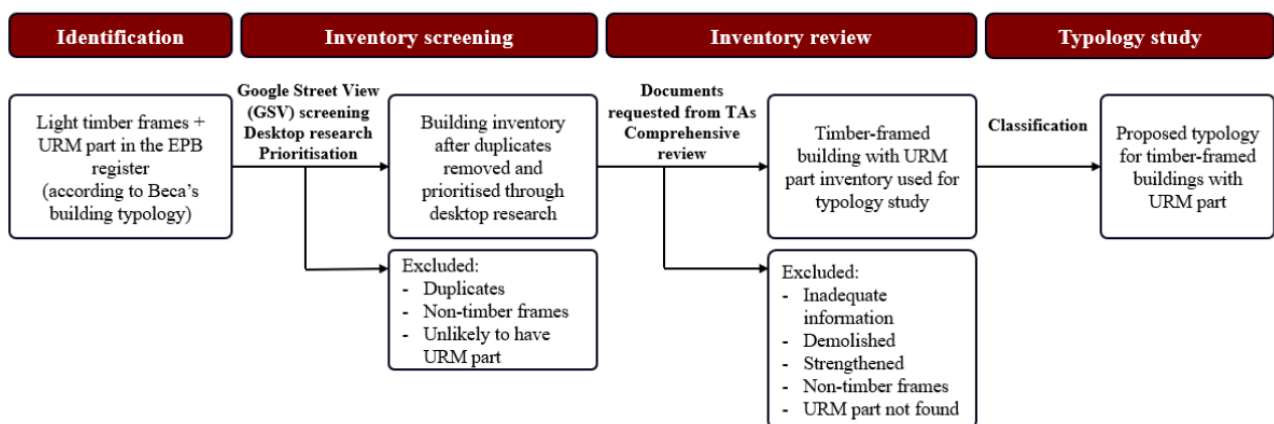
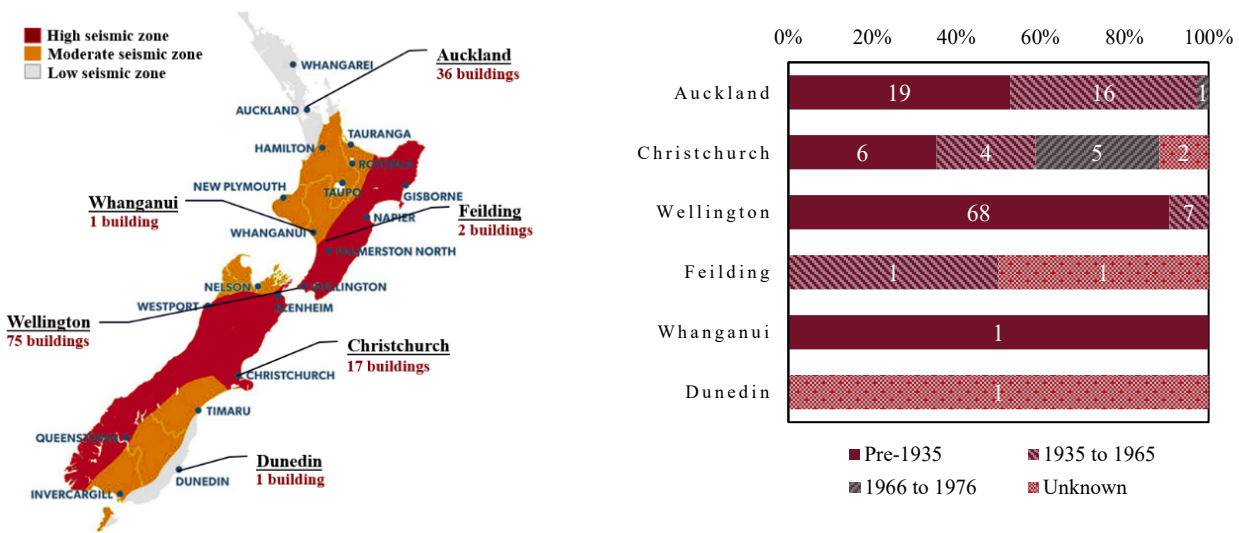


Figure 1: Workflow for building inventory screening and review

Key building characteristics identified through the inventory review include the design date, number of storeys, and occupancy class. The design date served as a proxy for building age and provided insight into the potential material degradation (Figure 2b). The majority of buildings in the inventory were constructed prior to the introduction of the first seismic provisions in New Zealand under the NZSS No. 95 in 1935 (New Zealand Standards Institute 1935). In several cases, building records indicated that unreinforced masonry (URM) parts were added at a later stage to structures that were originally exclusively timber-framed.

