NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING

# An overview of the base isolated building inventory in New Zealand

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## ABSTRACT

Base isolation has consistently demonstrated its effectiveness as a structural system in reducing earthquake-induced building damage and accelerating their return to functionality. Despite its proven success in minimising damage in past large-intensity earthquakes worldwide, its adoption in New Zealand remained limited. Following the 2010/2011 Canterbury earthquake sequence, this trend began to shift as society better recognised the need for resilience-based design beyond life safety. With the growing number of base isolated buildings and a relatively new draft guideline available, a database was developed to summarise the inventory in New Zealand. This database provides an overview of the current base isolated building landscape through trend and statistical analysis.

By the end of 2024, 67 base isolated buildings were identified, including 54 completed, 7 under construction, and 6 in the design stage. The database documents over 40 building parameters across four key areas: general information, design characteristics, isolator properties, and superstructure characteristics. The data was extracted from structural drawings and design feature reports. Analysis reveals that base isolation is primarily adopted in high-seismic-risk regions, with Wellington and Christchurch accounting for 73% of the total inventory. Commercial and residential buildings comprise 33% and 16%, respectively, reflecting the growing awareness of resilience beyond critical facilities. This study integrates diverse datasets into a foundational tool, aiming to support future research on the design and performance of base isolated buildings in New Zealand.

## 1 INTRODUCTION

Modern seismic design methods assist engineers in designing buildings to ensure predictable and ductile behaviour during severe earthquakes, preventing collapse and minimising loss of life (NZSEE, 2022). However, the current reliance on buildings designed to New Zealand (NZ) material standards hinges on the concept of inherent member ductility for energy dissipation, leading to physical damage that may be uneconomical to repair. Base isolation has been considered an effective solution to reduce earthquake-induced building damage. In base isolated structures, the building is decoupled from earthquake-induced ground motion, reducing the forces transmitted to the structural and non-structural components (Robinson, 1995).

Following damage observations of the 2010/2011 Canterbury earthquake sequence, the engineering industry has begun shifting toward low-damage design approaches to improve building seismic performance beyond the code minimum life safety, particularly through increased adoption of base isolation techniques (Whittaker, 2017). This shift led to a growing number of base isolated buildings across NZ. However, base isolation is currently not explicitly considered in NZ design standards like it is in ASCE/SEI 7-22 (ASCE/SEI, 2021) and Eurocode 8 (CEN, 2004). Therefore, it is considered an 'alternative' solution under the building code. In 2019, a draft Guideline for Designing Seismic Isolation Systems was published by the New Zealand Society for Earthquake Engineering (NZSEE) for trial use (NZSEE/MBIE, 2019). The guideline is intended to provide some consistency in the base isolation system design across the country. It also offers recommendations to achieve the required performance following the New Zealand Building Code (Whittaker, 2017). As the number of base isolated buildings increases and a relatively new draft guideline is available, assessing their performance becomes more challenging due to a lack of available and accessible data. To address this, this study constructs a database summarising the characteristics of base isolated buildings in NZ.

## 2 DATABASE BUILDING STATISTICS

The primary data sources for the database include technical literature, structural drawings, and design feature reports (DFRs) obtained from structural engineers and council property files. These documents were reviewed to extract key parameters of the base-isolated buildings covering four areas: general information, design characteristics, isolator properties, and superstructure characteristics. This study focuses primarily on buildings that utilise elastomeric rubber bearings, curved surface sliders, or flat sliders used in conjunction with these devices. At the time of writing, 67 buildings meeting these criteria were identified.

The collected data were compiled into a spreadsheet, forming the foundation for the quantitative analysis below. Instances marked as 'Unknown' in the figures indicate incomplete data. While effort was made to acquire the latest drawing information, some discrepancies between design drawings and as-built conditions may exist.

### 2.1 Existing buildings inventory

The number of base isolated buildings built in NZ each year and the cumulative total over the years is presented in Figure 1 and Figure 2, respectively. Key events related to changes in the adoption of base-isolated buildings are also shown. In 2024, 67 base isolated buildings have been identified, including 54 completed, 7 under construction, and 6 in the design phase.

