REPORT

Analysis of seismic risk mitigation programmes in overseas jurisdictions and a brief guide to regulatory approaches to life safety

27 February 2025

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TABLE OF CONTENTS

Executive Summary

This report provides an overview of seismic risk mitigation programmes for existing buildings across a number of key comparator jurisdictions (the United States, Taiwan, Japan, Italy, Türkiye, and Mexico) to identify best practices and challenges in managing seismic risks in existing buildings. The report analyses the regulatory frameworks, technical standards, and wider strategies for ensuring life safety in seismically vulnerable buildings. The report also provides a degree of context for these approaches by providing the theoretical frame and examples of regulatory approaches for managing personal life safety outside the seismic context.

The first point to note is that the New Zealand regulatory model operates in a unique regulatory environment. In all the examples studied (and most if not all others) the regulatory model operated by the state operates in tandem with a personal injury liability for seismic events which operates through the ordinary courts.[1] Thus, building owners and others, if they act is a way that is deemed to be negligent in the jurisdiction concerned, can be found liable for deaths or injuries caused by failures of existing buildings when the seismic risk is foreseeable. In some cases, criminal law can also play a role (for example in Italy criminal cases against public authorities for failure to mitigate known hazards are extremely common, although conviction rates are low).[2] In New Zealand no such civil liability exists, and public liability is much narrower. This means that the regulatory regime and the wider actions of the state stand alone in ensuring that the risk posed by existing buildings in earthquakes is at an acceptable level.

The review found that New Zealand is unusual in relying primarily on mandatory retrofitting or demolition to address the risks posed by existing buildings in earthquakes. Among the jurisdictions examined, valuable lessons can be drawn from California's 1986 URM Law, which set a strong precedent for using hazardous building inventories to encourage retrofits. This law required all local governments in the highest seismic hazard zone to identify unreinforced masonry (URM) buildings, establish seismic risk mitigation programmes, and report on their progress. As a result, over 70% of identified buildings were either retrofitted or demolished. Notably, mandatory retrofit programmes were the most effective, achieving an overall compliance rate of 87%, compared to just 13%–25% in jurisdictions with voluntary or notification-only approaches (see Appendix 2). Nevertheless, the law stands out from the New Zealand settings. First, it preserved the "local choice" by allowing the local governments to vary the approach based on the specifics of the building stock, economic environment, political and public support and availability of local government resources and capacity. Second, the law and subsequent local ordinances targeted a particular seismically vulnerable structural system - URM.

It is also an outlier through the lack of publicly funded incentives to encourage retrofitting/demolition of existing buildings deemed to be an unacceptable risk. Finally, the level at which buildings are deemed to be seismically vulnerable seems unusually low in comparison with other equivalent jurisdictions as is the level of retrofitting required (33% of NBS in New Zealand). Although comparisons are difficult, in Taiwan and California the requirement for retrofitted buildings appears to be at 80% and 75% of the current code

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[1] Court of Appeals of CA, Second District, Division Six. Myrick v. Mastagni, 2d Civil No.B209854, June 21, 2010

[2] https://www.cimafoundation.org/en/news/wikiprocessi-the-observatory-on-legal-responsibility-in-civil-protection-operations/

respectively. In the Taiwanese and Japanese example this appears to lead to a significant number of demolitions when buildings are deemed to pose an unacceptable risk.

In the jurisdictions studied only certain local jurisdictions in California utilise mandatory regulatory requirements, although the possibility exists for local governments in Japan to do so and has been used to manage “strategic” routes in the latter example. In other countries, mandatory requirements have generally applied only to public buildings and critical facilities such as schools and hospitals. However, publicly funded incentive schemes to drive improvements in privately owned buildings are common in the jurisdictions examined. Although privately owned building retrofits remain largely voluntary, such incentive schemes and mandatory requirements around assessments have played a significant role in improving economic and societal resilience to seismic events.

Report Summary and Recommendations

California has a long history of developing, enacting, and implementing mitigation policies. However, this example highlights that developing seismic risk mitigation policies is not only a lengthy process but can also become highly politicised. While the scientific community and building officials recognised the risks, property owners have actively lobbied against mandatory ordinances. City of Los Angeles serves as a key example, given the complexities associated with its size, government structure, and political culture. It took eight years to adopt the city's first mandatory ordinance requiring the retrofit of Unreinforced Masonry (URM) buildings. This process involved multiple technical and cost studies, numerous drafts of the proposed ordinance, and extensive public hearings before the council finally approved the measure in 1981. Despite several devastating earthquakes in the 1980s and 1990s, it was not until 2015 that the council moved to mandate retrofits for other vulnerable structures, including wood-framed soft-storey buildings and non-ductile concrete buildings.

Since the enactment of the URM ordinance, thousands of vulnerable buildings in Los Angeles have been seismically retrofitted, contributing to over 50 years of effective policy development and implementation. Early ordinances in California demonstrated that mandatory retrofitting policies are technically, economically, and politically feasible achieving 87% compliance rate among identified hazardous buildings within cities with such programmes. However, their success depends on careful planning, stakeholder engagement, public outreach, and, most importantly, financial support. A range of financial and policy incentive tools have been designed to directly or indirectly alleviate the financial burden of seismic retrofits. These examples are summarised in Appendix 3. While diligent enforcement throughout the compliance timeframes and consistent application of penalties on non-complying property owners are critical in the implementation of mandatory programmes, the role of financial incentives is particularly highlighted in the voluntary programmes. California’s jurisdictions with voluntary programmes and financial incentives achieved an average 20% rate for retrofits compared to 14% rate for such programmes without incentives. Moreover, across international case studies retrofitted buildings have shown significantly lower damage in recent earthquakes, validating the effectiveness of the retrofitting strategies employed.

Voluntary retrofitting of private buildings in Japan and Taiwan is largely driven by substantial government subsidies that cover evaluation and retrofitting costs. Property owners also benefit from access to low-interest loans, tax exemptions, and relaxed zoning provisions, such as increased floor area ratios for retrofitted buildings. Given the prevalence of multi-owner properties, particularly in residential settings, government policies focus on streamlining approval processes and reducing the consent threshold among owners to 50%.

The review did not identify any rating system equivalent to %NBS in the jurisdictions analysed for this report. In California, ordinances identify hazardous buildings based on specific criteria, such as structural system type and construction period. These buildings are then added to a local inventory, and property owners are notified. If an evaluation reveals structural deficiencies, the building can only be removed from the inventory of potentially hazardous buildings once the owner completes the required retrofitting in accordance with specified engineering criteria. Additionally, a registered design professional must provide a signed letter confirming that the work complies with the approved plans. Taiwan’s proposed draft legislation on the “Seismic Evaluation and Retrofit of Existing Buildings” introduces a "Certification Mark" system to differentiate buildings based on their seismic status. These marks indicate whether a building has been evaluated, undergone targeted retrofitting for a major deficiency (e.g., soft-story retrofit), or completed a full seismic retrofit.