The distribution of timber-framed buildings with URM parts by number of storeys is presented in Figure 2c. The inventory is largely composed of low-rise buildings, predominantly single-storey and two-storey buildings. Although the number of storeys alone is not a direct indicator of seismic vulnerability, it is a critical parameter for understanding the vertical positioning and height of URM parts that can influence seismic demand and potential falling hazards.

Occupancy class informed the associated implications from the potential exposure of URM parts to occupants and nearby pedestrians as well as neighbouring buildings (Figure 2d).



(a) Dataset distribution across six selected locations (b) Building design date by location



(c) Number of storeys by location (d) Occupancy class by location

Figure 2: Building characteristics by location

3 PROPOSED TYPOLOGY FOR URM PARTS WITHIN TIMBER-FRAMED BUILDINGS

In the proposed typology, URM parts within timber-framed buildings are placed into three categories based on their structural/non-structural function: non-loadbearing, loadbearing, and ancillary components. A single building may contain two or more types of URM parts (see Figure 3).

The non-loadbearing category includes parts such as brick veneer and internal partition walls that are not intended to contribute to the primary structural load path. Loadbearing URM parts comprise elements that provide structural support and are part of the load-resisting system. Ancillary URM parts consist of gables, parapets, and chimneys, which do not contribute to the primary structural system but may present seismic consequences due to their mass, height, and vertical positioning. A summary of the defining characteristics of each URM part within the proposed typology is presented in Table 1.

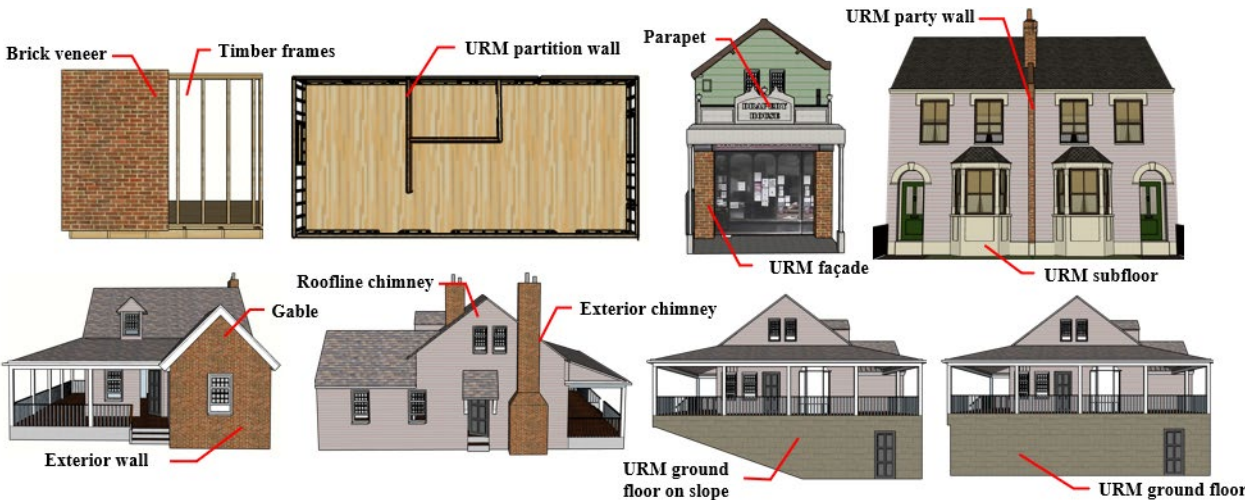


Figure 3: Examples of URM parts present within timber-framed buildings.

Table 1: Summary of URM part types and characteristics

No	URM part type	Characteristics
1. Non-Loadbearing URM walls within Timber Frame		
1.1	Brick veneer	An external URM wall enclosing timber framing, typically of single-leaf or cavity construction. Non-loadbearing with loads carried by the timber structure behind the veneer.
1.2	URM internal partition wall	An internal URM wall used to separate rooms or tenancies, typically introduced during alterations or changes of use.
2. Loadbearing Hybrid Timber–URM System		
2.1 Horizontally combined Timber-URM structures		
2.1.1	URM façade	A street-facing façade attached to the timber framing, typically associated with conversion from residential to commercial use. Occasionally includes parapets or decorative masonry and may intersect with side walls.
2.1.2	URM party wall	A loadbearing URM wall shared between adjacent buildings or tenancies. May extend above the roofline or terminate at roof level.
2.1.3	URM exterior wall	A URM wall located along the longitudinal or transverse perimeter of the building that may provide partial lateral resistance, with timber framing forming the remainder of the structure.

