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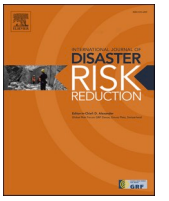

The influence of builders on seismic strengthening of housing

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ABSTRACT

Trust in information sources is essential for bridging the gap between intentions to seek seismic preparedness advice and the adoption of protective measures, such as retrofitting homes. Builders are one of the most frequently consulted sources when homeowners seek to strengthen or repair their homes for earthquake resistance. While research has focused on homeowners, engineers, and the seismic risk of tall buildings, the crucial role of builders at the residential housing level has been largely overlooked. Builders are typically the ones responsible for carrying out work in residential settings, such as renovations or maintenance. However, opportunities to promote and encourage seismic retrofitting during these works are generally missed. Using semi-structured interviews with builders and engineers, this study explores current industry trends, builders' needs and priorities, their perceptions of seismic strengthening, and their views on existing educational pathways. Findings suggest that although builders hold an influential position in the communication and implementation of seismic resilience measures, they are often excluded from discussions about preparedness and from the design of their own training opportunities. Homeowners' resistance and perceived liability risks discourage them from initiating conversations about seismic upgrades. Among other findings, this study highlights that meaningful engagement with builders is essential for improving the seismic resilience of Aotearoa New Zealand's residential housing stock.

1. Introduction

The 2010-2011 Canterbury earthquakes caused extensive damage to residential housing, resulting in repair and rebuild costs of NZ $12.5 billion [1,2]. While most houses met life-safety seismic performance objectives, they still experienced significant damage, from minor wall cracks to major foundation damage, loss of cladding, collapsed chimneys, and permanent structural displacements. Given that 75% of all residential buildings in Aotearoa New Zealand are timber-framed (BRANZ, 2019), strengthening these homes could significantly reduce damage in future seismic events. Recent research has called attention to the potential public demand for higher levels of building seismic performance, aligning with evolving societal expectations [3–5]. Higher levels of performance could be achieved through voluntary retrofitting. But to do this, people need to know where and how to do such retrofitting – and seeking information about this is a first step. Prior research has shown that trust in information sources is crucial in establishing links between

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intentions to seek information and undertaking actions, such as retrofitting houses [6]. One of the most utilised sources of information, when people intend to prepare their houses for earthquakes, is from builders [4].

While previous studies have focused on seismic risk communication for larger, often multistorey, buildings [7,8], little research has examined the role of builders in seismic risk reduction for low-rise residential homes, especially in higher-income countries. Unlike in informal housing in low-income countries, where builders often make design decisions, in Aotearoa New Zealand, standards and professionals, like engineers, guide design and construction. Yet, builders play a pivotal role, as they are responsible for implementing these standards and designs.

Campaigns in Aotearoa New Zealand encourage homeowners to consult either engineers or builders when retrofitting houses for seismic resilience [9,10]. However, there is limited research on builders' role and understanding of seismic strengthening, their priorities, how prepared they feel to communicate technical information to homeowners and take responsibility for that advice. Understanding how builders interpret seismic strengthening and how their interactions with homeowners and engineers shape retrofitting decisions is important for enhancing community resilience.

This work explores the roles, understandings, priorities, and experiences of builders in relation to seismic strengthening, as well as the dynamics between engineers, homeowners, and builders that influence seismic retrofitting decisions. Semi-structured interviews were conducted with builders and engineers to unpack builders' perspectives on seismic building strengthening. The work presented herein includes a reflexive thematic analysis of the interviews. Understanding builders' perspectives and opinions can ultimately contribute to identifying more effective methods of engaging with all parties involved in building a resilient Aotearoa New Zealand.

2. Builders in earthquake-prone regions

After almost every urban earthquake, the call goes out to improve building construction [11]. Hence, research has focused on builders' roles in post-disaster settings—how they aid reconstruction or obtain training to apply new knowledge [11,12]. However, some authors have also emphasised the need for teaching, training and engaging with low-rise residential community builders to increase resilience before earthquakes occur [13].

Most of the available literature targets informal construction practices in low or middle-income countries [14]. In communities in hazard-prone regions, such as the Caribbean, whose residents are constantly preparing for and recovering from disasters, houses are constructed primarily through informal processes—relying on builder experience [15]. In many cases, builders rely on custom, tradition, and informal practices, with seismic risk largely overlooked [16]. Research conducted in Turkey, the Philippines, Indonesia, Pakistan, Nepal, and Fiji shows that housebuilders are confident about the safety of the houses they construct. However, in practice, a substantial proportion of masons and builders do not adhere to building codes [17]. Researchers have compared these informal construction practices with engineered practices [16]. Although informal construction practices exhibit country-to-country variation and the research community acknowledges the potential risks these variations may pose, there is a notable absence of studies examining construction practices aimed at disaster preparedness in countries where construction practices have been widely standardised (such as Aotearoa New Zealand) and where issues with housing construction persist.

In countries where low-rise residential house construction has been standardised, for example, by following prescriptive standards, which target life safety (e.g., NZS 3604:2011 [18]), some level of damage is still expected after a major earthquake. This is because such standards prioritise life safety rather than preventing all forms of damage. While these approaches reduce the need for bespoke engineering and help keep construction costs down, the effectiveness of these designs still depends on builders' understanding of the intent and limitations behind them. Prior studies have indicated that even in systems that simplify construction, misinterpretation or incomplete understanding of design principles can lead to vulnerabilities [17].

Whether in the context of new construction or retrofitting for seismic strengthening, improving housing performance requires a clear understanding of builders' technical capacity and their perceptions of housing safety in a disaster context. Rather than focusing on "unsafe design" or construction errors, the challenge often lies in the level of understanding around the purpose and function of specific detailing requirements. Despite the critical role builders play, there is limited research on how to effectively engage with them to communicate technical recommendations and support capacity-building for safer and more resilient housing.

3. Perceptions of housing performance

Perceptions of seismic performance influence builders' willingness to engage in seismic strengthening. These perceptions are shaped not only by technical knowledge but also by how builders and homeowners interpret seismic risk, vulnerability, and expected levels of damage. Prior research shows that homeowners' beliefs about how well their houses will perform in an earthquake strongly influence whether they seek strengthening [4]. Understanding these perceptions provides context for interpreting builders' experiences and intentions, particularly when communicating information with homeowners.

Public perceptions of housing safety after earthquakes often diverge from technical realities. In one study, homeowners in Turkey and the Philippines perceived their homes as strong enough to withstand a large earthquake. In contrast, others in Indonesia, Pakistan, Nepal, and Fiji were not confident in the construction of their homes [17]. In Wellington, Aotearoa New Zealand, homeowners expect their houses to suffer minimal to moderate damage after a large earthquake, with these expectations of damage being influenced by prior experience since the last large earthquake in Wellington (i.e., 2016 Kaikōura earthquake) did not result in significant damage to low-rise residential house structures [4,19]. These studies have shown that perceptions of damage are primarily influenced by prior experiences.

Homeowners' perceptions of performance have also been influenced by who has built or retrofitted houses. For example, in

Indonesia, Nepal, Japan, and Turkey, people tend to rely more on engineers, whereas in Pakistan, they tend to rely more on masons and government guidance [17]. In Wellington, Aotearoa New Zealand, the few homeowners who have undertaken retrofitting indicated they first relied on a builder to carry out seismic strengthening work on their houses and second, on engineers [4].

As homeowners often believe their houses will perform well during earthquakes, builders similarly express confidence in the safety of the houses they construct. However, this confidence in building construction varies depending on the context (i.e., country). For example, a study found that in countries such as Indonesia, Pakistan, and Nepal, builders often assume that adherence to traditional methods is sufficient for safety and do not consider themselves responsible for the vulnerability of the homes they construct [17].

4. Communication and engagement challenges

Generally, research on communication within the construction sector has focused on large projects, such as commercial or infrastructure developments, which involve multiple layers of hierarchy, including project managers, site supervisors, subcontractors, and specialised trades. Much of this work has focused on communication breakdowns among personnel on-site, which have been linked to reduced productivity and poor project outcomes [20]. However, communication challenges are not exclusive to large projects; across the construction sector, poor on-site communication has also been identified as a key factor contributing to poor construction outcomes. The primary causes of poor communication are the absence of a shared language between managers and workers, workplace stress, negative attitudes towards site workers, misinterpreted instructions, and inadequate communication skills among workers [21].