Seismic Risk Mitigation in the United States

Seismic risk mitigation in the United States is largely implemented at state and local levels, with California leading the way as a global pioneer in seismic safety. California’s experience demonstrates how targeted regulatory measures, and technical innovation can effectively reduce seismic risks. However, while California has implemented mandatory laws for URM buildings in Seismic Zone 4 jurisdictions (Appendix 2), state mandates for mitigation of risks in other vulnerable building types such as wood frame soft-story or non-ductile concrete buildings are lacking, instead California’s Health and Safety Code was amended in 2005 to encourage establishment of local ordinances for seismic retrofit of any building type identified as being potentially hazardous. Therefore, the progress in these areas relies heavily on local initiatives in select jurisdictions.

Unreinforced Masonry (URM) Buildings:

California’s URM ordinances were driven by the devastating 1933 Long Beach earthquake, which led to the passage of the Riley Act, banning new URM construction statewide. In the 1970s and early 1980s, Long Beach and Los Angeles emerged as leaders in seismic risk mitigation, adopting mandatory ordinances to address the vulnerabilities of URM buildings. Following their lead, California introduced the URM law in 1986, requiring 365 jurisdictions in Seismic Zone 4 (the highest-risk zone) to inventory URM buildings by 1990, establish a loss reduction program (whether mandatory, voluntary, or notification-only), and report progress—such as inventory counts and compliance rates—to the California Seismic Safety Commission (CSSC).

Since the URM law, 260 jurisdictions have implemented mitigation programs whereas 82 jurisdictions had no URM buildings. By 2006, the California Seismic Safety Committee (CSSC) reported that approximately 70% of more than 25,500 identified URM buildings had been either retrofitted or demolished, of these mandatory programmes were found to be the most effective achieving 87% mitigation rate (retrofit – 70%, demolition – 17%).

Mandatory programmes were commonly designed with explicit differentiation of timeframes and in some cases retrofit standards (for example, for smaller, regular-shaped buildings some cities allowed retrofit to alternative, simplified standards like Bolts Plus). Buildings were prioritised for compliance based on risk tiers grouped by number of stories, number of occupants, number of units or soil classification. For example, the City of Los Angeles ordinance categorised URM buildings into four risk groups – essential buildings, high risk, medium and low risk. Except for essential buildings, URMs were prioritised based on the number of occupants therefore compliance was mandated sooner for structures that were perceived to have higher risk. Retrofit deadlines ranged between four to ten years, depending on tier. In jurisdictions that did not mandate retrofits, local governments encouraged seismic upgrades through strict disclosure requirements (e.g., notifying tenants and lenders), limited financial assistance, and development incentives.

In addition to implementing priority levels, some cities allowed phased/incremental retrofits. For example, the City of Los Angeles ordinance allowed for a dual time approach, with time extensions that encouraged installation of anchors in the first year after notification. Whereas, Oakland established two-tiered hazard mitigation standards – mandatory (Bolt Plus standard) and voluntary (UCBC Appendix Chapter 1).

Outside California, attempts to introduce mandatory URM ordinances have been largely unsuccessful. Both Seattle (Washington) and Portland (Oregon) initiated URM inventory efforts before the 2000s and explored mandatory retrofit legislation. However, these efforts remain stalled, primarily due to financial constraints on local councils and opposition from property owners. Instead, both cities have passive triggers in their municipal codes, requiring seismic evaluations and potential upgrades in cases of change of use or increased occupancy load.

Wood-Frame Soft-Story Buildings:

Soft-story structures, often featuring weak ground floors, gained attention following severe damage in the 1989 Loma Prieta and 1994 Northridge earthquakes. Los Angeles and San Francisco have introduced mandatory retrofitting ordinances targeting soft-story buildings, with compliance timelines phased based on building priority. Most existing programmes have been implemented in the last 10 years. The programmes require targeted retrofits on the ground floor which ensures that compliance can be achieved within shorter timeframes (on average 5 years to complete construction) and at a lower cost than for a full seismic retrofit.

These local initiatives highlight the gap in statewide requirements for soft-story buildings and the reliance on city-driven efforts to mitigate risks. Currently, only 14 jurisdictions enacted mandatory ordinances (a significant reduction from 256 jurisdictions with active mitigation programmes under the URM law). Prior to adoption of mandates, cities allocate time and resources to inventory vulnerable buildings. Large cities such as Los Angeles and San Francisco became pioneers in implementing mandatory retrofitting ordinances for soft-story buildings, setting the standard for smaller jurisdictions to follow. Smaller jurisdictions within California, often with fewer resources and political influence, have been able to adopt similar programs, tailoring them to their own local needs while benefiting from the framework set by the larger cities. This “top-down” model, where large jurisdictions lead and smaller ones follow, has proven to be an effective mechanism for scaling seismic risk mitigation across regions, creating a unified approach while allowing for local adjustments.

Similarly to URM, mandatory soft story ordinances are proving to be effective with Los Angeles and San Francisco currently achieving 76% and 94% mitigation rates respectively. Despite progress, the cost of retrofitting remains a major barrier in municipalities that are yet to adopt a mitigation programme, the process that requires political and community consensus and significant investment in detailed studies establishing long-term resilience strategies (for example, Los Angeles’ Resilience by Design and San Francisco’s Community Action Program for Seismic Safety.

Non-Ductile Concrete Buildings:

Non-ductile concrete structures, constructed before the adoption of modern seismic codes (generally pre-1980), are known to pose significant risk. Los Angeles is one of the few cities addressing these buildings, mandating retrofits for thousands of high-risk structures. The absence of a statewide mandate underscores the reliance on individual municipalities to initiate and enforce such programmes. In existing programmes, recognising the significant cost burden, ordinances allow 20-25 years to complete construction. A recent review of the non-ductile ordinance in Los Angeles highlighted that for an average 7-story building in the programme, total retrofit work can range from US$ 2-7 million. Retrofitted buildings also do not generate significant premiums in rents, making it difficult for property owners to secure bank lending. The Los Angeles programme was implemented in 2015, therefore only 6% of buildings have been fully retrofitted to date. Due to the absence of an explicit penalty for non-compliance, some building owners may be taking a “wait and see” approach to understand the consequences of missing the time limit.

A comparatively small number of jurisdictions implemented programmes to address older concrete buildings, limited to Southern California, with timeframes that span decades, recognising the financial burden as well as allowing for technical innovations in retrofit solutions. Therefore, outcomes of implementation of these programmes are still limited.

Lessons from California:

California’s seismic risk mitigation approach underscores the effectiveness of:

Mandatory Regulations: Enforced retrofitting with clear timelines ensures compliance for URMs and soft-story buildings in select jurisdictions.