The number of base isolated buildings increased significantly in the years following the 2011 Christchurch Earthquake and the 2016 Kaikōura Earthquake. Since 2012, an average of two new buildings have been designed annually, with a peak of 7 new constructions in 2017. These buildings are categorised as either 'New' or 'Retrofitted', distinguishing between newly constructed structures and those incorporating base isolation into existing buildings. New constructions account for 81% of the total, while 19% are retrofits.

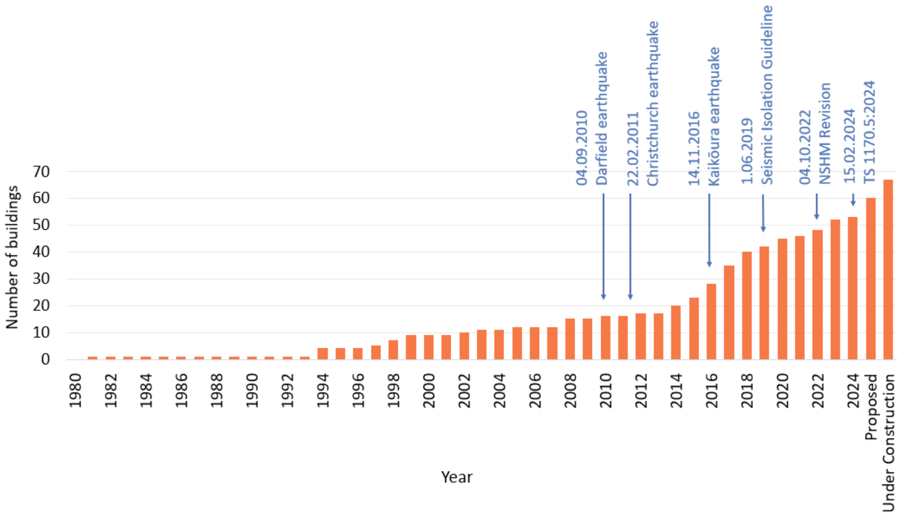



*Figure 1: Number of base isolated buildings built in New Zealand per year*

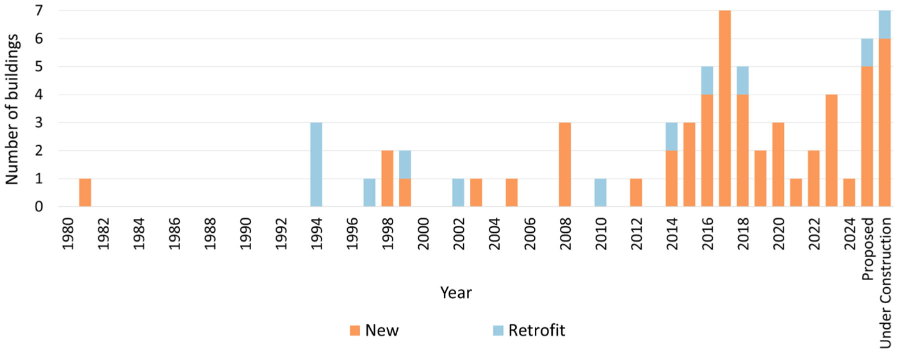



*Figure 2: Cumulative number of base isolated buildings in New Zealand*

## 2.2 Distribution across New Zealand

The distribution of base isolated buildings across NZ, along with the corresponding peak ground acceleration (PGA) at a 10% Probability of Exceedance (PoE) in 50 years for $Vs_{30}$ = 250 m/s, is shown in Figure 3 and Figure 4, respectively. Wellington and Christchurch have the highest concentrations of base isolated buildings, accounting for 45% and 28% of the total, respectively. This reflects efforts to improve building resilience following the 2011 Christchurch and 2016 Kaikōura earthquakes. Meanwhile, the presence of base isolated buildings in lower seismic activity highlights a growing awareness of the benefits of this technology.