Most seismic risk communication focuses on building owners and large buildings [4,22,23]. To effectively communicate seismic risk, it is crucial to acknowledge the diverse perceptions, priorities, and limitations of decision-maker groups [7,24], such as engineers, builders, owners, landlords, and tenants. To date, there has been limited research examining how seismic risk is communicated with and understood by builders in low-rise residential settings. By improving the clarity and accessibility of seismic risk information, builders could better align their efforts to build a safer and more resilient building stock in Aotearoa New Zealand.

Efforts to improve communication and construction quality have led to the development of government programmes, certification schemes, and quality control measures aimed at enhancing construction and retrofit standards and reducing earthquake-related damage. However, research indicates that these interventions do not always achieve their intended outcomes, and deficiencies in construction quality can still contribute to earthquake damage. For example, in Australia, it was found that using a registered builder did not necessarily result in better outcomes compared to owner-builders, as both experienced issues with construction defects, particularly in renovations and extensions [20,25]. Even buildings that successfully meet consent requirements may contain incomplete or substandard work [25]. This suggests communication and implementation challenges within the construction industry that require further attention, and highlights the need for more effective control of on-site construction practices to ensure rigorous adherence to building codes [16].

One-way approaches to sharing technical construction recommendations or unfamiliar technology with those building houses highlight the need to collaborate with communities to build safer housing [14]. Research has shown that, in general, home builders who are willing to use technological innovations, that have not yet been fully assimilated into the home building industry, are those who also seek to reduce uncertainty about those innovations [26]. Site-level innovation is frequently driven by builders themselves in response to practical challenges, rather than by manufacturers or designers [27].

Introducing new construction systems, technologies, and knowledge requires extensive training and time for practitioners to fully assimilate them into their practices [28]. Following the 2009 earthquake in West Sumatra, Indonesia, builders received training in constructing earthquake-resistant houses. Although the combination of lecturing and practice sessions helped builders understand the new knowledge, builders were influenced by prior experience. Builders faced a dilemma when choosing new solutions that improved the safety of the house, but also increased construction costs [12]. Therefore, promoting earthquake awareness and resilience through all sectors is crucial for more sustainable development [11].

Effective technical construction capacity-building should involve active collaboration with communities to learn their perspectives and then centre and address their needs and concerns given their available resources and alternatives [29,30]. Misalignments between builders' perceptions and engineering knowledge of housing safety pose challenges in promoting hazard mitigation. For instance, the perceptions of the appropriate use of hurricane straps for mitigating roof damage were analysed, where engineering studies showed that the installation of appropriately designed hurricane straps (in terms of specified quantity, fasteners, and locations) could significantly improve outcomes in hurricanes [30]. However, many builders do not expect damage to key roof connections where hurricane straps can help; instead, they perceive that it is more important to strengthen the connections between metal roof panels and the roof.

Research has shown that to help people build safer houses and better understand how to reduce damage from disasters, it is crucial to have clearer and more effective ways of sharing technical information. This includes improving the communication of construction practices, such as strengthening buildings, so that builders and communities can not only receive the information but also understand the technical information and the reasons for it. It's also important to create space for two-way dialogue, rather than just top-down instruction, so that local knowledge and questions can inform the process [31].

5. Aotearoa New Zealand's context

Although much of the international literature focuses on informal construction contexts, the challenges identified are also relevant to formally regulated environments such as Aotearoa New Zealand. Studies from countries with less standardised construction systems

highlight issues such as limited seismic awareness and communication gaps between builders, engineers, and homeowners—patterns that also appear in Aotearoa New Zealand, though within a different regulatory and cultural context. These parallels suggest that many of the barriers to seismic strengthening are not solely the result of informal construction practices but reflect broader dynamics that can occur across diverse building environments.

In Aotearoa New Zealand, most research on seismic retrofitting of infrastructure focuses on commercial and multi-story buildings. When referring to seismic strengthening, the most common thought stems from the Building (Earthquake-prone Buildings) Amendment Act [32], which was enacted in 2016 to create a national framework for identifying and remediating buildings considered 'earthquake-prone'. Earthquake-prone buildings (EPBs) are considered to pose the greatest life safety risk to the public, and their assessment is carried out against the strength of an equivalent new building, resulting in a rating expressed as the Percentage of New Building Standard (%NBS) [33]. The EPB framework is focused on reducing the risk of loss of life, rather than preventing damage. In contrast, retrofitting residential houses, which are not captured under the EPB framework, primarily aims to reduce damage and disruption.

Limited research has been conducted to investigate the barriers to implementing retrofitting in the residential housing sector, despite the fact that 80% of New Zealanders live in one- to two-story stand-alone houses, most of which are timber-framed (BRANZ, 2019). In Aotearoa New Zealand, the construction of most new residential timber-framed buildings is governed by NZS 3604:2011 [18], a national standard that provides methods for designing and constructing timber-framed structures up to three storeys (among other limitations). This standard is used by builders, architects, and engineers, and is widely regarded as a key tool for ensuring that homes meet seismic performance expectations.

While Aotearoa New Zealand's construction sector benefits from regulated, standardised practices, issues still arise. Builders may lack a deep understanding of the philosophy behind seismic design, leading to mistakes during construction. Moreover, updates to NZS 3604 require continual adaptation from the construction sector, which can sometimes lag behind in awareness and compliance. Despite the formalised framework, effective seismic strengthening still depends on builders' engagement with technical and communicative aspects of construction.

5.1. Education

In Aotearoa New Zealand, work carried out on houses can be classified as restricted and non-restricted building work, which will define the level of certification the builder must hold to carry out the work. Restricted Building Work (RBW) is classified as work that significantly affects the house's primary structure, weather tightness or certain fire safety aspects and requires building consent. Non-Restricted Building Work (non-RBW) might not require building consent or does not affect or involve work to the primary structure or its weather tightness. RBW must be designed and carried out by Licensed Building Practitioners (LBPs). Also, some architects, engineers, electrical workers, plumbers, gasfitters, and drain layers can do or supervise RBW. Although they might not be listed on the LBP register, they are deemed to hold licences in certain classes.

LBPs' license scheme indicates that builders have been assessed as competent in a particular area of building work, and LBPs must not carry out or supervise RBW outside of their licensing class. The scheme includes seven licensing classes based on specific roles or occupations that are crucial to a building's performance (BB: Brick & Block laying; C: Carpentry; D; Design; EP: External Plastering; F; Foundations; R: Roofing; S: site; and A: All). All licence classes except for Carpentry (C) include *Areas of Practice (AoPs),* which are specialised types of work within the scope of a licensing class that require specific competencies, skills, or experience. LBPs are not restricted to working within their AoPs, LBPs can undertake all work covered by their licence class. The license classes are restricted to carrying out work in certain building categories, which, for example, depend on whether the building is a single-sleeping home and its total risk score. The Building Act defines the total risk score based on the wind zone, number of storeys, roof elevation, eaves width, envelope complexity and deck design.

Every two years and to keep the minimum standard required to keep the licence(s), LBPs must undergo skill maintenance activities including elective and mandatory activities (where Carpentry, Foundations, Roofing, External Plastering, Bricklaying and Blocklaying must complete 12 h of elective activities, Site or Design in AoP 1 must complete 15 h of elective activities, and Site or Design in AoP 2 or 3 must complete 18 h of elective activities). Mandatory activities include Codewords relevant to your licence class and a short quiz for each Codeword, and the skills maintenance process will also be audited. While LBPs must go through the certification process and skill maintenance provided and supervised by the Ministry of Business, Innovation and Employment (MBIE), other building practitioners can carry out building work that is not restricted, such as Certified, Registered Masters or Qualified builders.

In 1998, a group of trade-qualified builders started a membership for New Zealand Certified Builders (NZCB) with the aim of protecting homeowners from unqualified builders and unethical practices. The NZCB-accredited builders' membership by the NZCB is given after meeting certain standards of competency and professionalism. To become an NZCB-accredited builder, the builder must have a certain amount of practical building experience and pass a rigorous assessment process that includes both practical and theoretical assessments. The first requirement to apply for the NZCB accreditation is to hold a recognised trade qualification equivalent to or better than the National Trade Certificate in Carpentry Level 4.

