NEW ZEALAND SOCIETY FOR
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Earthquake prone building policy implementation in Lower Hutt

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ABSTRACT

Lower Hutt building stock dates back to early nineteenth century, with the majority of older buildings concentrated in central business district and around historic precincts in Jackson Street. Inevitably, buildings built at different times pose different challenges and levels of risk. Lower Hutt was focused in this project, which is a wedge-shaped alluvial plain between two mountain ranges and the harbour. Wellington fault, deemed to have a high probability of generating medium to large magnitude earthquake in near future, runs along the western side of the valley. To describe the building inventory, historical development in design standards was discussed first, with a view to associate potential structural weaknesses to building age. Earthquake prone building policy background was briefly discussed, and the implementation approach adopted was discussed. Building inventory information was gathered from several databases, including those available in public domain as well as the databases developed in-house by HCC for different seismic resilience initiatives. The databases were collated geospatially and were interrogated to find patterns, to understand potential vulnerabilities associated to the Lower Hutt building stock, and to identify buildings that merit further attention.

1 INTRODUCTION

A brief history of earthquakes in New Zealand, how they correspond to the development of the building standards, and the legal continuum to manage earthquake risk associated to existing buildings in New Zealand is discussed in this section.

1.1 Historical New Zealand earthquakes and standards

Seismic resistant design practices has developed over time in New Zealand, as new knowledge emerged from research and lessons were learnt from past earthquakes. Earthquakes in New Zealand have caused 501 deaths directly or indirectly between 1840 and 2016. The history of buildings in Lower Hutt precede the earliest standards for seismic design, and therefore the complete range of earthquake actions standards need to be referred to in order to compare historic design to modern day code, for the whole building stock.

The 1855 Wairarapa earthquake is believed to be the largest magnitude historical earthquake in New Zealand, estimated to be M_W 8.1 and centred at Wairarapa fault (Grapes & Downes 1997). 74 years later, the M_w 7.3 Murchison earthquake in 1929 caused 17 deaths, mostly from landslides, and damaged many chimneys and brick buildings in Nelson, Greymouth and Westport. Despite the inadequacy observed in the behaviour of unreinforced masonry (URM) buildings under seismic loads, no national regulations followed until the 1931 M_w 7.4 Napier earthquake killed 256, mostly as the result of the collapse of URM buildings and facades in Napier, Hastings and Wairoa (McSaveney 2006). In response, the Draft General Earthquake Building By- law was drafted with 0.1g (where 'g' is the gravitational acceleration at mean sea level) as the minimum required horizontal loading in structural design. Up to this point there was no requirements for seismic load resisting design in New Zealand. Eventually the NZSS No. 95 bylaws (NZSS 1935) were enacted, which were merely a revised version of the previous draft document. However, the minimum required horizontal loading finally was 0.08g. Chapter 8 of NZSS 1900 (NZSS 1965) required 0.12g to be the minimum required horizontal loading in design in Wellington region, which could be scaled based on hazard zone map for other regions.

In NZS 4203 (NZS 1976), the minimum required horizontal loading in design for use in Wellington region was increased to 0.29g, an unprecedented increase which makes 1976 a landmark in seismic design. Revised NZS 4203 (NZS 1992) introduced limit-state design and resulted in further increase in seismic design coefficient for lower Hutt CBD to roughly 0.43. The current seismic loading standards, NZS 1170.5 (NZS 2004), have been amended overtime and still can benefit from further amendments. As an indication, the earthquake loading used to design a building to current earthquake loading standards is 5-6 times larger of that has been used to design buildings prior to 1976. Following the 2010/2011 Canterbury earthquake series, the Canterbury Earthquake Royal Commission recommended review of NZS 1170.5 provisions, in particular provisions relating to spectral ordinate, torsional effects, vertical accelerations, design actions on floors acting as diaphragms, and effects of beam elongation (CERC 2012). Refer to Figure 1 for a visualisation of the development of the New Zealand seismic loadings standards between 1900 and 2012, with a timeline of earthquakes of magnitude ≥M_w 6.