In light of the increased seismic hazard outlined in the revised National Seismic Hazard Model (NHSM) in 2022 (Gerstenberger et al., 2022), Figure 4 highlights that base isolated buildings in Wellington are expected to experience higher PGAs than previous estimates from the 2010 NSHM. In some areas, the increase in PGA at a 10% PoE in 50 years has more than doubled. This significant increase underscores the need to reassess the seismic performance of existing base isolated buildings in Wellington and consider retrofits where necessary. Additionally, the rise in seismic demand around the country raises concerns that some of the buildings designed prior to the revisions may have insufficient rattle space for the expected demands.

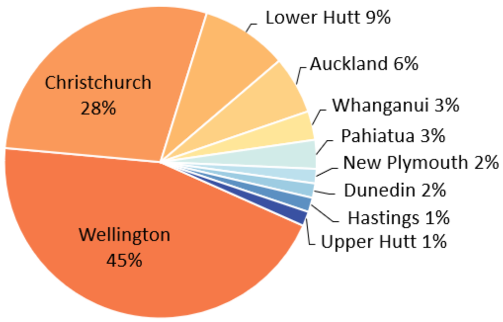



*Figure 3: Distribution of base isolated buildings across New Zealand*

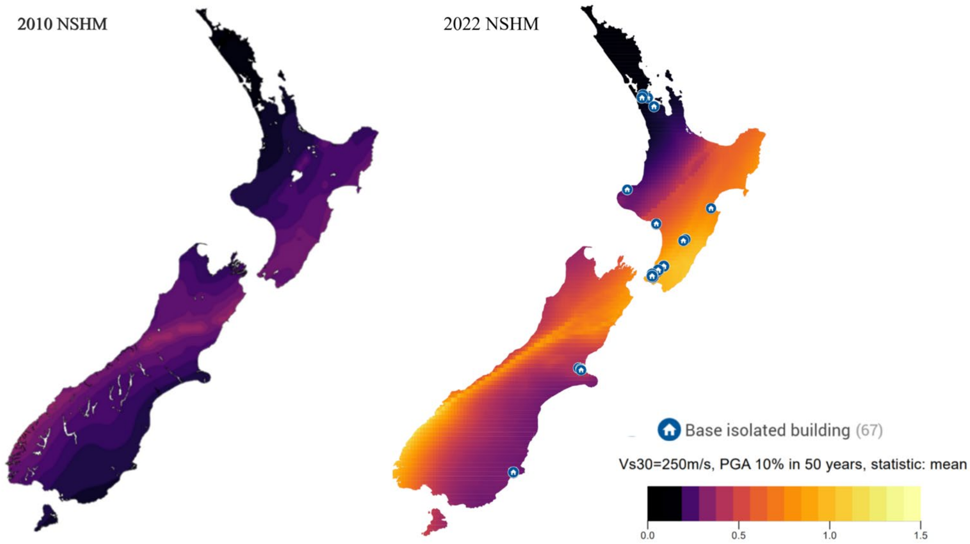



*Figure 4: Comparison of 2010 and 2022 PGA hazard maps with the distribution of base isolated buildings*

# 3 STRUCTURAL CHARACTERISTICS

## 3.1 Building Use and Importance Level

Building use is categorised into five groups: hospital, commercial, industrial, public, and residential. Commercial occupancy includes office spaces and retail, while public occupancy covers government buildings and cultural or educational facilities. Figure 5 indicates that commercial buildings dominate the base isolated building stock, accounting for 33%, followed by hospitals at 27%.

Base isolation is commonly implemented in high-importance buildings where operational performance objectives must be achieved under moderate seismic demands. Hospitals and large public assembly buildings are typically classified as IL3 or IL4, reflecting their higher importance and the need to maintain functionality immediately after a seismic event. Figure 6 shows a relatively even distribution of base isolated buildings across importance levels, with IL4 buildings comprising the largest share at 31%. Notably, IL2 buildings comprise 27% of the total, suggesting that base isolation buildings are being adopted beyond critical facilities as the market increasingly recognises the benefits of reduced structural damage and continual functionality of buildings after earthquake events.