Like NZCB, Registered Master Builders Association (RMBA) is also a leading trade organisation for builders in Aotearoa New Zealand; however, no formal examinations (qualifications) are needed and a minimum of eight years of continuous building experience is required, comprising five years or more as a building contractor or management of a building business. Differently, Qualified Builders (QB), another association, must complete an apprenticeship and gain a National Certificate in Carpentry Level 4, usually an Aotearoa New Zealand Certificate of Education Achievement qualification — a combination of on-the-job training and theory work and typically takes 3-4 years to complete — and no compulsory ongoing training or knowledge maintenance. Another association

focused on inspections is the New Zealand Institute of Building Inspectors (NZIBI). The requirements to become an NZIBI inspector are (1) a level of qualification attainment equivalent to an NZ Trade Certificate in a construction-related field, (2) a member of another professional group, (3) a minimum of five years construction experience and (4) can substantiate that they are of good standing in the community and can provide two referees or sponsors to act on their behalf.

Builders are updated through newsletters or technical magazines, such as the Build magazine, published by BRANZ (Building Research Association of New Zealand). BRANZ is an independent research, testing, and advisory organisation that supports the building and construction sector, publishing information through various channels, including the Build magazine. The Build magazine seeks to provide practical technical information to enhance building design and construction practices, as well as information on industry issues, including changes in the Building Code and standards, new opportunities, and trends. In 2021, a survey was sent out with the October issue of the Build magazine, and 566 readers completed the survey. It was found that 65% of those responding were LBP builders – different from 2019, when 67% were LBP builders. Another publication, Building Today, is the official magazine of the Registered Master Builders Association and serves as a key platform for sharing industry news, best practice guidance, and updates on training, regulations, and innovations relevant to builders across Aotearoa New Zealand.

5.2. Assessing houses in Aotearoa New Zealand

In Aotearoa New Zealand, owners can request several general assessments or inspections, which builders or NZIBI can carry out. Although the NZIBI offers a general inspection and focuses on pre-purchase reports, there are other entities offering earthquake safety checks. For instance, Quakecheck, which uses the NZIBI inspectors, is part of an independent building inspector group that operates under the umbrella of NZ House Surveys [34]. Another voluntary assessment that includes low-rise residential houses is QuakeStar which aims to extend the EPBs legislation to cover buildings that are out of scope. QuakeStar assigns five rating levels considering safety, damage, and repair time. The assessments are carried out by assessing engineers and reviewed by a reviewing engineer, where both must be on the QuakeStar approved list.

Several programmes for homeowners to earthquake-check their houses have been launched to improve the resilience of houses [9,10]. They usually provide simple checks and recommend getting professional advice from an engineer or licensed building practitioner. For example, ‘Single residential homes are not part of the earthquake-prone building legislation, but find out what you can do to strengthen your home and keep your family safer in an earthquake’ is what you can find on the Wellington City Council webpage [10].

6. Research method

Engineering research increasingly emphasises systems that account for human perceptions and needs, including behaviour and organisational dynamics [5,35–38]. As such, this research took a qualitative approach to explore the experiences of builders' perceptions and priorities working with seismic risk information [39–41].

6.1. Data collection

This project involved semi-structured interviews with builders and engineers. This study employed interpersonal recruitment, which refers to approaching potential participants through existing professional networks, word-of-mouth referrals, and direct outreach to individuals known to have extensive experience in residential construction contexts. Initial contacts were made via personalised emails, during which the purpose of the study and participation expectations were explained. Potential participants were also invited to suggest colleagues, which helped extend the recruitment pool. The approach aimed to include individuals with several years of professional experience to ensure informed insights (more than a decade). Participants with direct experience in residential construction, particularly timber-framed housing, given its prevalence in Aotearoa, were targeted. Efforts were made to include a mix of builders and engineers from both small-scale operations (including sole traders) and larger firms to reflect the diversity of the construction sector. This approach recognised that much of the housing stock in Aotearoa is built by small to medium-sized companies, and their perspectives are critical to understanding real-world practices. The method focused on fostering relationships and trust with

Table 1
Participant characteristics.

Participant	Role	Location	Experience (years)	Organisation type
1	Builder	Christchurch	30+	Small business
2	Builder	Wellington	40	Small business
3	Builder	Wellington	18	Small business
4	Builder	Rotorua	10	Small business
5	Builder	Auckland	20+	Small business
6	Builder	Christchurch	10	Small business
7	Builder	Wellington	35+	Sole trader
8	Builder	Wellington	15	Small business
9	Builder	Bay of Plenty	20	Small business
10	Engineer	Wellington	10	Multinational
11	Engineer	Wellington	30+	Multinational

participants to ensure the credibility of the data collected [42]. Participants were invited via email or a phone call, and prior to the interview, an information sheet and consent form were provided. The information sheet outlined the purpose and value of the research, how data might be used and gathered, how to withdraw information and maintain confidentiality.

A total of 11 interviews were conducted—two with engineers who have experience working with builders and nine with builders. Engineers were included because they regularly collaborate with builders in seismic and structural work and could offer complementary insights into builders' practices, communication dynamics, and barriers to engaging in seismic strengthening. Engineer participants were based in Wellington, while the builders were located across Auckland, Rotorua, Wellington, Bay of Plenty and Christchurch. Table 1 summarises some of the participant characteristics, such as years of experience, company size, and geographic location. This national spread was intended to capture a range of perspectives from different regions and building contexts. While the sample size was relatively small, this reflects the specialised nature of seismic retrofitting, which currently involves a limited number of builders with expertise in the low-rise residential sector. The geographic diversity of participants, combined with their extensive professional experience, allowed the study to reach thematic saturation. Saturation was determined when no insights, or meaningfully different perspectives emerged during later interviews, and data consistently reinforced patterns, providing a robust foundation for theory-building.

Interviews were conducted online and over the phone and were recorded. The 60-min semi-structured interview explored participants' (1) prior experience, including their education, training and what projects they have been involved in, (2) their perceptions of seismic building risk, specifically their experiences, needs and involvement related to seismic strengthening practices, and (3) communication practices, focusing on interactions with engineers and clients, and perspectives on communicating seismic risk. For example, participants were asked questions such as: What training or learning have you already undertaken? Have you been asked to do seismic strengthening? How do you keep yourself updated about new technologies or code updates? In your experience, what are some of the critical challenges of communicating seismic building risk?

The project was deemed as low-risk and thus did not require a review by one Massey University's Human Ethics Committees. The researcher(s) named in this document are thus responsible for the ethical conduct of this research (Low-Risk Ethics Notification Number: 4000027805).

6.2. Analysis

Interview recordings were transcribed and analysed using the reflexive thematic analysis procedure described by Braun and Clarke [39] and Byrne [40]. This method emphasises the active role of the researcher in identifying patterns and making decisions to group them throughout the analysis process. An inductive coding strategy was used, allowing themes to emerge from the data without being constrained by pre-existing categories. This approach was chosen to capture the participants' perspectives and experiences as they related to the research questions.

The transcripts were read closely to identify codes that captured meaningful features of the data. Initial codes were iteratively

Table 2
Summary of themes, key issues, and implications for practice.

Theme	Key issues identified	Implications for Practice
Theme 1: Builders' Awareness About Seismic Strengthening	• Builders often do not associate their work (e.g., bracing, connections) with seismic resilience. • Limited conversations with clients or engineers about seismic risk; varies by region. • Homeowners rarely initiate seismic-related discussions.	• Increase visibility and clarity of seismic-related tasks within routine construction work. • Develop targeted communication tools and prompts to support builders initiating conversations. • Regionally tailored engagement materials may help facilitate discussions on seismic strengthening.
Theme 2: Cost and Homeowners Influencing Builders' Willingness to Strengthen Houses.	• Seismic retrofitting perceived as expensive by builders and homeowners. • Builders are reluctant to suggest strengthening due to liability and homeowner resistance. • Homeowners struggle to see value in preventive measures.	• Provide clear cost-benefit information and simple retrofit options to support decision-making. • Offer communication resources to reduce builder discomfort when raising seismic issues. • Public campaigns could increase homeowner awareness and reduce pressure on builders.
Theme 3: Builders' Barriers to Engage in Building Strengthening	• Increased compliance and administrative burden limit capacity for additional seismic tasks. • Builders feel undervalued.	• Improve support systems to reduce admin burden. • Strengthen collaboration with engineers to reduce design-related liability and uncertainty. • Provide practical, hands-on training for applying NZS 3604 in retrofit contexts.
Theme 4: Diverse Learning Paths and Gaps in Seismic Risk Understandings	• Training pathways vary widely; learning is mostly on-site and experience-based. • LBP system provides oversight but limited seismic-specific education; online training is viewed as ineffective. • Misunderstandings of design principles can cause construction issues.	• Develop trusted, practical training delivered by organisations such as BRANZ. • Emphasise hands-on, scenario-based learning rather than online modules. • Provide simple explanations of seismic design philosophies to improve implementation accuracy.