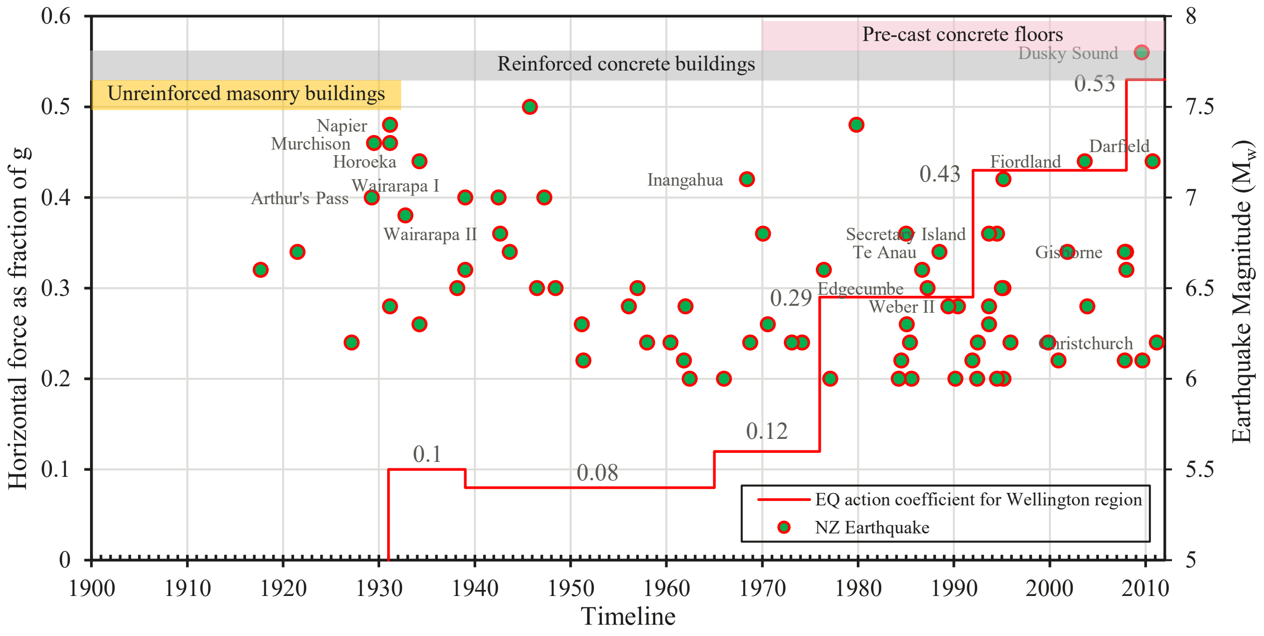


Figure 1: Historical development of New Zealand standards and earthquakes ≥ Mw 6 (1900-2012)

It is noteworthy that the current version of NZS 1170.5 (NZS 2004) does not include explicit requirement for collapse prevention by the exhibition of ductility at the maximum considered earthquake, which is an approximately 1/2500 year event that corresponds to a return period factor of 1.8. The seismic loadings code has developed over time mainly from experience of New Zealand earthquake events and will continue to do so as more lessons are learned and understanding about earthquake resilience increases.

1.2 Existing buildings and earthquake risk management

Earthquake loading standards have changed overtime in New Zealand and many existing buildings may not meet the seismic resistance requirements of the present day. Therefore, to be used in conjunction with the Building Act 2004, the Ministry of Business Innovation and Employment issued the potentially earthquake prone buildings (EPB) methodology (MBIE 2017) to identify, assess, and manage EPBs. The EPB methodology introduced three profile categories to identify potential EPBs: all buildings constructed of brick, block or stone masonry without any reinforcement (URM) built in any year fall under profile A; profile B are buildings built before 1976 that are taller than 12 metres or three storey high; and low-rise buildings built before 1935 that do not fall into profile A are classified as profile C (see Fig. 2). Structures of any type of material that has a significant amount of URM present such as masonry facades, bearing wall, gable end wall and brick chimneys are also classified as profile A (see Fig. 2). The profile categories proposed in EPB methodology worked to address “worst of the worst” buildings. However, there still exists an opportunity to address potential EPBs that might have been left out in this seismic resilience initiative. To identify potential EPBs that might not fit well with the profile categories A to C, two new categories were introduced herein: 1). profile D for buildings built between 1935 and 1976 but less than 10 m in height and profile E for buildings more than 10 m high built after 1976. Preliminary study presented herein was aimed to identify buildings that could have been left out in EPB methodology and to understand relative seismic risk at a high level by interrogating the identified buildings’ geospatial attributes. This project can serve as the first step in moving forward to achieving seismic resilient in Lower Hutt.