Financial Incentives: Tax credits for the historic buildings, property tax assessment limitations, municipal bonds, low interest loans and pass-through cost-sharing mechanisms alleviate financial burdens (see Appendix 3).

Research and development of cost-effective retrofit methodology: The state and municipalities have made significant investments in developing research on retrofit methodology and ascertained retrofit costs of various retrofit alternatives. The 1984 ABK study is a foundational work in the field of seismic retrofit methodologies for URM buildings. Multiple cities commissioned cost studies in preparation for ordinances.

Technical Standards: Simplified retrofitting methods for specific building types, modelled after the “Bolts Plus” example or other alternate methods, balance safety and cost-effectiveness.

Local Initiatives: City/county-driven efforts compensate for the lack of statewide mandates for soft-story and non-ductile concrete buildings.

Stakeholder Engagement: Early involvement of property owners and tenants fosters cooperation and compliance.

Older concrete buildings: Non-ductile concrete structures are widely recognized as a significant seismic risk. While a few jurisdictions in Southern California have introduced mandatory retrofit ordinances, these programs are still in their early stages. Initial findings indicate that retrofit costs are substantial, typically ranging from US$2–7 million per building, posing a major barrier to full compliance. This presents an opportunity for New Zealand regulators to engage with these jurisdictions to gain insights into challenges, policy responses, and potential solutions that could inform seismic risk mitigation efforts.

Despite these achievements, financial barriers and public resistance remain persistent challenges, emphasising the need for more robust state-level leadership to complement local initiatives. California’s experience demonstrates the importance of integrating diverse strategies tailored to local conditions.

Seismic Risk Mitigation in International Jurisdictions

Taiwan:

Taiwan’s approach combines mandatory seismic evaluations and retrofit of public buildings with extensive financial and educational support for voluntary retrofit of private buildings. Subsidies and low-interest loans incentivise retrofits, while public awareness campaigns emphasize the importance of seismic resilience. Taiwan’s strategy effectively balances regulatory enforcement with community engagement, ensuring widespread compliance. In addition to technical measures, Taiwan invests significantly in public education and research to foster long-term resilience. For example, national campaigns have helped to demystify retrofitting processes and highlight the importance of structural safety in reducing casualties. Whereas in preparation for the public school retrofit programme, the National Centre for Research developed a methodology for the seismic evaluation and retrofit of schools between 2000-2009.

Japan:

Seismic retrofitting is primarily voluntary in Japan, but certain high-risk or critical-use buildings and structures along major evacuation routes may face mandatory requirements to ensure public safety. The government promotes retrofitting through financial assistance and awareness campaigns to encourage compliance.

Japan's Seismic Retrofit Promotion Law, officially known as the "Law for Promotion of Seismic Retrofitting of Buildings," was enacted in December 1995 following the devastating Great Hanshin-Awaji (Kobe) earthquake earlier that year and was further revised in 2006 and 2013 to incorporate lessons from later earthquakes. The law aims to enhance the earthquake resistance of existing buildings, particularly those constructed before the 1981 revision of seismic standards.

Key Provisions of the Law:

Encouragement of Seismic Assessments: Owners of large buildings, especially those used by the public, are encouraged to conduct seismic evaluations to determine the earthquake resistance of their structures. This initiative targets buildings over a certain scale, such as schools, hospitals, and commercial facilities.

Promotion of Retrofitting Measures: If a building is found to be seismically deficient, the law promotes undertaking necessary retrofitting measures to meet current safety standards. This includes structural enhancements such as adding reinforced concrete shear walls, steel bracing, or implementing seismic isolation techniques.

Support and Subsidies: To facilitate compliance the government provides financial assistance to building owners for conducting seismic assessments and retrofitting, including subsidies and tax incentives. These economic measures are available to local governments that have established a "Plan for Retrofit Promotion."

Obligations for Public Buildings: Seismic retrofitting is required for public facilities such as schools, hospitals, and government buildings, because these structures play critical roles in disaster response and recovery. By 2022, nearly 100% of public schools have been made earthquake resistant.

Japan’s integration of technological innovation with mandatory regulations sets a benchmark for effective seismic risk management. State ownership of buildings (including residential housing) remains high, which provides the ability for the state to drive seismic improvement.

In addition, the culture in Japan would appear to make soft regulatory instruments (such as publicity around seismic vulnerability) particularly effective. Finally, the use of financial incentives has been a long-term policy achieved by public consensus. This achievement is partly due to the stability of Japan's political system and partly due to the widespread acceptance of seismic resilience as a community good.

Italy:

Italy's "Sismabonus" tax incentive program offers up to 85% deductions for seismic retrofits. While this model demonstrates the potential of financial incentives, uptake has been limited by bureaucratic challenges and insufficient public awareness. Unlike California, Italy relies primarily on voluntary compliance, which has hindered progress in mitigating seismic risks. Efforts to expand the programme's reach are ongoing, focusing on simplifying application processes and increasing awareness. Regional governments are also exploring additional funding mechanisms to complement national efforts.

Türkiye:

The country's seismic resilience strategy combines transformative building code reforms and large scale urban transformation projects. The country's building codes are regularly updated to incorporate advancements in engineering and risk mitigation. Notably, the 2007 and the 2018 revisions introduced rigorous design criteria for new buildings and retrofitting of older structures. Following the 1999 Marmara earthquake, Türkiye introduced comprehensive seismic risk mitigation measures. One example is the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP). Since 2006, the project initially secured US$ 563 million from the World Bank to mitigate seismic risk in public buildings. By 2018 the total amount of committed financing is in excess of EUR€ 2 billion secured from international financial institutions. Currently, 1,624 buildings have been retrofitted or reconstructed including 88% of Istanbul's schools built before 1998. Improvement of seismic resilience of residential buildings is achieved through the Law on the Regeneration of Areas Under the Risk of Disaster enacted in 2012. The law introduced the framework for earthquake-focused urban transformation through the rehabilitation, demolition and renewal of areas at risk, as well as plots of land where risky buildings exist. Although due to poor monitoring and quality of construction of pre-1999 buildings, it appears that demolishing and reconstructing buildings is favoured over retrofitting, particularly when existing structures are deemed too vulnerable or when redevelopment offers economic benefits, especially in areas with high population growth and house price appreciation.

Mexico:

Mexico focuses on post-earthquake evaluations and selective retrofitting. While these measures address immediate risks, the lack of proactive, mandatory programmes limits long-term resilience. Mexico's approach underscores the need for a shift toward preventive strategies, including mandatory retrofitting and enhanced building codes. Recent initiatives have begun to incorporate more advanced engineering techniques, reflecting lessons learned from previous seismic events. Challenges remain in enforcement, retrofitting, and financial affordability of seismic resilience, especially for vulnerable populations.