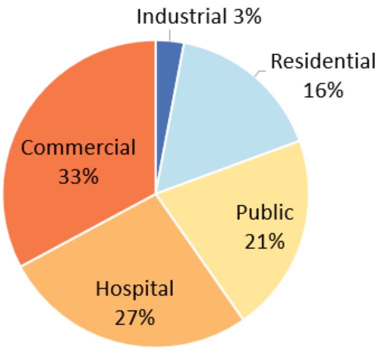



*Figure 5: Building use*

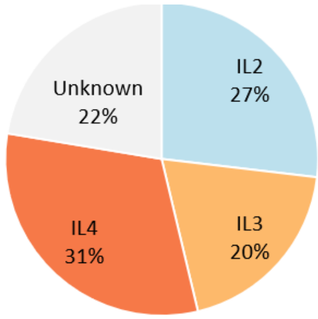



*Figure 6: Importance level*

## 3.2 Type of Isolator

Among the base isolated building stock in NZ, five different categories of isolator devices are currently in use, with lead rubber bearings (LRB) and Triple Friction Pendulum (TFP) bearings being the two dominant types. As illustrated in Figure 7a, LRBs and TFPs account for 65% and 16% of the usage, respectively. Other isolator types, such as Double Concave Slider (DCS), have also been utilised in a limited number of buildings across the country.

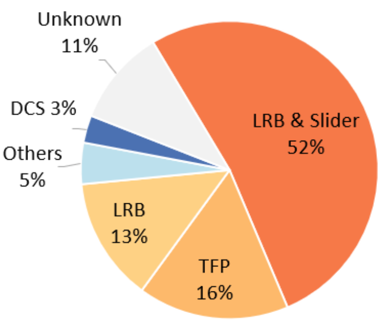
LRB consist of alternating layers of rubber and steel with a central lead core, providing rigidity under service loads and energy dissipation by yielding under lateral loads. During large displacements, plastic deformation of the lead absorbs energy as hysteretic damping, with equivalent viscous damping typically ranging from 15% to 35% (Kelly, 2001). A key advantage of LRBs is their combination of rigidity at service loads, flexibility under earthquake loads, and damping in a compact unit. However, the properties of LRB are size dependent and become less favourable under large displacement due to reduced vertical load capacity resulting from the decreased effective rubber area.

Curved surface slider bearings provide restoring force through the curved shapes of the elements, with energy dissipated by friction due to movement on the sliding surfaces. When all isolators in a system share the same geometry and friction properties and are subjected to the same displacement, the total force in each bearing is proportional to the supported weight. This allows the centre of rigidity and centre of mass of the isolation system to coincide, minimising the torsion moment. These bearings can have single, double, or multiple sliding surfaces to provide displacement capacity (Kelly, 2001). For example, DCS bearings feature two concave surfaces and a single solid puck, exhibiting bilinear hysteretic behaviour. In contrast, TFP bearings consist of three internal pucks and four sliding surfaces, typically configured to display trilinear hysteretic behaviour (Whittaker, 2016). Following the 2011 Christchurch earthquake, TFP bearings gained popularity due to their recentering capabilities and ability to traverse large displacements at lower forces relative to isolator size.

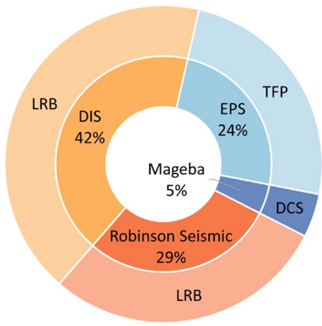
Flat slider bearings exhibit an elastic-perfectly plastic hysteresis shape without strain hardening after the applied force exceeds the friction coefficient multiplied by the applied vertical load. This limits the total base shear on a structure to the sliding force, making them attractive for design. However, their lack of centering force results in unconstrained displacement, and a larger force is required to initiate sliding, preventing their use as a sole isolation component (Kelly, 2001).

As a result, LRBs are often paired with flat slider bearings, forming the most common isolation system in New Zealand. Flat sliders are typically placed around the building perimeter, where high axial loads are expected, and to prevent excessive uplift forces in LRBs. Figure 7b presents the ratio of LRBs to flat sliders within the current building stock. The histogram shows that most ratios fall between 0 and 2, indicating that configurations with similar LRBs and flat sliders are frequently adopted. The specific performance objectives and design requirements of each building can influence the ratio choice. A higher proportion of LRBs typically enhances energy dissipation, providing better control over structural displacement. In contrast, more flat sliders offer more flexibility and control of the post-elastic stiffness in the LRB system. Research by Chun et al. (2007) and Fan and Tian (2012) indicates that base isolation systems combining sliding-type bearings and LRBs are more effective at reducing floor acceleration and base shear than those with LRBs alone.