reviewed, compared, and refined. Codes that described similar concepts or addressed related aspects of the research questions were gradually clustered together into higher-codes. Through several rounds of coding, 28 codes were organised into four overarching themes based on similarity and relevance to the research questions. These themes were not predetermined but were shaped through analytic reflection on how the coded data interacted. Theme development involved continuously re-reading the coded extracts, confirming that themes were clearly distinct from one another. Coding and theme development were carried out using NVivo, which supported data management and the organisation of codes and themes. The four themes, their key issues and potential implications are summarised in Table 2 and further developed in the sections below:

- Theme 1 on Builders' Awareness About Seismic Strengthening. This theme captures knowledge gaps, risk perceptions, and communication practices between builders, engineers, and owners.
- Theme 2 on Cost and Homeowners Influencing Builders' Willingness to Strengthen Houses – seismic retrofitting is perceived as expensive by builders and homeowners, influencing retrofitting uptake.
- Theme 3 on Builders' Barriers to Engage in Building Strengthening – the current legal and economic environment affects engagement. Many also expressed frustration at being undervalued; however, their role is critical in the aftermath of major events.
- Theme 4 on Diverse Learning Paths and Gaps in Seismic Risk Understandings – highlighting training routes, role limitations, and barriers to effectively communicating seismic risk.

As reflexive thematic analysis recognises the researcher as an active interpreter of meaning, it is important to acknowledge how the analytic lens may have shaped this work. The analysis of the interviews was conducted primarily by authors with an engineering background, whose familiarity with seismic strengthening concepts informed conversations with participants and supported the interpretation of technical content. At the same time, this background may have influenced the types of questions asked and the aspects of participants' accounts that were most salient during analysis. Because the study focuses on the perspectives of builders, care was taken to remain attentive to participants' language, priorities, and lived experience, and to avoid imposing engineering-centric assumptions on their narratives. Throughout the research process, the authors actively reflected on their own preconceptions, challenged initial assumptions, and adapted their interpretations as they developed a deeper understanding of builders' perspectives.

7. Results and discussion

The interviews with builders and engineers provided a deeper understanding of the priorities, preferences, knowledge, and challenges associated with seismic building strengthening. The following sections present the results and discuss the main takeaways by themes.

7.1. Theme 1: Builders' perspectives of their role in seismic strengthening

This theme explored builders' general understanding of seismic strengthening, the disconnection between construction practices and seismic provisions, perceived costs of seismic strengthening, and shared responsibility and value.

Although builders were generally familiar with structural elements such as connections and bracing units (i.e., the standardised lateral capacity of resisting elements defined by the NZS3604), in general, they did not associate these features with seismic resilience. This lack of awareness was particularly evident in the interview recruitment process, where builders were uncertain about the term "seismic strengthening". Many admitted they primarily associated seismic strengthening with large-scale commercial or office buildings rather than residential houses. As a result, there was some initial confusion about the scope of their participation. This echoes the focus of research investment, where the vast majority of research focuses on large-scale projects when it comes to seismic strengthening [8,43].

While residential low-rise houses did not account for large-scale structural failures during events such as the Canterbury earthquakes, the overall economic losses were substantial due to the large number of houses affected and site-specific factors, including liquefaction and foundation damage [44]. This highlights a gap in addressing seismic vulnerabilities within residential sectors, not because individual houses are necessarily poorly constructed, but because small-scale risks across many dwellings can accumulate to significant social and economic impacts. For example, one builder shared that they initially assumed the research was focused on large commercial buildings rather than residential houses, highlighting a widespread disconnect in understanding the seismic vulnerability of residential structures. Even when builders carried out tasks such as installing critical connections under houses, which directly relate to seismic resilience, they didn't always recognise these activities as part of a broader strategy for seismic strengthening.

> "I thought you were talking about big office buildings" (Builder)

In interviews, several builders mentioned that despite decades of experience, they rarely had direct conversations about seismic risk with clients or engineers. Instead, their involvement in seismic-related work typically occurred incidentally through renovations or inspections that incorporated structural elements compliant with the building code, rather than through explicit seismic strengthening efforts. This pattern appeared to be influenced by geographic location: builders operating in regions with lower perceived seismic hazard, such as Auckland or Rotorua, were less likely to consider or discuss seismic risks, whereas those in Wellington or Christchurch, a higher-risk area, were more familiar with earthquake topics.

> "I have been a builder for 40 years, and nobody has asked me to strengthen houses seismically." (Builder)

This observation appeared to reflect two key issues: first, that builders do not always recognise aspects of their work as contributing to seismic strengthening; and second, that homeowners seldom seek information, or initiate discussions or requests for seismic retrofitting. Some builders expressed concern that many homeowners lack understanding of the seismic function of key structural elements, which may contribute to the absence of such conversations. This aligns with earlier research that identifies limited public awareness and educational gaps as fundamental barriers to improving seismic resilience in residential construction [13].

The findings also align with international studies showing that builders often do not explicitly associate construction tasks with seismic risk reduction [17]. However, unlike research on non-engineered houses, where builders frequently rely on traditional practices without reference to codes, builders in Aotearoa New Zealand operate within a formalised regulatory environment that they follow but do not always conceptualise in terms of seismic performance. This contrast extends the previously mentioned gap in seismic awareness, which not only occurs in less formal construction contexts but can also occur in highly regulated systems.

7.2. Theme 2: Cost and Homeowners Influencing Builders' willingness to strengthen houses

This theme explores how the cost of retrofitting influences willingness to offer seismic strengthening. Builders view seismic retrofitting as expensive and often avoid taking on design responsibilities, focusing instead on executing plans. Although builders can identify retrofit opportunities, they rarely suggest them due to concerns about cost and liability risks. Homeowners also resist seismic upgrades, perceiving them as costly and offering no immediate benefits, which discourages builders from initiating these conversations.

All of the interviewed builders considered seismic retrofitting as a costly endeavour. This reluctance to take on seismic design responsibilities seemed to stem from the business model most builders operate under, which focuses on carrying out physical construction work rather than being involved in design. Interviewees indicated that they generally focus on executing projects according to plans, with limited attention to the reasons behind the design. This finding aligns with the literature that suggests that construction practices are heavily guided by project execution and compliance rather than by an understanding of the reasoning behind designs [45].

Such a construction-focused business model creates an environment in which seismic considerations are often treated as secondary, particularly in residential settings where budget constraints are tight. Builders indicated that they often act as project managers in renovation jobs and may avoid involving engineers due to the additional cost to homeowners. While builders indicated they could identify and propose opportunities for seismic retrofitting, these opportunities are frequently missed due to concerns about escalating project costs. The quote below reflects builders' perceptions that the cost of residential construction has increased in recent years due to a shift in who is allowed to design houses. In the past, Aotearoa New Zealand's building system allowed experienced architectural designers to undertake a significant portion of the design work for houses. However, recent regulatory changes and increased complexity in compliance have led to a greater reliance on engineers for tasks that were once within the scope of designers. Builders indicated that this change has added a layer of professional fees and formal requirements, driving up the overall cost of housing.

> “Since designers were removed from the design and engineers had to be hired, the cost of houses has increased so much.” (Builder)

This gap is compounded by a reluctance among builders to engage with seismic design responsibilities, often deferring these decisions to engineers. As indicated in the quote below, builders stated discomfort with taking on tasks that involve seismic calculations, highlighting a broader issue with the current industry structure. Under the LBP system, although they could make decisions about seismic work, builders believe they are not equipped to make design-related decisions. Many builders articulated that while confident in executing plans, they prefer not to take responsibility for design choices, particularly due to a lack of specialised training in this area, and potential liability issues.

> “I don't know that the system is set up for us, at the moment, for builders, to take responsibility for design work, and I'm not sure that builders want to take that responsibility. I don't think they think themselves capable of completing the design work to meet regulations. I think they're happy to identify problems or things that have been missed in the design, but I think they want some assurance and certainty that the work that they're doing is, in fact, appropriate.” (Builder)

From the builders’ perspective, homeowners also share some responsibility in the decision-making process around seismic strengthening. This has also been observed in prior research, indicating that any kind of housing retrofitting is a shared responsibility [46]. However, interviewees indicated that homeowners do not fully understand the long-term benefits of seismic strengthening, particularly when faced with the upfront costs. Builders expressed frustration that even when they explain the risks of not strengthening a house, homeowners are reluctant to spend money on preventative measures, despite the potentially catastrophic damage that an earthquake could cause. This hesitation is compounded by a lack of visible, immediate benefits—homeowners are less likely to invest in measures that address a risk they cannot see or feel, especially when the risk is framed as a “what if” scenario.