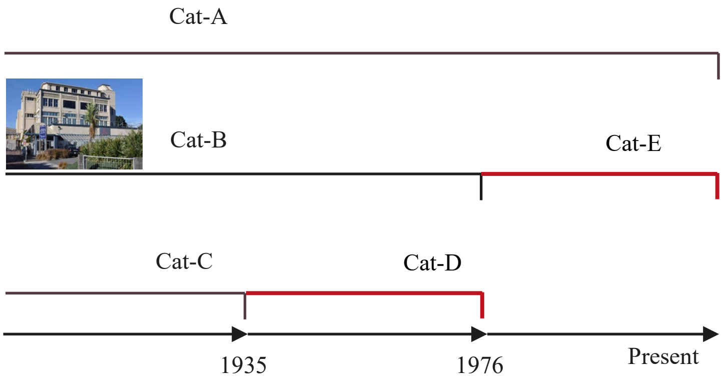


Figure 2: Building profile categories identified in EPB Methodology

2 LOWER HUTT BUILDING STOCK AND EARTHQUAKE HAZARD

2.1 Lower Hutt building stock

It is difficult to obtain information around historic building construction in Lower Hutt but population growth may serve as an indicator. The Lower Hutt population has increased over time. Before 1840 the Hutt valley was dense forest and swampland, with three Maori Pa sites Tatau-o-te-po, Pito-one and Hikoikoi in the present-day Petone area. In the year 1840, the first immigrant ship arrived, and settlers built a township on the banks of the Hutt river, known as Brittania. Only months later most settlers moved to Thorndon because of flooding from the Hutt river. In 1855 the Wairarapa earthquake raised land in Muka Muka by 2.7 metres (GeoNet 2019) and some of the Hutt valley, draining areas of swampland. Settlers moved back to Lower Hutt and by the 1870's industrial and residential developments had accelerated. The stop-banks begun construction in 1901, and the Seaview oil tanks in the 1930's. The population of Lower Hutt passed 20,000 in 1940 and it became a city. A large number of public/commercial buildings were constructed in the next decade or so. In 1989 new boundaries were established after re-organisation of the local government (Ihimaera-Smiler 2014).

Figure 3 shows the geospatial building data for Lower Hutt and location of fault lines as report by Langridge et al. (2016).Analysis of the building data showed that 72 URM buildings existed in Lower Hutt as of 2015, of these many have undergone some level of strengthening since then. Many pre-1935 buildings also prevail in Lower Hutt, which have been considered in the EPB initiative. A large portion of Lower Hutt buildings was built between 1935 and 1976 in areas of high earthquake risk and therefore this merit further investigation. Likewise, the EPB methodology addressed mostly pre-1976 high rise buildings but research has shown that typical weaknesses are present in buildings even built several years after 1976 (Puranam et al. 2019). The experiences of the 2010/2011 Christchurch and the 2016 Kaikoura Earthquakes highlighted key structural vulnerabilities in buildings built after 1976, which have not been sufficiently addressed in EPB profiles. This being the motivation, an effort was made herein to investigate further number, location, and characteristics of these buildings. The current building stock excluding single family dwellings in Lower Hutt is pre-dominantly 1-2 stories high (approx. 40,000 buildings), with around 84 known three or more story high buildings.