2.2 Vertically combined Timber-URM structures		
2.2.1	URM sub-floor	A URM sub-floor system that supports timber-framed upper storeys. This configuration is typical in residential buildings.
2.2.2	URM ground floor with timber-framed upper floor	A URM ground floor that supports timber-framed upper storeys. This configuration is typical in residential buildings and utilises the high compressive capacity of URM in multi-storey construction.
2.2.3	URM ground floor on slope (split levels)	A URM ground floor constructed on sloping terrain with stepped or split-level geometry. This configuration introduces vertical and plan irregularity.
3. Ancillary URM Components		
3.1	Chimney (exterior)	A URM chimney constructed in the exterior perimeter of a building from ground to roof level and typically tied to timber framing at floor levels. Behaves as a cantilever when subjected to seismic loading.
3.2	Chimney (roofline)	A URM chimney supported by timber framing at floor and roof levels, with vulnerability governed by the unrestrained height above the roofline.
3.3	Parapet	A URM wall extension above the roofline that is commonly found in commercial buildings and altered shopfronts with cantilever behaviour when subjected to seismic loading.
3.4	Gable	A gable-end URM wall tied to timber roof framing. Behaves as a slender cantilever element when subjected to out-of-plane loading.

4 SEISMIC IMPLICATIONS OF URM PARTS

A qualitative framework was adopted to examine the seismic implications of URM parts in timber-framed buildings. The parameters considered were building occupancy class, building design date, URM part type, URM part exposure, and seismic zones in New Zealand (Figure 4). The URM part types and their exposure collectively influence the potential seismic consequences to occupants, pedestrians, and adjacent buildings.

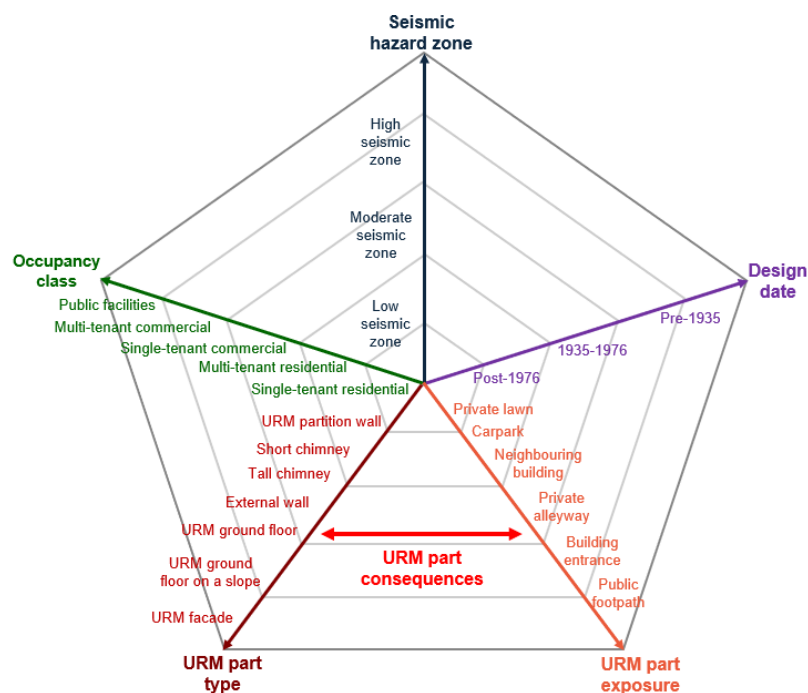


Figure 4: Parameters influencing the seismic implications of URM parts

4.1 Seismic implications of non-loadbearing URM parts

Non-loadbearing URM parts identified in the typology review include brick veneer and internal partition walls. These components do not form part of the primary gravity or lateral load-resisting system of the building. While their failure during seismic events is not expected to compromise overall structural stability or initiate progressive collapse, non-loadbearing URM parts may pose significant life-safety hazards due to falling masonry depending on their exposure such as proximity to side alleys, public footpaths, or buildings with high occupancy class.

4.2 Seismic implications of loadbearing element URM parts

URM parts that contribute to gravity and/or lateral load transfer represent greater concern in terms of seismic implications. Failure of these components may result in loss of load path and damage to interacting structural systems including timber diaphragms and roof framing. Loadbearing URM parts were further classified based on their interaction with the horizontal and vertical load-resisting systems of the building.

Horizontally combined systems comprise hybrid configurations in which lateral resistance is shared between timber framing and URM parts. These systems may be associated with buildings originally constructed as timber-framed residential structures and later modified for commercial use through the addition of URM façades and/or side walls. Such configurations may be susceptible to increased torsional response when subjected to seismic loading.

Vertically combined systems are characterised by vertical irregularity, in which a URM ground floor or subfloor supports timber-framed upper storeys. This configuration may result in concentration of seismic demands between storeys and increase the potential for damage at the interface between URM and timber floors when subjected to seismic loading.