This aligns with prior research findings where cost-benefit was a limitation influencing earthquake preparedness [4,47]. Even when builders attempt to explain the long-term risks associated with not strengthening a house, homeowners frequently view the recommendations as unnecessary or overly cautious. This hesitation to invest in preventive measures not only reflects a lack of understanding about seismic risk but also contributes to a vicious cycle where builders avoid initiating conversations about seismic strengthening. Consequently, increasing awareness of the benefits of seismic strengthening is crucial for encouraging preparedness [4,19]. For example, the quote below shows how builders are discouraged from even broaching the topic when they anticipate resistance from homeowners who view seismic upgrades as expensive and low-priority:

> "People ring you up … I would say 'I really think there is a seismic risk here, and you should put ties on there'. And they would say, 'Oh, OK, well, how much will that cost?' I would say, '$2000' … then there's a kind of resentment, and then if there is an earthquake, and their house is damaged. They will be 'Oh, but we've had the builder seismically proof the house'. And they'll be really angry. So that's the sort of thing I avoid … People think $2000 is much money … but it isn't in building." (Builder)

This disconnection creates a vicious cycle: if seismic strengthening is not perceived as adding immediate value to the property, homeowners are unlikely to undertake the necessary work. Builders, in turn, avoid raising the topic because they know that homeowners may not want to invest in something that doesn't have a direct or visible payoff. As one builder put it, the idea of spending extra time and money on hypothetical future risks is not a conversation that most builders want to initiate because they know the homeowner is likely to dismiss it as unnecessary.

> "[Seismic strengthening] doesn't drive business in any particular direction, and unless [seismic strengthening] makes improvements directly to a homeowner, who's going to appreciate the value and the cost … The builder is not going to have that conversation, [the builder] knows the homeowner is going to go hang on 'you're telling me to put some time and effort into a what if maybe could be? I can't even touch and feel that and get the benefit from it. Just let's just carry on'." (Builder)

7.3. Theme 3: Builders' Barriers to Engage in Building Strengthening

This theme explored the pressures and challenges builders face within the current legal and economic environment, which has significantly influenced their willingness to engage in seismic strengthening work. Many also expressed frustrations at being undervalued, and criticised a culture that prioritises speed and cost over quality. However, their role became critical after the 2010-2011 Canterbury Earthquake Sequence. In a context where mistakes carry financial and legal consequences, builders mentioned they are hesitant to take on additional responsibilities, particularly those related to seismic design.

Builders highlighted the increasing pressure they face due to compliance and administrative requirements in recent years. While they believe that seismic strengthening is important, builders reported feeling overwhelmed by these additional responsibilities, which, in their view, extend beyond the training and expertise they have received. Several participants felt that they were being asked to take on more responsibilities than they were trained for, as indicated below:

> "So builders as a whole, whether it's people on the tools, or people administering the contracts, or managing the people doing the building, everybody has to do more administration now and like, that's a skill that's not taught anywhere in the process." (Builder)

As builders grapple with the expanding scope of their work, many feel burdened by responsibilities they are not equipped to handle. When faced with decisions involving seismic risk, they indicated they often defer to engineers. This tendency reflects not only a practical recognition of their limitations but also a broader frustration with a system that demands more from them than they feel is fair or feasible. The increasing demands placed on builders, coupled with insufficient support for seismic-specific training, make it difficult for them to prioritise seismic strengthening, even when they acknowledge its importance.

The interviews also revealed that while the LBP system offers some oversight, it does little to address builders' educational gaps, particularly in relation to seismic risk. Builders themselves expressed scepticism about the effectiveness of the LBP system in meaningfully improving their understanding of seismic design. The system's focus on continuing education is perceived as insufficient to equip builders with the necessary skills to engage with seismic risks comprehensively. While some builders acknowledged the value of having a basic understanding of why engineers make certain design decisions, there was general doubt that formalising seismic education within the LBP system would significantly change builders' practices. This resonates with prior research, which suggests that practical experience-based learning may be more effective than formal requirements alone [15,16].

Although builders acknowledged that the LBP system introduced greater accountability, many felt infantilised by the way they are perceived and treated by society. Despite their increasing responsibilities, a common thread focused on feeling undervalued, with their expertise and contributions overshadowed by negative stereotypes. One builder vented frustration about how builders are perceived as low-skilled manual workers, even though they are tasked with significant responsibilities:

> "People treat them (builders) like children … I think throughout society there's this idea of you know, we want to keep builders as working class, low-paid, manual workers, so we don't want to pay them money, but we do want to give them all this [expletive] responsibility, and we want them to be accountable. But you can't have both. Do you know what I mean? I'm ranting." (Builder)

This sense of societal undervaluation seemed to be intensified by the pressure builders indicated they felt as they tried to balance the conflicting demands of contributing to seismic resilience while meeting increasingly stringent compliance expectations. Builders expressed being caught between a desire to promote seismic strengthening and the continuous pressure to build cheaper, faster, and more efficiently. They are often criticised in the media and by government policies that emphasise productivity without adequately recognising the complexity of their work. As one builder noted, this persistent criticism exacerbates their sense of pressure and contradiction:

> "Builders are constantly smashed in the media and by the New Zealand Government that we're gonna build cheaper, faster, and we're not being very productive. So that's always hanging on the shoulder of the builder parking there." (Builder)

This pressure was particularly apparent when builders were asked about their understanding of NZS 3604 (an Aotearoa New Zealand technical standard which sets out specifications and methods for designing simple light timber-framed houses). While many builders agreed that NZS 3604 is a useful and well-constructed document, they indicated they do not feel equipped to use it for design purposes, even though the LBP system allows them to do so. Builders noted that while most can read and follow a set of plans, interpreting NZS 3604 for complex tasks such as remediations or seismic strengthening is beyond their capacity, especially given the multitasking and pressure they face on job sites. One builder illustrated this challenge by explaining how such a workload increases the likelihood of errors:

> "So you (architect) tell me what size they are (bearers) because the potential for me to make a mistake is quite high even though I'm reasonably good at it. It's because I'm doing five different things at the same time." (Builder)

Despite these challenges, some engineers indicated they believe that builders should be more confident in applying NZS 3604 in residential projects, particularly because many tasks are repetitive and do not require complex calculations. One engineer emphasised that extending the scope of NZS 3604 could empower builders to handle more design elements without the need for engineering input:

> "I would extend the scope of the 3604 because they are things that are always the same, and you don't need an engineer to calculate it." (engineer)

However, this perspective underscores a significant disconnect between the expectations placed on builders and the support they perceive they receive. While engineers see NZS3604 as a practical tool that could enable builders to take on more responsibility, builders described a very different experience. For them, the guidelines are not simply a set of repetitive tasks but a document they must interpret under conditions of time pressure, administrative burden, and competing on-site demands. Builders reported that, without adequate seismic-specific training or opportunities to deeply engage with design principles, they often feel unsupported in taking on responsibilities that engineers assume should be straightforward. In this sense, the two groups articulate parallel but misaligned understandings of what NZS 3604 enables in practice.

These challenges are not just theoretical—they became starkly evident during the 2010–2011 Canterbury Earthquake Sequence, when the urgent need for reconstruction collided with limited capacity and expertise. Builders and engineers recalled how rapid recovery demands often compromised long-term performance, and the shortage of experienced contractors further amplified concerns about the quality of seismic strengthening practices during that period.

> "After the Christchurch earthquake, I saw a lot was done poorly, to sort of get it done and make houses liveable. However, you got back to see those houses later, and you see cumulative damage due to those poor, rapid solutions, which were good in the short term, in immediate response, but not in the long run. A lot of companies were created to respond to the Christchurch earthquake damage; they might not have had any experience, but they had to come up with solutions that might be questionable now. "(Engineer)

Participants repeatedly mentioned the long-term consequences of the rushed repairs. Reflecting, a builder mentioned that these issues could have been avoided. This raises the question of whether homeowners who chose not to rush repairs—and instead waited for the industry to have clearer solutions—may have ultimately made better decisions, especially given that some houses remain unfinished even 14 years later [48]. Still, the psychological impact on residents cannot be overlooked, where ongoing stress and emotional fatigue have been identified during lengthy and uncertain recoveries. Even if waiting may have led to better repair outcomes, it came at a significant personal cost [49,50].