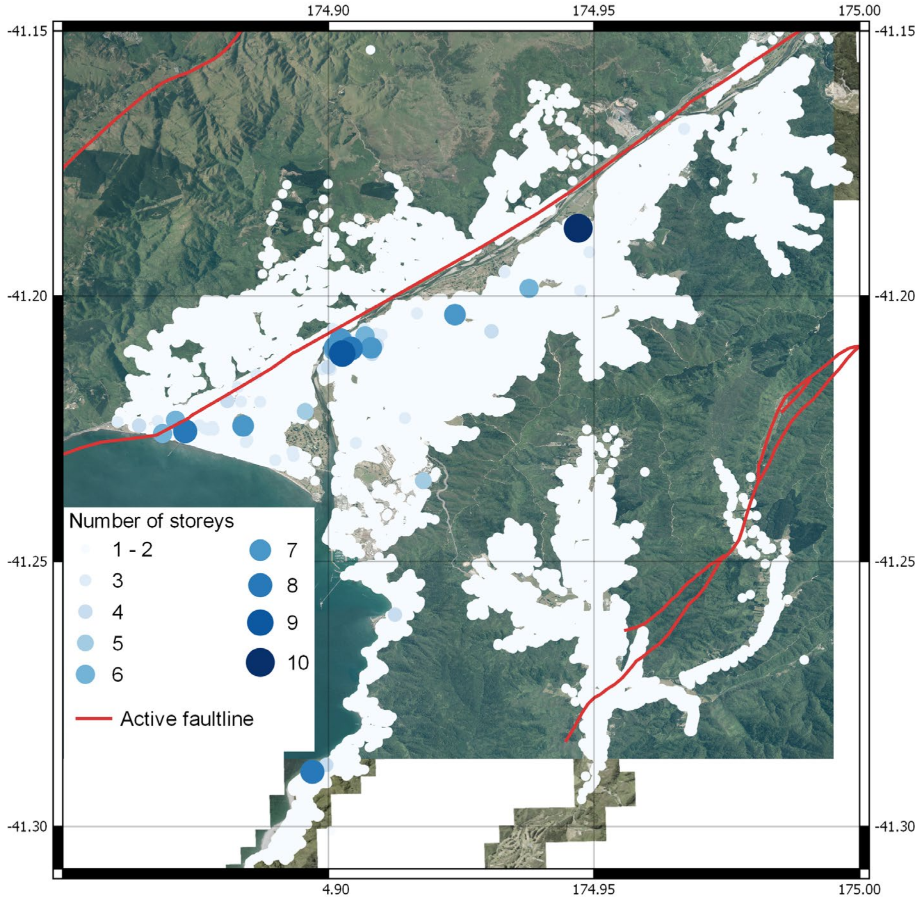


Figure 3: Spatial distribution and height of buildings in Lower Hutt

2.2 Earthquake hazard in Lower Hutt

Lower Hutt is particularly susceptible to earthquake hazards as found through its short history and paleo seismology. The Hutt valley is a sediment filled basin fanning from Taita to Petone, at which point is up to about 350 metres deep (Boon et al. 2011). The Wellington fault runs along the base of its western hills, parallel to the Otaki and Whiteman's valley faults, and further East is the Wairarapa fault. Wellington fault is an oblique dextral strike-slip fault (GNS 2018), expected to offset about 5 metres horizontally at the surface, and capable of generating a M_w 7.5 earthquake (Saunders et al. 2016), with a probability of producing large earthquakes every 500 to 1000 years (GNS 2018). The segment of Wellington fault adjacent to Hutt valley last ruptured 710 to 870 years ago (Van Dissen et al. 1992), with a probability of 11% to rupture in the next 100 years (Rhoades et al. 2010). Geomorphological studies show that slip on the Wairarapa fault produces uplift in the Hutt valley basin but is overwhelmed by subsidence caused by the Wellington fault. The estimated mean subsidence of the Hutt valley caused by a single rupture event on the Wellington fault ranges from no subsidence at the Taita Gorge to 1.9 m near Petone, 1.5 m near Seaview, and 1.7 m in Lowe Hutt central near the Ewen Bridge (Townsend et al. 2015). Section 14H 1.1.1 of the Hutt City District Plan states the predicted vertical movement in the next large earthquake to be up to 0.5 m. Another active fault-line in Hutt valley is the Whitemans valley fault, which poses only a small contribution to the overall seismic hazard in the region (Begg & VanDissen 1998) because of its recurrence interval of about 15 times that of the Wellington fault. It is believed that the Whiteman valley fault extend into Wainuiomata. More or less all Lower Hutt buildings are within 6 kilometres distance from one the aforementioned fault lines. In the Hutt City District Plan, around 150 m wide zone around Wellington fault has been designated as Wellington Fault Special Study (WFSS) area to mitigate fault rupture hazard (GNS 2016), however limited information exists on management of consent applications in this region. The Greater Wellington GIS viewer shows that liquefaction risk is high in area around Petone, Seaview and reduces in suburbs farther away from shore towards hills. Whereas slope failure risk is high in hilly suburbs. The combined earthquake risk is high around Petone and Seaview, whilst Lowe Hutt central is zoned between moderate high to moderate.