4.3 Seismic implications of ancillary URM parts

Ancillary URM parts include architectural components that are commonly incorporated in timber-framed buildings. Examples of ancillary URM parts are chimneys, parapets, and gable-end walls. Although these components do not have a primary role in structural stability of the building, their elevated position and cantilever behaviour may cause significant seismic implications due to the potential for falling debris, particularly where exposure to occupants or pedestrians is high.

4.4 URM part exposure

The level of exposure of URM parts is a key factor in evaluating their seismic implications. URM parts associated with high occupancy levels or high pedestrian activity present greater concern than those facing areas with limited accessibility such as private lawn or restricted areas.

4.5 Summary of seismic implications of URM parts

The seismic implications of URM parts were evaluated for each building using the parameters described above, which capture both consequences and exposure to derive a qualitative seismic risk for each URM part. For buildings containing multiple URM parts, the governing seismic risk was taken as the maximum risk level across all assessed URM parts within the building. The resulting seismic risk of buildings in six locations was classified on a scale ranging from very low to very high as shown in Figure 5.

Buildings in Wellington exhibit the highest concentration of moderate to high seismic risk, with a very small proportion evaluated as very high risk. This pattern reflects the combined influence of higher seismic hazard, sloping site conditions, and the frequent presence of multiple URM parts within individual buildings. A more moderate distribution of risk for buildings in Christchurch was observed, with most buildings classified

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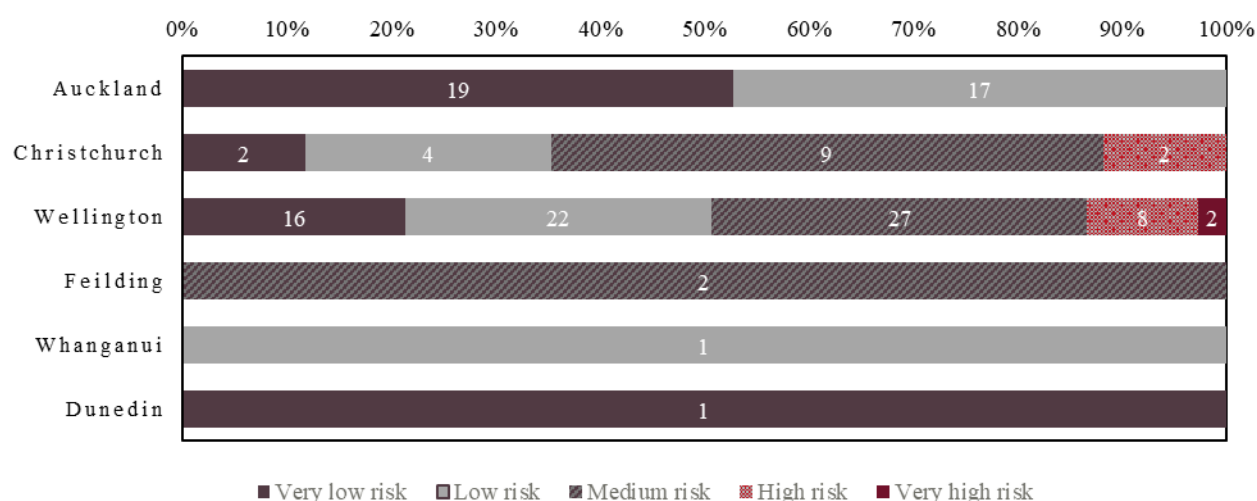


Figure 5: Distribution of seismic implications (presented as seismic risk) by location

within the medium range. Buildings in Auckland are dominantly very low risk, consistent with the lower seismic hazard of Auckland. The building count in Feilding, Whanganui, and Dunedin are comparatively small, and therefore the results for these locations should be interpreted cautiously.

5 CONCLUSION AND FUTURE WORKS

A comprehensive inventory review was conducted to identify URM parts within timber-framed buildings, followed by an evaluation on their seismic implications using a qualitative evaluation framework. The seismic implications and risk associated with URM parts was found to vary widely depending on the structural role, configuration, and exposure of each part. Loadbearing and elevated significant ancillary parts exposed to public spaces or high occupancy level were generally associated with higher risk levels.

The results presented are indicative and intended to inform an understanding rather than provide definitive seismic performance assessments. Limitations arise from the qualitative nature of the framework and the variability in the available building information. Further analytical and experimental studies are recommended to quantify the seismic behaviour of timber-framed buildings incorporating URM parts. Nevertheless, the qualitative framework was based on the concept of a more proportionate risk-based approach for the seismic evaluation of such buildings.

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