> "I don't know whether it was pressure of time or what it was … Our industry shouldn't have been passed that point. It was just terrible. Our industry should have moved on further than to do such poor work." (Builder)

While there is general awareness of the challenges associated with the reconstruction and repair of residential low-rise houses following the 2010-2011 Canterbury Earthquake Sequence, there has been limited formal documentation or dissemination of lessons learned from the repair work. As a result, the opportunity to promote good practices and incorporate these lessons into preparations for future seismic events may have been largely missed. These findings also reinforce research showing that communication issues are a persistent challenge across the construction sector. Prior studies have identified that unclear information flows, inconsistent guidance, and limited shared understanding between different professional groups can reduce construction quality and undermine risk-mitigation efforts [20,21].

These worries about substandard work also extended to broader concerns around the growing influence of 'Do It Yourself' culture. Builders noted that popular renovation programs and homeowner guides often present structural upgrades—such as seismic strengthening—as simple and accessible, encouraging untrained individuals to attempt this work themselves. According to participants, this trend not only results in poor-quality and potentially unsafe outcomes but also undermines the credibility of the construction industry.

> "I think the first thing you could do is ban all those programs that show people fixing up houses over the weekend … it doesn't exist. The construction industry isn't like that." (Builder)

7.4. Theme 4: Diverse learning paths and gaps in seismic risk understandings

Theme 3 explored learning paths and how training activities can enhance the building construction sector, including topics related

to seismic risk mitigation. However, some participants questioned the value of including seismic-related content, expressing concerns about its effectiveness when delivered in an online format.

Interviewed builders came from a variety of training backgrounds. While many have completed certifications or apprenticeships, they emphasised that much of their learning had occurred through hands-on, on-site experience and collaboration with more experienced professionals, echoing international findings that builders primarily learn through hands-on experience rather than formal training [14,15]. Builders frequently mentioned belonging to associations such as Master Builders or Certified Builders, yet none referenced the LBP system as a core part of their training. When asked about the LBP system, builders acknowledged its benefits but also highlighted some limitations.

> "It's not extremely thorough, but it does require you to demonstrate that you've been keeping up to date to a point" (Builder)
>
> "I think the intention behind it's really good, and if everybody did it, it would probably be a better construction world. But I don't think it addresses training, shortfalls, learned experience … A computer doesn't teach you how to be a good builder" (Builder)
>
> "The license-building practitioners' scheme is really just formalising continuing education, and it requires a limited amount of reading and a limited amount of proof that you are continuing to engage with new products and processes." (Builder)

This sentiment seemed to indicate that while the interview participants perceived the LBP as a system that provides some degree of oversight, they felt it fell short in providing substantial education, especially regarding seismic risk. When asked about including seismic risk training in the LBP curriculum, most builders thought it would be a positive addition, but they doubted whether it would be sufficient to improve builders' understanding of seismic strengthening significantly.

> "[LBP system] has an educational component to it, like skills maintenance. The bar is still low on that, and the builders aren't really taking it seriously. So, if you were to bring along something deep and meaningful that will require builders to say, you

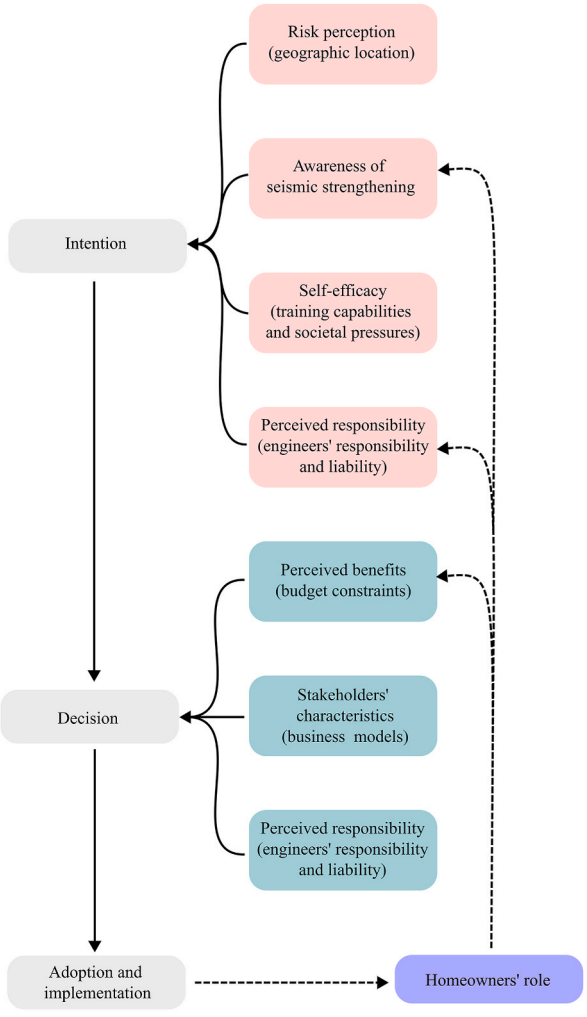

Fig. 1. Conceptual framework illustrating factors influencing builders' engagement with seismic strengthening.

know, look at this for the next 45 minutes and upskill big, I think they're going to struggle through the LBP system to take it seriously." (Builder)

However, opinions diverged when it came to the value of educating builders on seismic risk. Interviewed engineers mentioned that builders would benefit from understanding the rationale behind certain design decisions, which would help them appreciate the importance of seismic elements in construction. For example, as mentioned by an engineer below, the lack of understanding of design principles can result in issues during the construction phase.

"If the builder doesn't understand the philosophy behind it, you go through these real issues … They just assumed they could change one thing to balance another out, and that would be fine. But it is not like that." (Engineer)

The variety of learning paths within the industry presents a challenge in creating a unified understanding of seismic risk among builders. However, one resource repeatedly mentioned by interviewees was BRANZ (Building Research Association of New Zealand), which many saw as a trusted authority in the construction sector. Builders expressed confidence in the quality and integrity of BRANZ resources, such as technical bulletins, product certifications, and educational courses, which they use regularly in their work.

"BRANZ resources, such as their product certifications, technical bulletins, and courses, are very useful to us. I would say that's probably my go-to place for information because I think that information has integrity." (Builder)

The data reveal that even within Aotearoa New Zealand's highly regulated system, builders report similar challenges to those documented in informal construction contexts, such as limited access to meaningful seismic training. By showing that these issues persist across very different construction environments, our findings extend the literature by highlighting a broader, cross-contextual gap in how seismic design principles are communicated to builders.

7.5. Conceptual framework

Together, these four themes illustrate how builders' understandings, practices, and constraints collectively shape the uptake of seismic strengthening in low-rise residential construction. Fig. 1 presents a conceptual framework of the factors identified across all themes. This framework adapts the approach of Egbelakin et al. [51], who developed a motivational model identifying the phases and factors influencing seismic strengthening decisions. While various factors influence building decision-making, homeowners can also influence these factors and might change builders' perceptions of, for example, benefits or responsibilities.

The framework shows that the process of adopting and implementing seismic strengthening comprises three phases: intention, decision, and implementation. While the framework was developed to explain the decision-making process involved in undertaking seismic strengthening, it can also be applied to understand the decision-making process involved in communicating strengthening options. In this context, the "intention" phase can be understood as the intention to raise seismic strengthening with homeowners—an issue explored in Theme 2, where builders described the challenges of initiating these conversations due to homeowner resistance, perceived costs, and liability concerns.

The intention or willingness to seismic strengthen houses is influenced by builders' limited awareness of the seismic implications of their everyday tasks (Theme 1), risk perceptions, and diverse learning pathways and gaps in understanding of seismic design principles (Theme 4), which limit builders' ability to confidently navigate strengthening opportunities.

The decision phase refers to the extent to which a builder is willing to adopt and implement seismic strengthening, which can be influenced by cost-driven decisions (Theme 2) and has been shown to ultimately reduce the likelihood of undertaking seismic strengthening. These challenges are intensified by regulatory pressures within the industry, which constrain builders' capacity to engage with seismic considerations even when they recognise their importance (Theme 3).

The framework and themes show that improving seismic resilience requires addressing not only the broader economic, educational, and cultural conditions that shape builders' roles, but also communication gaps, thereby directly responding to the research questions presented herein about how builders perceive, understand, and contribute to seismic strengthening in residential settings.