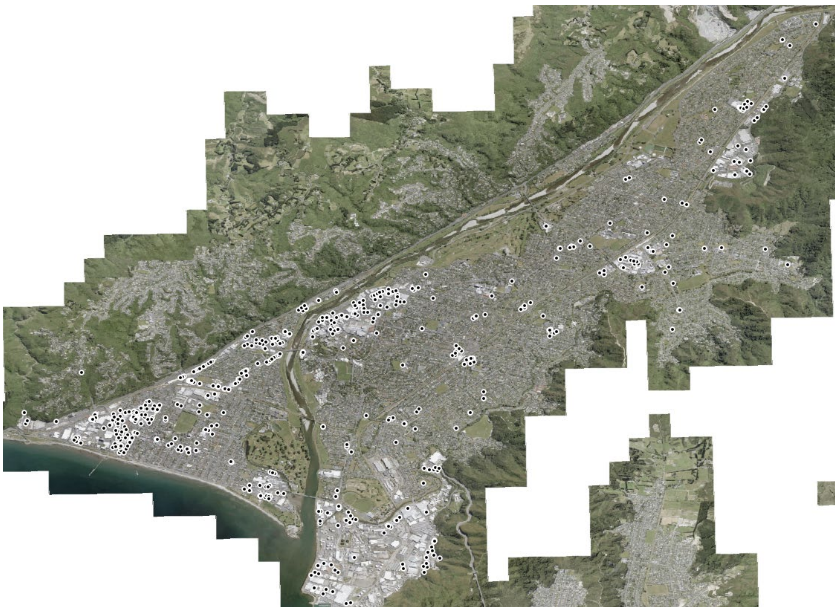
3 SEISMIC RESILIENCE DATABASE INITIATIVE

3.1 Source dataset

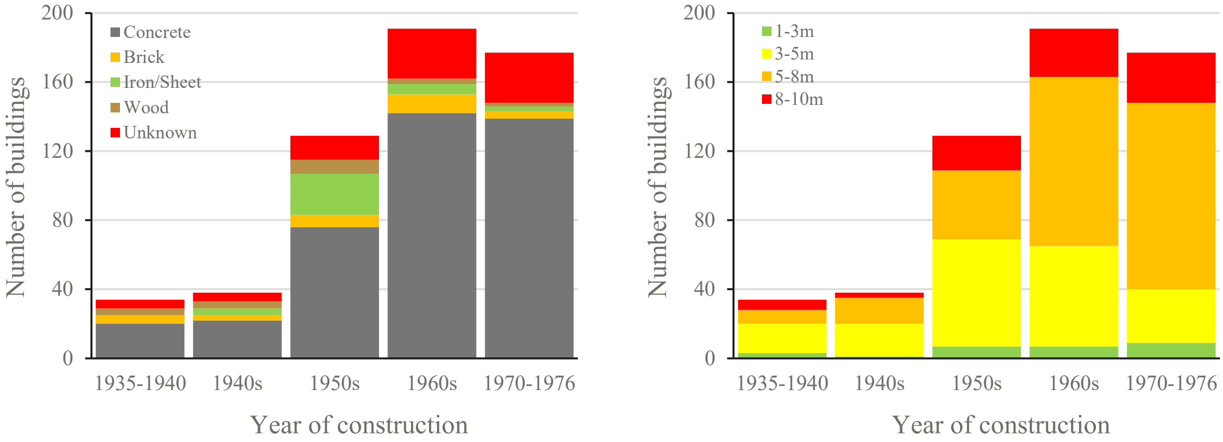
Two main datasets were sourced for the study with the help from Land Information Systems team at HCC. Of these, the first dataset was building polygons from Quotable Value filtered to exclude residential, parking, vacant, and rural properties. This dataset (with 10,807 data entries) was further refined by merging entries with same OBJECTID, bringing the total property polygons to 3661. The remaining 3661 dataset entries were then matched with the HCC building polygon dataset (with 72,510 building polygons). The building polygons with intersecting centroid were identified and the remaining 92 polygons with conflicting centroids were further analysed using HCC public viewer. The final merged dataset consisted of 2352 building polygons (see Fig. 3 for geospatial distribution of these building polygons). Data attributes from other datasets developed as part of other HCC seismic resilience initiatives were collated with processed building polygon dataset.