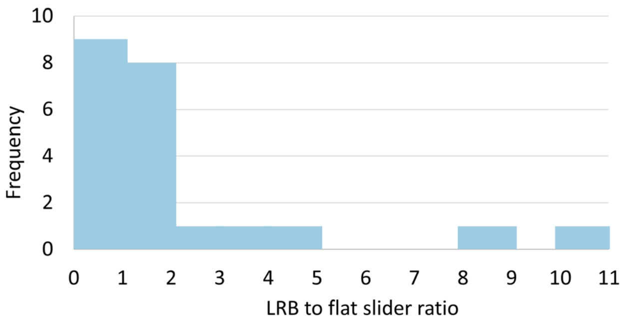
Engineering preferences and supply availability also influence the choice of isolation technology. As seen in Figure 7c, LRBs are primarily supplied by Dynamic Isolation Systems (DIS) and Robinson Seismic, contributing 42% and 29% of the market, respectively. Meanwhile, Earthquake Protection Systems (EPS) dominates the market for TFP bearings in NZ.




*a) Isolator type*




*b) Supplier breakdown*




*c) LRB to flat slider ratio*

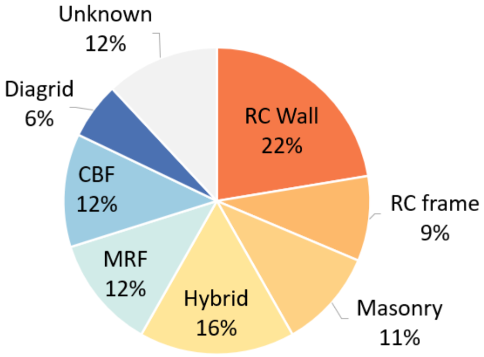
*Figure 7: a) Type of isolators used, b) Isolator device manufacturers, c) LRB to flat slider ratio*

## 3.3 Superstructure System

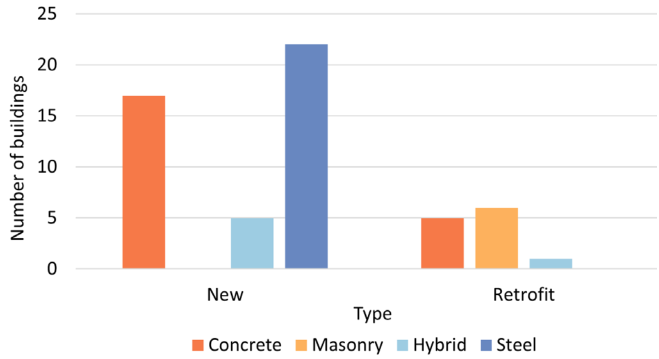
As shown in Figure 8a, seven different types of lateral load resisting systems were identified. Reinforced concrete (RC) and structural steel are the most commonly used materials for lateral load resisting systems (LLRS), contributing 31% and 30% to the base isolated building stock. 16% of the buildings use "hybrid" systems, defined as a combination of structural systems in orthogonal directions or across storeys. The results indicate that RC walls are the most frequently implemented lateral load system, being used in 22% of the buildings. The other LLRS display a relatively even distribution across base isolated buildings.

To further examine the application of base isolation in each lateral load system category, Figure 8b-d explore the distribution of LLRS materials by building type, region, and time. Figure 8b shows that base isolated buildings with masonry as LLRS are typically associated with retrofitted projects. This approach is particularly advantageous when traditional earthquake-strengthening methods are either not cost-effective or risk compromising the heritage value of the structure. Base isolation retrofit methods could provide earthquake protection while minimising invasive structural alterations.