8. Future directions

Several limitations of this study and next steps for seismic strengthening of low-rise residential houses are discussed below. First, this study involved a relatively small sample due to the specialised nature of seismic retrofitting in the residential sector. This is compounded by the fact that most research on seismic communication in Aotearoa New Zealand, focuses on Earthquake-Prone buildings [8], rather than low-rise residential houses. Future research should explore seismic risk communication within the wider construction sector and broaden the range of participants to develop targeted and more inclusive strategies. During the development of this study, modules on seismic risk management were included under the LBP system. While this is a step forward, delivering it through hands-on formats rather than online-only modules would enhance learning, as builders in this study reported that current skill-maintenance requirements do little to support seismic learning.

Second, while builders recognised the value of seismic strengthening, they identified a range of challenges that limit uptake. These challenges were not limited to communication but were often tied to cost concerns, additional workload, and regulatory requirements. Communication still plays an important role, but it must be considered within this wider context, as done for other contexts such as EPBs [8,24,33,52,53]. Clear and accessible information about the cost–benefit of different strengthening techniques would better equip builders to engage in these difficult conversations. At the same time, a multipronged approach could help share the responsibility

for communication. For example, training builders earlier in their careers could increase awareness of both the benefits and practicalities of retrofitting, while public campaigns or homeowner education initiatives could encourage demand from clients, reducing the burden on builders to raise the issue unprompted. Such strategies could make conversations about strengthening less one-sided, less awkward, and ultimately more effective.

Third, the interviews were not intended to gather insights into the Canterbury earthquake recovery or the do-it-yourself culture; however, topics were brought up by participants. This reflects the need for future research on lessons learnt from reconstruction in low-rise residential settings and a greater emphasis on effective implementation during recovery, both in impacted areas and for areas not impacted.

Fourth, the liability of suggesting seismic strengthening was a recurring topic, not just herein but also elsewhere in Aotearoa New Zealand [8]. While this paper explores some examples of builders' responsibilities, there is a need for further research to be conducted on the legal status (i.e., guarantees or insurance) of the builder's role in seismic strengthening.

Although many interviewees highlighted the challenges faced by an overwhelmed industry, builders remain eager to engage with seismic strengthening efforts. This raises two key questions: what information is essential to educate, and how it should be communicated. Further research should identify the critical content and underlying principles that need to be conveyed, while also exploring innovative learning methods—particularly addressing effective communication. Builders expressed concerns about the current training formats, such as online courses, questioning their effectiveness. Therefore, it is important to investigate ways to improve training delivery (such as hands-on training or resources provided by trusted providers) to ensure builders actively engage with and apply seismic strengthening knowledge.

Industry organisations are well placed to support builders' seismic capability because they are viewed as trusted sources of information. BRANZ, for example, could play a strong role in developing resources that translate seismic design intent into accessible language, using visual explanations and common case examples. NZCB and RMBA could incorporate seismic strengthening modules into their continuing professional development programmes, using an approach that aligns with builders' preference for hands-on learning. Joint initiatives across these organisations could also help position seismic strengthening as part of "good building practice", making conversations about strengthening a routine aspect of residential work rather than an exception.

The engineering community also plays a key role. However, the limited engagement between builders and engineers is concerning, as seismic risk is widely understood within engineering circles but not always communicated effectively to those responsible for on-site implementation. Limited engagement between the two groups contributes to uncertainty, missed opportunities, and frustration about unclear or highly technical design details. To address this, engineers could take a more proactive role in communicating design intent, including builders in the development of guidelines or any other initiatives. Such practices would support more consistent implementation and foster trust across professions.

9. Conclusion

Through a series of interviews with builders and engineers, this research highlights significant gaps in awareness, training, and responsibility with regard to seismic strengthening in residential construction. Despite builders acknowledging the importance of seismic resilience, structural, educational, and cultural barriers often limit their engagement, with responsibility frequently deferred to engineers and resistance encountered from homeowners. The increasing regulatory and workload demands, combined with a societal undervaluation of builders and insufficient seismic-specific training, contribute to seismic strengthening being deprioritised within the industry. While initiatives to involve builders have been undertaken, these efforts may not fully address their practical needs or capabilities. Given the pivotal role builders play in enhancing the seismic performance of homes, it is essential to foster stronger collaboration between engineers and builders and shift homeowner perceptions about the value of investing in seismic resilience. Addressing these challenges is vital to advancing a more effective adoption of seismic strengthening practices to ultimately improve the seismic resilience of residential buildings.

CRediT authorship contribution statement

Catalina Miranda: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Aaron Opdyke:** Writing – review & editing, Validation, Supervision. **Fei Ying:** Writing – review & editing, Validation, Supervision. **Julia S. Becker:** Writing – review & editing, Supervision, Funding acquisition. **Charlotte Toma:** Writing – review & editing, Writing – original draft, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