3.2 Profile D buildings

The source dataset was filtered for height, resulting in 2099 buildings with height less than 10 m. Of these, 569 buildings fitted the proposed profile D. Around 50-60% of these buildings were within the WFSS area, posing larger earthquake risk to Hutt city building stock. Figure 4a shows spatial distribution of the profile D buildings. The building dataset was interrogated for primary wall material, which does not represent the lateral load resisting system accurately but can be a rough indication about possible construction type used for the building. By far the most prevalent construction material used for this type of buildings was concrete i.e. more than 75% of the buildings in the dataset (see Fig. 4b), with pre-1950 buildings mostly low-rise and post-1950 ranging from low to medium height buildings (see Fig. 4c). When interrogated the dataset for condition of the building, most of the buildings in profile D ranged between good to average condition.



(a) geospatial distribution

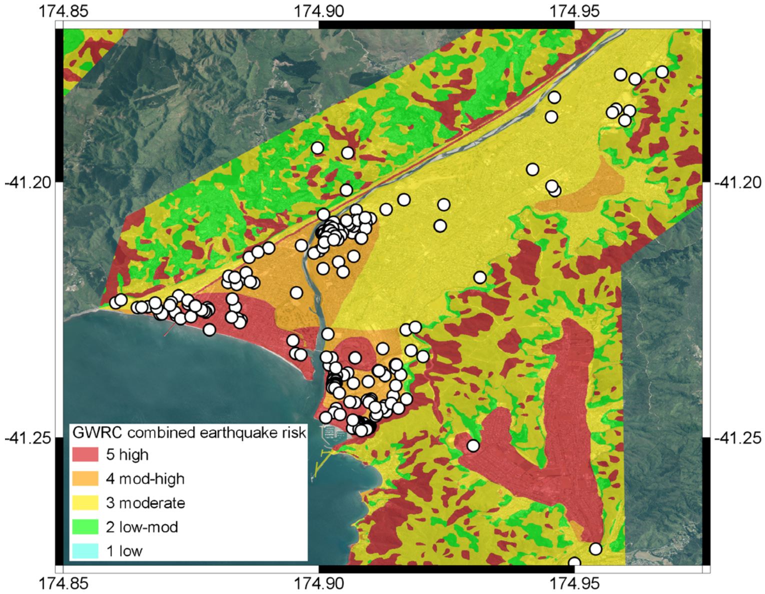


(b) wall material *(c) building height*

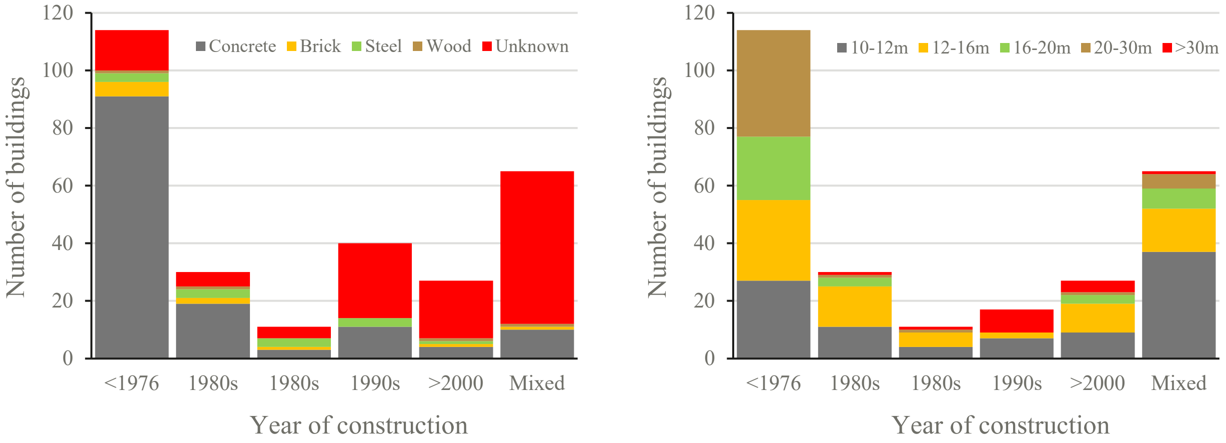
Figure 4: Geospatial distribution and characteristics of profile D buildings (569 buildings)