Most commonly structural retrofits are implemented because of earthquake damage. Cases of proactive retrofit are rare. For example, strengthening may be required for change of use or other significant modifications to the building. In post-disaster response, rehabilitation and reconstruction of housing is typically covered with public funds and support from private foundations. The school rehabilitation programme stands out. After the 1985 earthquake, more than 2,000 school buildings in Mexico City and other high seismic hazard regions were rehabilitated. Simplified and unobstructive methods that could be executed over summer holidays to minimise disruption to education activities were developed. Damage assessment of public school buildings caused by the 2017 earthquakes showed that damage intensity in seismically designed post-1985 buildings was significantly lower than that observed in pre-1985 structures.

Technical Standards in Seismic Risk Mitigation

Technical standards play a crucial role in ensuring the effectiveness of seismic retrofitting programmes. The analysis of technical standards across jurisdictions highlights the following:

Simplified Retrofitting Methods:

Variations of California’s “Bolts Plus” approach provides a cost-effective solution for URM retrofitting. This method ensures life safety while minimising the financial burden on property owners. However, some concerns remain in the engineering community of the effectiveness of early implementation of Bolts Plus.

Similar simplified methods are used for soft-story buildings, focusing on bracing and anchoring to address structural vulnerabilities efficiently. Such methods have proven effective in balancing technical feasibility with economic constraints.

Incremental Approaches:

Several jurisdictions allow for incremental hazard mitigation. For example, the City of Los Angeles provided time extensions to URM building owners that installed anchors within the first year of notification. The City of Oakland established two-tiered hazard mitigation standards for URM buildings – mandatory (Bolt Plus standard) and voluntary (UCBC Appendix Chapter 1). The City of West Hollywood non-ductile concrete ordinance follows a two-phase approach for compliance to address major deficiency first and then remaining deficiencies. In Taiwan, within the current “Private Building Seismic Weak Story Retrofit Program”, Plan A is designed to address soft story vulnerabilities and Plan B sets standards to achieve 80% of modern seismic code standards.

Performance-Based Standards:

Japan has adopted performance-based engineering standards that allow for innovative and flexible retrofitting solutions. These standards emphasize outcomes rather than prescriptive methods, enabling the use of advanced materials and technologies.

Mexico has incorporated performance-based standards into its post-earthquake assessments, ensuring that retrofits are designed to meet specific safety objectives. These standards are increasingly being adapted to reflect the unique challenges posed by Mexico’s diverse building stock.

Comparative Analysis of Regulatory Approaches

Command and Control models:

Command and Control models of regulation, in the form of Mandatory retrofitting, as seen in California, achieves higher compliance rates compared to voluntary approaches. Enforcement mechanisms, such as penalties for non-compliance, are critical to ensuring adherence. Voluntary programmes, while less contentious, often fail to achieve the necessary scale of risk reduction. However, in very few examples were command and control models used alone. Instead, most jurisdictions utilised a variety of models to deliver reduced vulnerability from existing buildings.

Use of mandatory command and control models requires effective external monitoring as seen in the non-seismic safety examples discussed in the report. This is something that is particularly important in a seismic context as prior approval regulation seems unfeasible (although note the New Zealand example of using "change of use" within the Building Act as a proxy for this).

Economic Regulation:

Financial incentives, in the form of tax credits, subsidies, and low-interest loans play a vital role in offsetting the high costs of retrofitting and incentivising private owners to reduce vulnerability. Models such as Italy's "Sismabonus" and California's tax exemptions for seismic upgrades illustrate the importance of accessible funding to deliver reduced seismic vulnerability. In Japan the utilisation of these tools has been a fundamental part of the overall regulatory model. Expanding these mechanisms is essential for enabling risk mitigation but evidence suggests that used in isolation, these tools are not sufficient to achieve the goals desired.

Information Regulation and Public Information:

Public awareness campaigns, as implemented in Taiwan and Japan, are essential for fostering support and understanding among stakeholders. Early involvement of property owners, tenants, and local governments enhances programme success. Collaborative decision-making processes have also been shown to improve compliance rates. These elements can be incorporated into wider mandatory information provision, such as applied in Food Standards and product safety. In these instances, the use of such information requirements can drive improved knowledge around seismic risk and provide the possibility of market forces playing a role. This has been seen to some extent in the Wellington property market, although the danger of non-regulated information being utilised is also seen in this example.

Economic and Social Considerations:

Seismic risk mitigation must account for the financial and social contexts of affected communities. Tailored strategies, such as Türkiye's urban renewal projects and Palo Alto's URM ordinance demonstrate how local conditions influence policy design and implementation. Ensuring equity in access to resources is a fundamental consideration.

Other Regulatory Considerations

The report explores a selection of non-seismic life-safety examples which provide a number of alternative options for the regulation of existing buildings which suffer from seismic vulnerabilities. The lack of a rights-based regime for personal injury means that such comparisons must be made carefully. The brief discussion does provide some alternative models although most are used in some of the seismic examples elsewhere.

In the context of New Zealand, therefore, the notable use of a variety of regulatory models to deliver life-safety is the key lesson here. For example, Food Safety regulation utilises mandatory standards, requirements on labelling and an institution charged with the delivery of the regulatory goals (MPI). In the seismic context, the additional use of financial incentives to reduce the risks to the wider community and the costs to the state in seismic events provides a further regulatory tool.

This report only touches on these options and further research would be required to explore these options in more detail. Nevertheless, the overview provided allows for a context in which the following recommendations can be made.

Key Features of Effective Seismic Risk Mitigation Programmes

1. Prioritise Essential and Other High-Risk Buildings with Known Vulnerabilities for Mandatory Retrofitting

Target URMs, soft-story structures, and older concrete buildings, particularly those with high occupancy or public use. For example, California's mandatory ordinances prioritise buildings based on occupancy size or number of units. Japan's Seismic Retrofit Promotion Law targets retrofit of buildings over a certain scale, such as schools, hospitals, and commercial facilities. Similarly, over 90% of public school buildings that needed retrofits have been mitigated.

2. Tailor Regulations to Complexity of Construction Typologies

Multiple seismic events demonstrated the types of buildings that represent high collapse risk. They are generally, URM buildings, non-ductile concrete buildings and buildings with weak lower stories. California's ordinances target separate building types based on structural types and period of construction with different priority tiers, retrofit standards and compliance timeframes. In California, URM buildings were addressed first which helped with learning lessons with implementation, raising public awareness and gave confidence with expanding programmes to other building types.

3. Allow Incremental Retrofitting for Certain Building Types

Allow incremental or phased approach for compliance that require mitigation of major deficiencies first followed by retrofit of remaining structural deficiencies (e.g. Los Angeles URM anchors, City of West Hollywood NDC, Taiwan's Plan A and Plan B).