References

[1] G. Beattie, The response of houses to the Canterbury earthquake series 2010-2011, in: Paper Presented at the World Conference Earthquake Engineering, 2012. Lisboa.
[2] G. Thomas, B. Kim, G. Beattie, R. Shelton, Lessons from the Performance of Houses in the Canterbury Earthquake Sequence of 2010-11, 2013.
[3] M. Davis, K. Porter, The public's role in seismic design provisions, SAGE Publications Ltd STM 32 (3) (2016) 1345–1361, https://doi.org/10.1193/081715EQS127M.
[4] C. Miranda, J.S. Becker, C.L. Toma, L.J. Vinnell, Homeowners' perceptions of seismic building performance and implications for preparedness in New Zealand, Nat. Hazards Rev. 24 (1) (2022), https://doi.org/10.1061/(ASCE)NH.1527-6996.0000600.
[5] A. Tanner, S. Chang, K.J. Elwood, Incorporating societal expectations into seismic performance objectives in building codes, Earthq. Spectra 36 (4) (2020) 2165–2176, https://doi.org/10.1177/8755293020919417.
[6] D. Paton, Disaster risk reduction: psychological perspectives on preparedness, Australasian Journal of Psychology 71 (4) (2019) 327–341, https://doi.org/10.1111/ajpy.12237.
[7] E.H. Doyle, J.S. Becker, *Understanding the Risk Communication Puzzle for Natural Hazards and Disasters*: Oxford Research Encyclopedia of Natural Hazard Science, 2022.
[8] C. Miranda, C. Eade, C. Brown, J. Becker, E. Doyle, Communicating seismic building risk with commercial building tenants, Bull. N. Z. Soc. Earthq. Eng. 58 (3) (2025), https://doi.org/10.5459/bnzsee.1713.
[9] Natural Hazards Commission – Toka Tū Ake, Be Prepared, 2020. Retrieved from eqc.govt.nz/be-prepared/.
[10] Wellington City Council. (n.d.). Earthquake Resilience Checklist. Retrieved from wellington.govt.nz/property-rates-and-building/building-earthquake-resilience/strengthening-your-home/earthquake-resilience-checklist.
[11] J. Lewis, Housing construction in earthquake-prone places: perspectives, priorities and projections for development, Aust. J. Emerg. Manag. 18 (2) (2003).
[12] B. Hidayat, Z. Afif, Knowledge transfer to builders in post-disaster housing reconstruction in West-Sumatra of Indonesia. Paper Presented at the Proceedings of the 3rd International Conference on Construction and Building Engineering, 1Civil Engineering Department, Faculty of Engineering, Universitas Andalas, Padang, Indonesia, 2017.
[13] D.C. Greene, Increasing resilience to earthquakes through educating community builders: teaching earthquake-resistant building techniques in Guatemala, in: G. R. Wessel, J.K. Greenberg (Eds.), Geoscience for the Public Good and Global Development: towards a Sustainable Future, 520, Geological Society of America Special Paper, 2016, pp. 295–309, https://doi.org/10.1130/2016.2520(26.
[14] A. Opdyke, A. Javernick-Will, M. Koschmann, Household construction knowledge acquisition in post-disaster shelter training, Int. J. Disaster Risk Reduct. 28 (2018) 131–139, https://doi.org/10.1016/j.ijdrr.2018.02.038.
[15] B. Goldwyn, Y. Gonzalez Vega, A. Javernick-Will, A.B. Liel, Identifying misalignments between the informal construction sector's perceptions and engineering assessments of housing safety in future disasters for capacity development, Int. J. Disaster Risk Reduct. 77 (2022).
[16] S. Winarno, A. Griffith, P. Stephenson, Reducing earthquake risk to non-engineered buildings: a study of design and construction practices in Indonesia, Int. J. Constr. Manag. 10 (1) (2010) 75–86, https://doi.org/10.1080/15623599.2010.10773139.
[17] K. Okazaki, T. Saito, Seismic risk perception concerning non-engineered houses, Paper presented at the WCEE 15th, Lisboa (2012).
[18] NZS 3604, Standards New Zealand, Timber-framed buildings, Wellington, New Zealand, 2011.
[19] C. Miranda, J.S. Becker, L.J. Vinnell, C.L. Toma, D.M. Johnston, Seismic experience and structural preparedness of residential houses in Aotearoa New Zealand, Int. J. Disaster Risk Reduct. 66 (2021), https://doi.org/10.1016/j.ijdrr.2021.102590.
[20] A. Mills, P. Love, P. Williams, Defect costs in residential construction, J. Construct. Eng. Manag. 135 (1) (2009) 12–15.
[21] A. Olanrewaju, S. Tan, L. Kwan, Roles of communication on performance of the construction sector. Paper Presented at the Creative Construction Conference, Primosten, Croatia, 2017.
[22] R.J. Ball, E.H. Doyle, M. Nuth, W.J. Hopkins, D. Brunsdon, C. Brown, Behavioural science applied to risk-based decision processes: a case study for earthquake prone buildings in New Zealand, Civ. Eng. Environ. Syst. 39 (2) (2022) 144–164, https://doi.org/10.1080/10286608.2022.2089980.
[23] T. Hoang, I. Noy, O. Filippova, K.J. Elwood, Prioritising earthquake retrofitting in Wellington, New Zealand, Disasters 45 (4) (2020) 968–995, https://doi.org/10.1111/disa.12450.
[24] J. Becker, D. Paton, D. Johnston, Communication of Risk: a Community Resilience Perspective, 2015.
[25] J. Georgiou, P. Love, J. Smith, A comparison of defects in houses constructed by owners and registered builders in the Australian State of Victoria, Struct. Surv. 17 (3) (1999) 160–169.
[26] T.M. Toole, Uncertainty and home builders' adoption of technological innovations, J. Construct. Eng. Manag. 124 (4) (1998) 323–332.
[27] S. Slaughter, Builders as sources of construction innovation, J. Construct. Eng. Manag. 119 (3) (1993) 532–549.
[28] J.F. Audefroy, Haiti post-earthquake lessons learned, Environ. Urbanization 23 (2) (2011) 447–462, https://doi.org/10.1177/0956247811418736.
[29] R.J. Chaskin, Building community capacity: a definitional framework and case studies from a comprehensive community initiative, Urban Aff. Rev. 36 (3) (2001) 291–323, https://doi.org/10.1177/10780870122184876.
[30] B. Goldwyn, C. Velasquez, A.B. Liel, A. Javernick-Will, M. Koschmann, Capacity-building to support safer housing through appropriate hurricane strap use, Nat. Hazards Rev. 24 (2023), https://doi.org/10.1061/NHREFO.NHENG-1708.
[31] J. Rose, K. Chmutina, Developing disaster risk reduction skills among informal construction workers in Nepal, Disasters 45 (3) (2020), https://doi.org/10.1111/disa.12435.
[32] Building Act, Ministry of Business, Innovation, and Employment, 2004. New Zealand.
[33] MBIE, Risk guidance for buildings, Ministry of Business, Innovation and Employment (MBIE) Retrieved from building (2022) govt.nz/assets/Uploads/getting-started/seismic-risk-guidance-for-buildings.pdf.
[34] C. McRae, G. Mcclure, L. Henrich, C. Leah, A. Charleson, Reactions to earthquake hazard strengthening commercial buildings and voluntary earthquake safety checks on houses in Wellington, New Zealand, Int. J. Disaster Risk Reduct. 28 (2018) 465–474, https://doi.org/10.1016/j.ijdrr.2017.12.007.
[35] M. Koliou, J.W. van de Lindt, T.P. McAllister, B.R. Ellingwood, M. Dillard, H. Cutler, State of the research in community resilience: progress and challenges, Sustain Resilient Infrastructure 5 (3) (2018), https://doi.org/10.1080/23789689.2017.1418547.
[36] C. Miranda, C. Toma, M.T. Stephens, J. Becker, Predictions of damage to timber-framed houses. II: aligning social and engineering predictions of earthquake damage before and after strengthening, Nat. Hazards Rev. 24 (4) (2023), https://doi.org/10.1061/NHREFO.NHENG-1812.
[37] B.A. Payne, S. Abeling, J.S. Becker, K.J. Elwood, H. Ferner, D. Brunsdon, D.M. Johnston, Earthquake stories: experiences of building performance in earthquakes to inform future standards. Paper Presented at the New Zealand Society of Earthquake Engineering Technical Conference, 2021.
[38] E.J. Sutley, J.W. van de Lindt, L. Peek, Multihazard analysis: integrated engineering and social science approach, J. Struct. Eng. 149 (9) (2017), https://doi.org/10.1061/(ASCE)ST.1943-541X.0001846.
[39] V. Braun, V. Clarke, Reflecting on reflexive thematic analysis, Qualitative Research in Sport, Exercise and Health 11 (4) (2019) 589–597, https://doi.org/10.1080/2159676X.2019.1628806.

[40] D. Byrne, A worked example of Braun and Clarke's approach to reflexive thematic analysis, Qual. Quantity 56 (1) (2022) 1391–1412, https://doi.org/10.1007/s11135-021-01182-y.
[41] N.K. Denzin, Y.S. Lincoln, The SAGE Handbook of Qualitative Research, SAGE Publications, 2017.
[42] B.A. Israel, A.J. Schulz, E.A. Parker, A.B. Becker, Review of community-based research: assessing partnership approaches to improve public health, Annu. Rev. Publ. Health 19 (1) (1998) 173–202, https://doi.org/10.1146/annurev.publhealth.19.1.173.
[43] J.S. Becker, E. Garden, M. Van der Velde, M.A. Coomer, A. Rampton, D.M. Johnston, D. Blake, G. Newman-Hall, Impact of the 2016 Kaikōura Earthquake on Wellington CBD Apartment residents: results of a Survey. GNS Science Report: BRANZ. (2019). Trends in materials used in new houses 2010–2019, BRANZ Research Now: Physical characteristics of new buildings #1 (2018).
[44] N.A. Horspool, A.B. King, S.L. Lin, S.R. Uma, Damage and losses to residential buildings during the Canterbury earthquake sequence. Paper Presented at the New Zealand Society in Earthquake Engineering, 2016.
[45] M. Loosemore, N. Andonakis, Barriers to implementing OHS reforms – the experiences of small subcontractors in the Australian construction industry, Int. J. Proj. Manag. 25 (6) (2007) 579–588, https://doi.org/10.1016/j.ijproman.2007.01.015.
[46] P. Gee, Engaging Residents in Multifamily Building Retrofits, American Council for an Energy-Efficient Economy (ACEEE), 2013.
[47] J. McClure, M. Spittal, R. Fischer, A. Charleson, Why do people take fewer damage mitigation actions than survival actions? Other factors outweigh cost, Nat. Hazards 16 (2015), https://doi.org/10.1061/(ASCE)NH.1527-6996.0000152.
[48] M. Jacobs, Homeowners Still Battling for Compensation 14 Years After Earthquakes, The Press, 2025. Retrieved from thepress.co.nz/nz-news/360578379/homeowners-still-battling-compensation-14-years-after-earthquakes.
[49] G. Prayag, L.K. Ozanne, S. Spector, A psychological wellbeing perspective of long-term disaster recovery following the Canterbury earthquakes, Int. J. Disaster Risk Reduct. 63 (2021), https://doi.org/10.1016/j.ijdrr.2021.102438.
[50] E. Tanaka, H. Tennichi, S. Kameoka, H. Kato, Long-term psychological recovery process and its associated factors among survivors of the Great Hanshin-Awaji Earthquake in Japan: a qualitative study, BMJ Open 9 (2019), https://doi.org/10.1136/bmjopen-2019-030250.
[51] T. Egbelakin, S. Wilkinson, R. Potangaroa, J. Ingham, Enhancing seismic risk mitigation decisions: a motivational approach, Construct. Manag. Econ. 29 (10) (2011) 1003–1016.
[52] MBIE, Seismic risk resource for commercial building tenants, Ministry of Business, Innovation and Employment (MBIE) Retrieved from building (2024) govt.nz/assets/Uploads/getting-started/seismic-risk-resource-for-commercial-building-tenants.pdf.
[53] K.E. Rowan, The technical and democratic approaches to risk situations: their appeal, limitations, and rhetorical alternative, Argumentation 8 (1) (1994) 391–409, https://doi.org/10.1007/BF00733482.