3.3 Profile E buildings

A filter was applied geospatial collated dataset to indicate buildings with any height value above 10, resulting in 306 building polygons. Of these 306 data points, duplicate entries for the same street address were removed and a total of 264 data entries remained, of these 114 buildings were built before 1976. It is noted that some of these data entries might be duplicate, showing multiple units in the same building but serves as a reasonable indicator for macro-scale preliminary study. The dataset requires refinement and validation, which could be undertaken in a future study. Spatial distribution of identified building with height more than 10m is shown in Figure 5a, with combined earthquake risk shown on Greater Wellington Regional Council's GIS viewer. The multi-storey dataset developed as part of another HCC project has a list of 85 buildings with 3 or more storeys, which seems to fit reasonably well with statistics presented herein. Information about wall material and building height in profile E buildings was found more ambiguous compared to profile D buildings (see Fig. 5b and 5c). Age of profile E buildings reported can be mis-leading at instances because some buildings might have been strengthened/ demolished or re-built recently. It can however be noted that several medium to high size buildings exists in high earthquake risk areas.



(a) spatial distribution and combined earthquake risk



(b) wall material *(c) building height*

Figure 5: Buildings with height > 10m (114 pre-1976 + 150 profile E buildings)

3.4 Primary use of Profile D and E buildings

Figure 6 shows the main occupancy of these identified buildings. Most profile E buildings are used for commercial and/or community usage, whereas the profile D buildings for commercial or industrial premises.

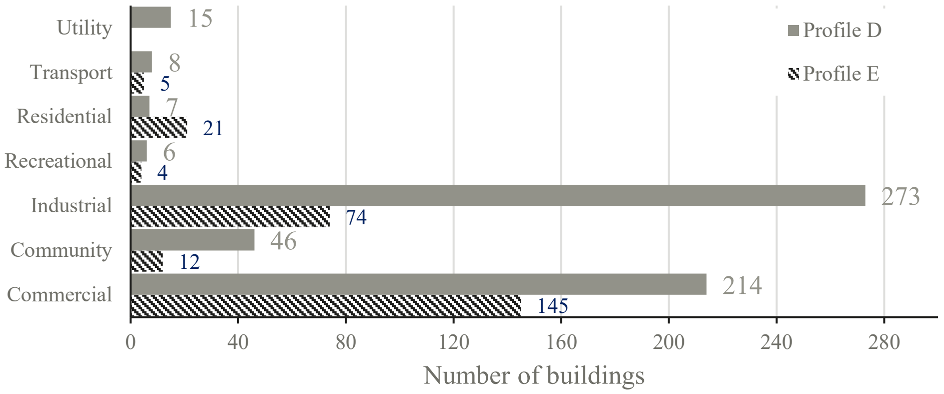


Figure 6: Characteristics of buildings with height > 10m and profile D

A unique characteristic of Lower Hutt building stock is the presence of a substantial low-rise industrial building built between 1935 and 1976 in area surrounding the Wellington fault line founded on deep soft soils. These buildings, when combined with the seismic hazard, can potentially be unsafe in a large earthquake. Whilst the building pose safety risk to occupants, it also is a major risk to economy of the city.

4 CONCLUDING REMARKS

Lower Hutt buildings are unique in its characteristics and is within proximity of three identified earthquake faults, with Wellington fault passing right through the city. EPB methodology and profile categories used to identify potential EPBs was briefly discussed. Whilst the EPB does address the majority of the potential EPBs and Hutt city council pro-actively managing the risk, the uniqueness of the location and construction practices adopted in relatively newer buildings built after 1935 are very likely to have seismic vulnerabilities. This was further interrogated and an overview of key outcomes of the analysis was reported. Collation of different databases is reasonably challenging because each was prepared for a certain purpose and more interconnection between information databases can be created by using a unique building identifier. Around 40,000 single/double story high buildings and only 85 three and more story high buildings prevail in Lower Hutt, of these 72 buildings are unreinforced masonry. Non-residential buildings built between 1935 and 1976 with a height less than 10 m are not addressed in the existing profile categories in EPB policy but around 569 buildings were identified to exist. These are mainly industrial/commercial buildings with possibly some known earthquake vulnerabilities. The buildings were referred to as profile D buildings. A large population of profile D buildings is within the Wellington Fault Special Study area, with reasonable uncertainty to manage this elevated seismic risk. The problem exacerbates owning to the presence of soft subsoil. Buildings with height more than 10m were categorised as profile E. Approximately, 264 buildings were identified. Of these, 114 buildings were built prior to 1976 but it is likely some of these buildings has also been strengthened later. Further investigation of other databases and satellite imagery resulted in 84 three and more story buildings.

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