4. Develop and Adopt Simplified/Targeted Retrofit Standards

Simplified and targeted technical standards reduce retrofit costs and encourage compliance while reducing life safety risks. Simplified standards, Bolts Plus, were implemented by several jurisdictions in California for certain types of URM buildings (for example, see San Francisco, Oakland, proposed standards in Seattle). Targeted retrofit methods were developed for wood frame soft story buildings in California and under Plan A in Taiwan's Private Building Seismic Weak Story Retrofit Program.

5. Tailor Strategies to Local Contexts

Design policies should be tailored to the unique economic, social, and cultural conditions of each jurisdiction. For example, the URM law mandated the inventory of hazardous buildings but allowed local authorities the flexibility to develop their own risk mitigation programs—whether mandatory, voluntary, or notification-only. A valuable resource for designing an effective retrofit program is FEMA's Natural Hazard Retrofit Program Toolkit[3], which outlines key steps in the process. These include: assessing risks and vulnerabilities through an inventory of at-risk buildings; considering the local context, including physical conditions and market dynamics; and examining costs and identifying potential funding sources to support

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[3] Mary Witucki, Asia King, Toby Davine et al., *Natural hazard retrofit program toolkit: a guide for designing a disaster-resilient building retrofit program in your community*, Federal Emergency Management Agency (FEMA), 2021. https://www.fema.gov/sites/default/files/documents/fema_natural-hazards-retrofit-program-tookit.pdf#page=6.08

implementation. These elements form the foundation for the design, preparation, and execution of a successful retrofit program.

6. Establish Rigorous Ongoing Monitoring and Reporting

Monitor compliance progress by establishing milestones and timeframes for notification, seismic evaluation, building consent application and approval and retrofit completion. Public reporting on progress/compliance rates for each milestone. Californian ordinances require building owners to meet several milestones between the time they are notified to meeting the compliance requirements.

7. Implement Robust Enforcement

Establish clear timelines, monitor compliance, and impose penalties for non-compliance to ensure progress. Expand local authorities' powers to enforce compliance or order evacuation. For example, the city of Long Beach hard-line approach to compliance has been credited for the effectiveness of their URM programme.

8. Establish an Authority to Oversee Programme Implementation

Following examples set in California with Seismic Safety Commission and Taiwan's National Centre for Research on Earthquake Engineering, establish an authority that will monitor compliance, develop technical reports and conduct public outreach programmes.

9. Invest in Research on Cost Effective Retrofit Methodologies

Investigate and test retrofit alternatives and develop detailed cost estimates of each method. Develop partnerships with research institutions as evidenced in Berkeley and Taiwan.

10. Allow an Exemption from Future Retrofits

A building that is seismically retrofitted in compliance with the applicable building code within certain period from the date the mandatory seismic retrofit requirement shall not be identified as a potentially earthquake-prone building pursuant to any building code adopted after the date of the building retrofit. Such explicit provisions exist in retrofit ordinances in California, for example, Oakland's URM buildings, Berkeley's Soft Story and proposed URM ordinance in Seattle and exempt retrofitted buildings for a period of 15 years.

11. Enhance Financial Support

Introduce accessible funding mechanisms, including tax incentives, subsidies, and cost-sharing models, to alleviate the financial burden on property owners. Introduce limits on property rates assessments where seismic retrofit does not trigger rates reassessment. Incentives instruments are summarised in Appendix 3.

12. Engage Stakeholders in Programme Development

Conduct public awareness campaigns and promote collaboration among property owners, tenants, and local governments to build consensus and support for seismic risk mitigation. The success of mitigation programs depends on community buy-in, and failing to engage affected stakeholders can lead to significant delays in adoption or compromise the program's overall effectiveness.

13. Extend from Principles of California Historic Buildings Code

Currently there is no document or procedure in New Zealand that compares to the California Historic Building Code. The development of New Zealand procedures for the protection of designated heritage buildings merits consideration. California has developed a separate code specifically for historic buildings - California Historic Building Code (CHBC). This code considers the challenges of retrofitting historic structures while preserving their architectural integrity and allows for a more flexible approach to seismic retrofitting, ensuring that historical value is maintained while addressing seismic vulnerabilities

14. Disclosure Requirements for Buildings with Known Vulnerabilities

Require sellers of commercial and multi-unit residential buildings to provide earthquake risk disclosure report for specific types of buildings. Mandatory disclosure at time of sale is a key part of the state law in California.

Conclusion

This analysis highlights the critical importance of a multifaceted approach to seismic risk mitigation, blending regulatory enforcement, financial incentives, community engagement, and technological innovation. By learning from the successes and challenges of other jurisdictions, New Zealand can refine its policies to build a more resilient and safer built environment.

Part I: Seismic Risk Mitigation in the United States

In the United States seismic risk mitigation policies are primarily implemented at the state and local government levels. In other words, there are no federal-level laws requiring mandatory inventory and retrofit of seismically vulnerable buildings. California is among the world's most seismically active areas, experiencing several damaging earthquakes, and emerged as a leader in seismic safety within the US and beyond. While most of its buildings are some of the most earthquake-resistant structures, a portion of buildings could be at risk of collapse. These buildings were built prior to earthquake resistance codes were introduced in 1930's or designed to codes that were later found to be inadequate. Seismic events in the state have demonstrated that the types of buildings that represent high collapse risk are generally:

- Pre-1940's Unreinforced Masonry (URM) buildings
- Pre-1980's Non-Ductile Concrete (NDC) frame buildings
- Pre-1980's Wood frame buildings with soft, weak, open or otherwise vulnerable lower stories
- Pre-2000's Buildings with precast concrete tilt-up walls
- Pre-2000's Steel moment frame buildings

State legislation and mitigation programmes have a long history of managing collapse risk in the most vulnerable buildings. Local programmes are instituted through ordinances and range from passive approaches (e.g. triggered seismic evaluation due to change of use) to active approaches that require seismic evaluations and retrofit. The ordinances typically target specific types of buildings and apply to a time period when building codes were less stringent.

URM buildings were the first target for seismic reinforcement programmes due to its lack of ability to resist the shaking effects of earthquakes. In California, URM buildings were typically constructed prior to mid-1930's when the state-wide Riley Act 1933 effectively banned construction of URM buildings following the widespread damage and loss of these buildings in 1933 Long Beach earthquake. Cities of Long Beach and Los Angeles were among the first areas to introduce local ordinances targeting URM buildings.

Unreinforced Masonry Buildings Seismic Ordinances

Long Beach

In 1959 Long Beach introduced an ordinance that gave the city authority to require property owners to remove or mitigate falling hazards on URMs such as parapets and appendages. Following legal action and growing resistance from property owners, the city council initiated a review of the ordinance in 1970. The following year, the council passed the mandatory strengthening ordinance titled "Earthquake Hazard Regulations for Rehabilitation of Existing Structures within the City". The city identified 928 URM buildings in 1971. The ordinance was further refined in 1976 and extended to 936 buildings[4].