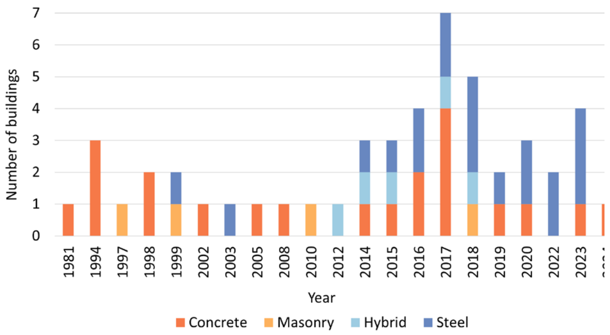
Structural steel has been increasingly favoured after the 2010/2011 Canterbury earthquakes, as illustrated in Figure 8c. On average, two new steel base isolated buildings have been built annually since 2014, whereas RC has remained relatively consistent at 1-2 buildings per year. Figure 8d highlights the regional variations in lateral load system material usage. Christchurch and Wellington indicate a diverse use of lateral load systems, with steel emerging as the dominant material in the last decade.



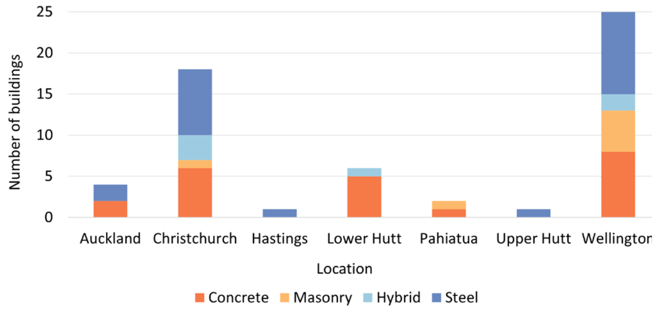

*a) System type*




*b) Material and building type*




*c) Changes over time*




*d) Material across the region*

*Figure 8: Distribution of lateral load resisting system*

## 3.4 Building Height

Figure 9 illustrates the distribution of base isolated buildings in NZ across various building heights, categorised as low-rise (up to 3 storeys), medium rise (4-8 storeys), and high-rise (9 or more storeys). Most base isolated buildings in NZ are medium rise, with approximately 50% falling into this category. High-rise buildings constitute the smallest percentage, suggesting that base isolation is less commonly used in taller structures in NZ. The application of base isolation in high-rise buildings presents challenges due to the longer fundamental period of the fixed-base superstructure and the high axial loads imposed on the isolator bearings.

## 3.5 Footprint Area

The footprint area, along with the number of storeys above ground, provides an indication of building size and its corresponding seismic mass. As illustrated in Figure 10, approximately one-third of base isolated buildings have a footprint area ranging from 1000 m² to 3000 m². High-rise buildings typically exhibit smaller footprint areas, while medium-rise buildings show a wider variety of footprint sizes. An exception among high-rise buildings with a large footprint area is due to multiple superstructures being supported on a common isolation plane.

## 3.6 Flooring System

Figure 11 shows that composite steel tray systems are the most commonly used suspended floor systems in base isolated buildings, accounting for 33%. However, this observation is not unique to base isolated structures. A study by Bruneau and MacRae (2017) found that most engineering firms in NZ preferred composite floor systems with cold-formed steel decking due to their ease of construction, lightweight properties, and cost-effectiveness. Flat slab and hollow-core flooring systems are commonly found in retrofitted base isolated buildings. As base isolation can reduce storey displacement, it could be an effective retrofit method for buildings with poor flooring systems or insufficient seating lengths, which may fall off under large storey drifts. Base isolation thus provides better protection from these vulnerable elements.