Features of the 1976 ordinance

Buildings were categorised into three groups based on the hazard index. The hazard index was derived from three variables: occupancy classification (e.g. emergency buildings, public

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[4] Daniel Alesch and William Petak, *The Politics and Economics of Earthquake Hazards Mitigation: Unreinforced Masonry Buildings in Southern California*, Institute of Behavioral Science, University of Colorado, 1986.

assembly buildings such as schools, retail, apartments etc, and private buildings such as offices, warehouses etc.); occupancy potential (life risk to occupants and public outside); and seismic resistance. The calculated hazard index was used to rank buildings based on their seismic vulnerability and classify into three grades:

- Grade I – Excessive Hazard (most dangerous - top 10% of the buildings); in addition, buildings with dangerous parapets and appendages were classed as *Immediate Hazard*;
- Grade II – High Hazard (more dangerous - the next 30% of the buildings);
- Grade III – Intermediate Hazard (least dangerous - the remaining 60% of the buildings).

The ordinance directed building owners to comply with the notices based on the risk classification. Non-compliant buildings were ordered to be demolished by the owners or demolished by the city at owners' expense. Owners of Excessive and *Immediate* Hazards buildings were notified on 30 January, 1981 and owners actions to repair or demolish must begin immediately. High Hazard buildings were given until 1985 and Intermediate Hazard until 1991. URM owners could make partial retrofits in which case the building would be reclassified and result in a revised compliance deadline extending to 1984 (Grade I) or 1991 (Grade II).[5]

By the end of 1980's all owners of buildings in the first two risk categories complied with the ordinance. The ordinance was updated in 1990 which revised the city's URM count to 560, leaving the least dangerous buildings to be addressed. The final retrofit for a URM building was completed in 2007. Long Beach's demolition rate was the highest among California jurisdictions with URM programmes. Nearly 40% of the entire URM stock - 370 buildings - were demolished[6] , raising concerns about the preservation of historic character and repurpose of URMs[7]. The city's hard-line approach to compliance has been credited for the effectiveness of the programme. To signal seriousness of the ordinance, the city ruthlessly followed through with demolitions of the most and more dangerous categories which failed to meet retrofit deadlines. In addition, given the city's long history of initiatives to reduce seismic risk, retrofitting issues were well understood by council staff, elected officials and the public.

Compliance in the Grade I and II categories was achieved without any financial incentives from the city. Therefore, the city did not perceive the urgency to extend incentives to the owners of the least dangerous buildings. In 1991, the city created a special assessment district to issue bonds for seismic retrofit financing[8]. In other words, the city facilitated access to financing for URM owners who could not otherwise secure long-term funding while retaining no repayment liability. The bonds were repaid through assessment liens against property, were payable in the same manner and time as general property taxes (rates) and represented

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[5] Daniel Alesch and William Petak, *The Politics and Economics of Earthquake Hazards Mitigation: Unreinforced Masonry Buildings in Southern California*, Institute of Behavioral Science, University of Colorado, 1986.

[6] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

[7] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

[8] Federal Emergency Management Agency, Seismic Retrofit Incentive Programs: A Handbook for Local Governments, California Office of Emergency Services, FEMA-254, August 1994.

liens against property, not as personal debt of URM owners (in case of sale, the debt is transferred with the property)[9].

Los Angeles

Long Beach URM ordinance served as the model for other California cities, and particularly Los Angeles. The Los Angeles URM retrofit ordinance, commonly known as “Division 88” named after the numerical section of the city municipal code, was enacted in 1981. The ordinance was eight years in the making, when then-Councilman, and subsequently Mayor, Bradley introduced a resolution to investigate the feasibility of adopting a URM mitigation programme in 1973[10]. The process became highly politicised with the seismic expert community advocating for the ordinance and property owners and tenant groups (concerned about rent increases) pressing against. The enacted ordinance applied to all URMs built prior to October 6, 1933, and buildings were divided into four classes: essential (hospitals, emergency medical centres, fire and police stations, emergency operations centres and communication centres), high (occupant load of 100 or more), medium (occupant load of 20 or more) and low risk (occupant load of less than 20). To differentiate among strengthening requirements, owners were given timeframes based on priority rating. The ordinance also allowed for a dual time approach, with time extensions that encouraged installation of anchors in the first year after notification. All construction work was expected to be completed within 15 years. If the owner did not take any action (submit building permit, complete construction), the city had the power to issue a notice to vacate the building within 30 days and order demolition after 90 days. The initial survey identified 8079 URM buildings. The ordinance was amended twice. Following the 1985 Mexico City earthquake the original timeframes were reduced from 15 to 10 years. The 1987 Wittier Narrows earthquake led to the revision of the technical requirements that positively benefitted the programme through improved building performance, reduced costs and easier construction without tenant displacement[11]. In 1996, the city passed an ordinance for voluntary strengthening of steel frame with URM infill buildings (non-bearing wall URM) which covered a further 1132 buildings. In 2006 the California Seismic Safety Committee reported that URM buildings in Division 88 programme achieved nearly 100% mitigation rate (retrofit and demolition)[12].

The City of Los Angeles enacted the mandatory URM ordinance without any financial incentives in place. The city tried to enact a municipal bond programme, like the one in Long Beach, but did not get enough votes to pass. Less than 80 buildings received some form of government assistance. Out of the roughly $1.7 billion spent on URM retrofits and replacements in Los Angeles, less than 10% came from government finances[13]. In addition,

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[9] Federal Emergency Management Agency, Seismic Retrofit Incentive Programs: A Handbook for Local Governments, California Office of Emergency Services, FEMA-254, August 1994.

[10] Daniel Alesch and William Petak, *The Politics and Economics of Earthquake Hazards Mitigation: Unreinforced Masonry Buildings in Southern California*, Institute of Behavioral Science, University of Colorado, 1986.

[11] Mary Comerio, *Impacts of the Los Angeles Retrofit Ordinance on Residential Buildings*, Earthquake Spectra, 8(1), 1992.

[12] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

[13] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

California state law provides that seismic retrofit is not considered an improvement to the property and protect owners from property tax (rates) increases for 15 years (the 2010 amendment removed the time limit on the exclusion, triggering reassessment only when the property is sold). At the federal level, historic building owners could claim 20% tax credit of the "qualified rehabilitation expenditures" (including seismic retrofit) over a 5-year period[14].

TABLE 1. LOS ANGELES URM RETROFIT ORDINANCE BUILDING CLASSIFICATION AND COMPLIANCE SCHEDULE

Class	Rating	Years to notification	Without anchors	With anchors	
			Years for full compliance	Years to install anchors	Years for full compliance
I	Essential	0-1/4	3	1	4
II	High Risk	1/4-1	3	1	6
III	Medium Risk	1-3 1/4	3	1	8-9
IV	Low Risk	3 ¼ - 4	3	1	10

Notes: Years for compliance from the date of notification

TABLE 2. LOS ANGELES URM ORDINANCE STATISTICS

URM stock	Inventory	Retrofitted	Demolished	No progress
Division 88 (mandatory)	8,079	6,133 (76%)	1,942 (24%)	4
URM infill (voluntary)	1,132	11 (1%)		1,121 (99%)
Total	9,211	6,144 (67%)	1,942 (21%)	1,125 (12%)

Source: CSSC Report (2006)

Developing data on retrofit technology and cost

Prior to implementation of URM ordinances substantial effort was invested in developing technologically and economically feasible solutions to mitigate seismic hazards in URM buildings. The multi-year ABK Study (1984) conducted between 1977 and 1984, titled *"Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings"*, is a foundational work in the field of seismic retrofit methodologies for URM buildings[15]. This study, funded by a National Science Foundation grant, was a landmark project conducted in response to the widespread recognition of the seismic vulnerabilities of URM structures. The basis of the published methodology was developed on research conducted by ABK and is supplemented by seven topical reports. The study outlined various retrofit approaches to mitigate seismic risks, including strengthening walls, anchoring parapets, and reinforcing connections between walls and roofs or floors while also provided methods to evaluate the cost-effectiveness of different retrofit options, helping policymakers and building owners prioritise retrofit projects based on both safety and financial viability.

A separate study of three URM buildings scheduled for demolition for a planned street widening programme in Los Angeles in 1978 was conducted by the Structural Engineers Association of Southern California to test rehabilitation techniques for such structures. The

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[14] National Park Service, *Historic Preservation Tax Incentives*, U.S. Department of the Interior, 2009. https://dahp.wa.gov/sites/default/files/HPTI_brochure.pdf

[15] ABK, *Methodology for Mitigation of Seismic Hazards in Unreinforced Masonry Buildings – TR-04: The Methodology*, ABK Joint Venture, El Segundo, CA, USA, 1984

empirical evidence gathered during testing helped relieve some of the political hesitation to enact the ordinance[16].

Nevertheless, ascertaining strengthening costs was one of the main issues contributing to the delays with enacting mitigation policies. During the development of the Los Angeles URM ordinance, the city commissioned a cost study (Wheeler and Gray, 1980) which evaluated several URM building types. Based on the findings in the Wheeler and Gray study, the city determined that the average strengthening cost ranged between 15-21% of the replacement cost of the buildings studied (this estimate came significantly lower than the 80% replacement cost suggested by the Chair of Apartment Association of Los Angeles several years earlier)[17].

San Francisco followed a similar approach by conducting technical and economic analysis of retrofitting requirements. Recht Hausrath and Associates conducted a comprehensive study analysing the socioeconomic and land use implications of retrofitting alternatives[18].

More accurate data started to be accumulated once the actual construction started to take place since the enactment of ordinances. For example, for Los Angeles, Steinberg[19] presented cost information on four buildings which were designed to comply fully with the ordinance. The study also presented data on 15 buildings for which preliminary cost estimates had been prepared. It was also observed that costs continued to decline as builders and engineers gained experience and developed strengthening approaches.

The URM Law

Following the lead of the cities of Long Beach in the 1970's and Los Angeles in the 1980's, the State of California declared, through Senate Bill 547 (Section 8875 et seq. of the Government Code), that the hazard posed by URM buildings is unacceptable and that communities in the highest seismic risk zone must identify them. The bill was enacted in 1986 and is commonly known as the URM law[20].

It was a lengthy process of developing a politically acceptable bill. Initially, California Seismic Safety Commission drafted Senate Bill 445 which was signed into law in 1979. The bill established a voluntary programme with important provisions included in the Senate Bill 445:[21]

- Each local agency may assess the earthquake hazard in their jurisdiction and identify hazardous buildings (built prior to codes with seismic resistant design, constructed with URM bearing wall);
- Appropriate retrofit should improve life safety only but local jurisdictions could establish higher standards for essential buildings (e.g. fire and police stations);

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[16] Daniel Alesch and William Petak, *The Politics and Economics of Earthquake Hazards Mitigation: Unreinforced Masonry Buildings in Southern California*, Institute of Behavioral Science, University of Colorado, 1986.

[17] Ibid

[18] Recht Hausrath and Associates, *Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings: Socioeconomic and land Use Implications of Alternative Requirements*, October 1990.

[19] Raymond Steinberg, *Typical Cost Data for Compliance with Division 68*, cited in Daniel Alesch and William Petak, 1986.

[20] California Legislature, *The URM Law*, California Government Code Section 8875, CA, USA, 1986.

[21] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 1995 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 1995.

- Retrofitted buildings were exempt for 15 years from being identified as a seismic hazard (retrofitted buildings shall not be identified as a potentially hazardous building pursuant to any building code adopted after the date of the retrofit)

Despite significant efforts by several organisations to promote the bill, local jurisdictions were unenthusiastic about passing resolutions to initiate the mitigation programmes. In 1983, the Coalinga earthquake was yet another reminder of the poor performance of URM buildings. Given lack of progress under Senate Bill 445, the Seismic Safety Commission (SSC) decided to draft another bill which would create a state-mandated legislation requiring cities and counties to establish hazardous building programmes[22]. The SSC drafted Senate Bill 1797 which required local governments to:

- Identify all potentially hazardous buildings (constructed before building code required earthquake-resistant design of unreinforced masonry);
- Establish a hazardous building mitigation programme which would notify the owner the building is hazardous and urge owners to bring the building to a higher safety standard.

However, in 1984 Senate Bill 1797 was vetoed by the Governor arguing that local governments already had the authority to establish mitigation programmes under SB 445.

In 1985, Senate Bill 547 was introduced which was a less comprehensive version of SB 1797. The updated bill was the compromise of the previous attempt to pass a statewide legislation giving local authorities flexibility in adopting mitigation programmes and limiting the application of mandatory requirements to Seismic Zone 4 only (the highest seismic zone). Although, the final bill did not apply to all areas of the state, Zone 4 included the major metropolitan areas of Los Angeles and San Francisco which contained approximately 80% of the state's population at the time. Another significant amendment was the expanded definition of potentially hazardous buildings to include unreinforced masonry walls that were non-bearing thus paving the way for local jurisdiction to extend the bill to concrete and steel-frame buildings with unreinforced infill walls, stair wells and elevator shafts[23]. After these and several other amendments, Senate Bill 547 was signed into law in July 1986.

The URM Law required 365 local governments (cities and counties) in Zone 4 to do the following:[24]:

1. Inventory URM buildings within each jurisdiction;
2. Establish loss reduction programmes for URM buildings by 1990;
3. Report progress to the California Seismic Safety Commission.

According to the 2006 report by the Commission[25], since the implementation of the URM Law 25,945 URM buildings were inventoried in the 365 jurisdictions. Out of those, 260 cities and counties established mitigation programmes (25,536 URMs), 82 jurisdictions had no URMs, 17 jurisdictions completed the inventory but did not start a mitigation programme (354 URMs) and six had incomplete inventories (55).