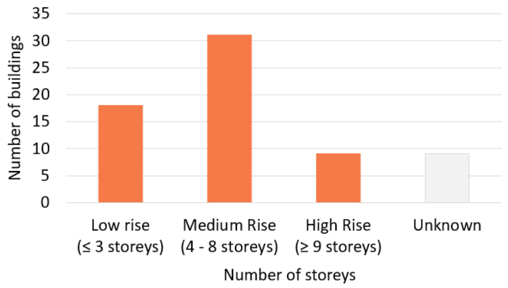



*Figure 9: Buildings distribution by number of storeys*

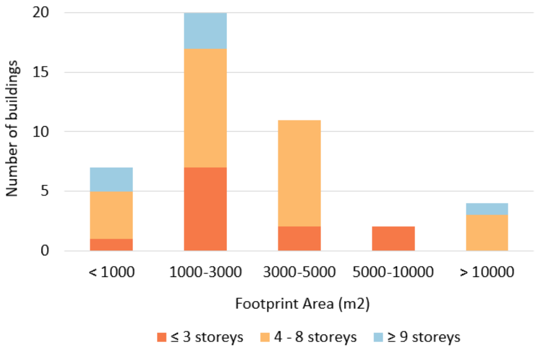



*Figure 10: Footprint area with the number of storeys*

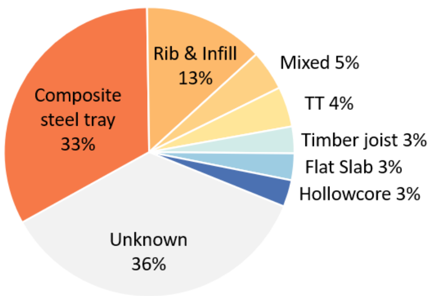



*Figure 11: Flooring system*

## 3.7 Isolation plane height

Safe access around isolators is essential for regular inspection, maintenance, and potential future replacement. According to Section 7.2 of the NZSEE Seismic Isolation Guideline, a crawl space with a minimum height of 1.2 m beneath beams extending into this area is recommended (NZSEE, 2019). Figure 12a show that approximately 10% of base isolated buildings do not meet this requirement, with isolators typically grouted to the slab. The selection of the vertical position of isolators, as defined in Figure 12b, is typically influenced by the surrounding environment and the operational requirements of the building. For buildings without a basement, an additional floor is necessary to function as the isolation layer, increasing construction costs. Conversely, buildings with basements, often to meet parking requirements, provide a practical advantage, allowing for the installation of isolation systems with minimal disruption to services and without the need for additional excavation.

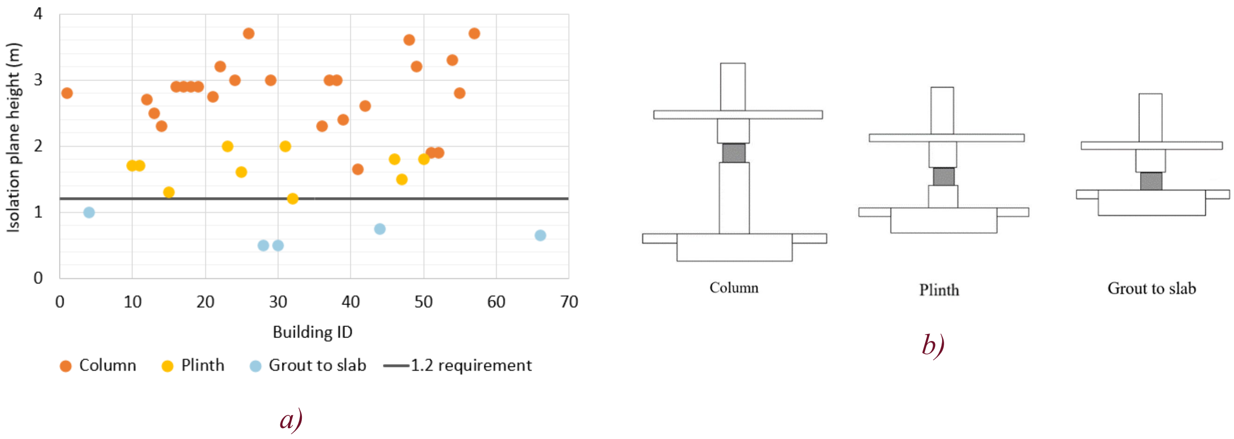



*Figure 12: a) Isolation plane height categories by isolator position, (b) Isolator position categories*

## 3.8 Soil Class and Foundation

While base isolated buildings are ideally constructed on firm soil, 80% are located on soil class D (deep or soft soil), with the remaining 20% situated on class C (shallow soil), as shown in Figure 13. Interpolation between class C and D spectra is sometimes implemented based on the site period. Soil classes D and E require increased loadings to be considered, resulting in higher design and construction costs. While soft soil does not preclude the use of base isolation, its effectiveness is reduced compared to stiff soil conditions. Figure 13 also reveals that 57% of base isolated buildings use shallow foundations, with 51% situated on soil class D. In cases of ground conditions with high water tables or liquefaction potential, raft foundations with base isolation techniques have been adopted as a cost-effective alternative to deep pile foundations. This option was sometimes made feasible through supportive gravel layers or ground improvement methods.

## 3.9 Aspect ratio

The height-to-width aspect ratio indicates the slenderness of buildings and plays a crucial role in the potential uplift or generation of significant tensile forces in isolators. Figure 14 illustrates that approximately 70% of the buildings have an aspect ratio below 1, indicating that the majority are relatively squat. Even among taller buildings, the aspect ratio remains below 3, suggesting that the design of base isolated buildings in NZ avoids excessive slenderness. Buildings with high aspect ratios can introduce additional complexities for base isolation. Higher aspect ratios increase the overturning demand on the isolators, which can lead to considerable uplift forces at the perimeter of foundations, presenting a challenge for corner isolators.

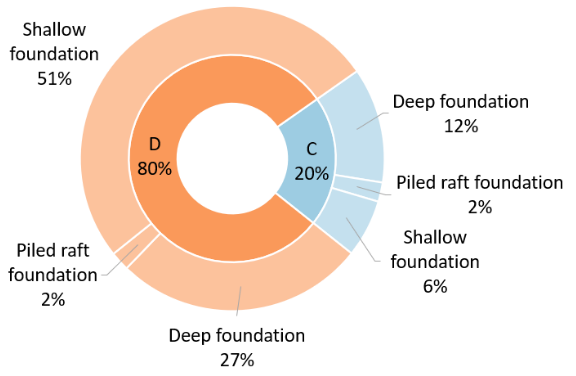



*Figure 13: Foundation type used in each soil class*

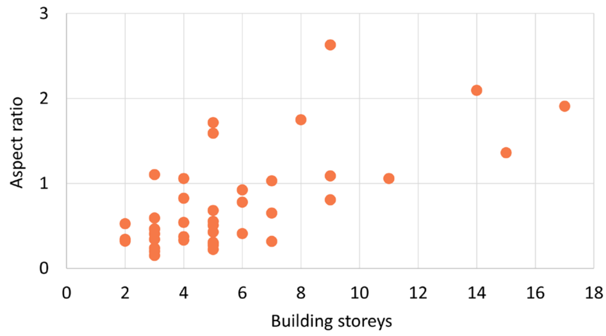



*Figure 14: Height to width aspect ratio*

## 4 CONCLUSION

A database of base isolated buildings was constructed to summarise the base isolated inventory in NZ. Data were extracted from primarily structural drawings and design feature reports and compiled into a spreadsheet. By the end of 2024, 67 base isolated buildings were identified in NZ, with 54 built, 7 under construction, and 6 in the design stage. The key findings are summarised as follows:

- Base isolation is predominantly adopted in high seismicity regions such as Wellington and Christchurch, which together account for 73% of base isolated buildings in NZ. Its use has expanded into non-critical facilities, such as commercial (33%) and residential (16%) buildings, reflecting a growing desire for seismic resilience across the country.
- LRBs and TFP are the most commonly used bearing types in base isolated buildings. LRBs account for 65% of usage, with 52% paired with sliders, while TFPs represent 16%. LRBs are primarily supplied by DIS (42%) and Robinson Seismic (29%), with EPS dominating the TFP market.
- Base isolation is mostly used in medium-rise buildings, which account for 50% of the total, with one-third of all base isolated buildings having footprint areas between 1000 m² and 3000 m².

The creation of the database provides a stocktake of the base isolated building inventory in NZ. Ongoing updates and data validation of this database will allow tracking of how design practice evolves in NZ, comparisons to international practice and quick assessments of potential vulnerabilities.

## ACKNOWLEDGEMENT

The authors would like to acknowledge the National Hazard Commission for funding the project and local engineers from Aurecon, Beca, Dunning Thornton Consultants, Holmes Consulting, Mitchell Vranjes and WSP for their assistance during the study.

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