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[22] Ibid

[23] ibid

[24] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

More than half (52%) of the jurisdictions with established mitigation programmes implemented mandatory strengthening requirements. This type of programme was the most effective in mitigating seismic risk. Voluntary programmes had a significantly lower rate of retrofits (70% within mandatory vs 16% within voluntary), however higher rates were observed in jurisdictions that provided financial incentives. Mandatory programmes worked well in locations where the market-driven environment to retrofit was strong, in particular in larger metropolitan markets. For example, both San Francisco and Los Angeles implemented mandatory programmes.

As experience of Senate Bill 1797 showed, mandating a uniform statewide programme would not have been well received by the local jurisdictions. Under the URM Law, each local government (within Zone 4) had a choice in the type of the loss reduction programme (i.e. mandatory, voluntary, notification only, or other type). This stems from the California's long tradition of strong local government control and independence on most matters[26]. This provision allowed each jurisdiction to tailor the mitigation programme on the political, economic and social priorities of the area. The Commission observed that the choice of the programme reflected the local balance of safety versus economy[27].

TABLE 3. TYPES OF MITIGATION PROGRAMMES ESTABILISHED UNDER THE URM LAW

Programme type	Summary	Effectiveness
Mandatory strengthening	Owners are required to strengthen or otherwise reduce risks within times prescribed by each local government. Timelines typically differentiate by importance level and occupant load.	Most effective. Mitigation rate (retrofit + demolition) 70%+17% [87%]
Voluntary strengthening	Local government establishes retrofit standards and require owners to evaluate the risks in their buildings. Owners submit a letter indicating their intention to reduce risks. Reports and letters are made available to the public.	More effective than Notification Only. Higher retrofit rates in jurisdictions with financial incentives. Mitigation rate 16%+8% [24%]
Notification only	Local government writes letters to owners stating that their building is potentially hazardous.	Least effective. Mitigation rate 7%+6% [13%]
Other types	Variations of other programmes with unique requirements (e.g. posting of placards, demolition)	Range of effectiveness. Mitigation rate 15%+11% [26%]

Source: (p20, CSSC95) (CSSC 2006)

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[26] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 1995 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 1995.

[27] ibid

TABLE 4. NUMBER AND SCOPE OF MITIGATION PROGRAMMES (AS OF OCTOBER 2006)

Programme	Jurisdictions	Population	URMs
Mandatory	134 (52%)	15,829,977 (64%)	19,043 (75%)
Voluntary	39 (15%)	2,593,002 (10%)	1,269 (5%)
Notification only	46 (18%)	2,630,043 (11%)	1,487 (6%)
Other	41 (15%)	3,676,738 (15%)	3,737 (14%)
Total	260	24,729,760	25,536

Notes: Population statistics from 2000 Census; Source: CSSC (2006)

Laws relevant to the URM law

URM Posting

State law (Government Code, Sections 8875.8 and 8875.9) requires owners to place placards at the main entrance to URM buildings warning the public about the earthquake risk. However, no government agency was made responsible for enforcing this requirement and compliance was minimal (CSSC 1995 report identified that only 2% of the URM buildings had placards).

URM disclosure

The same State law (Government Code, Sections 8893.2 and 8875.6) requires each seller of URM buildings to provide the Commercial Property Owner's Guide to Earthquake Safety to prospective buyers. The Guide contains disclosure on certain earthquake deficiencies, for example whether the walls and parapets are strengthened and if warning signs have been posted. The Commission developed the Guide and is required to regularly update it. As such, the disclosure form also includes questions about other vulnerable structural types including soft-story, non-ductile concrete and steel-moment frame. Although under the law the seller is not required to mitigate the risks before selling the property.

San Francisco

In compliance with the 1986 URM law, San Francisco mandated the retrofit of URMs with the passage of hazard reduction ordinance (225-92) in 1992. In between that time, the San Francisco Bay Area was hit by the 1989 Loma Prieta Earthquake. This earthquake caused a significant damage to URM buildings. The initial evaluation identified 1,976 bearing wall URMs. Owners were notified by February 1994 and were given up to 12 years to complete strengthening, depending on the building's risk profile. By 2006, the city's deadline for retrofitting, the mitigation rate stood at 86% (1,555 buildings were in compliance with the ordinance [78%] and 158 were demolished [8%]). An estimated 15-20 non-compliant buildings remain, some of these buildings are publicly owned[28].

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[28] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf and John Cote, *Momentum slows on fixing S.F's dangerous brick buildings*, SFGATE, 26 October, 2016. https://www.sfgate.com/bayarea/article/Momentum-slows-on-fixing-S-F-s-dangerous-brick-5847981.php

TABLE 5. SAN FRANCISCO BUILDING CLASSIFICATION AND COMPLIANCE SCHEDULE

Risk level	Definition	Timeline for compliance	Schedule for compliance
Level 1 (high risk)	Assemblies (>= 300 occupants), >3 stories on poor soil (areas of poor soil mapped)	2 1/2 years	Apply for building permit or demolition – 1 year Obtain building permit – 6 months Complete alteration – 1 year
Level 2	Non-level 1 on poor soil in certain mapped locations	4 years	Apply for building permit or demolition – 1 ½ years Obtain building permit – 6 months Complete alteration – 2 years
Level 3	Buildings in Level 2 mapped areas not on poor soils	10 years	Apply for building permit or demolition – 7 years Obtain building permit – 1 year Complete alteration – 2 years
Level 4	All other URMs	12 years	Apply for building permit or demolition – 9 years Obtain building permit – 1 year Complete alteration – 2 years

The city proposed several alternative retrofitting levels to address the life-safety hazard posed by URMs. Notably, the retrofit standards allowed for a simplified prescriptive approach of seismic upgrade to “Bolts Plus” for certain types of buildings. The "Bolts Plus" standard involves anchoring floors and roofs to masonry walls (bolting) and includes additional measures like bracing parapets and reinforcing walls to improve seismic performance. To be considered, buildings had to be fewer than six stories, without significant vertical irregularities or weak stories at the ground level, had qualifying cross walls and a specified minimum areas of solid URM wall, and excluded buildings housing assembly, educational or hazardous occupancies. It was estimated that around a quarter of URM buildings were retrofitted to the “Bolts Plus” standard and majority of the remaining buildings were compliant with the 1991 Uniform Code for Building Conservation[29]. At the time, the “Bolts Plus” alternative was a politically acceptable compromise that ensured support of the URM ordinance. The background process of establishing technical standards for San Francisco’s URM ordinance is discussed in FEMA-275[30]. In 1991, the State of California adopted Appendix Chapter 1 of the Uniform Code for Building Conservation (UCBC) (a companion document to the Uniform Building Code (UBC) as a model code. The original basis of the technical provisions of the Appendix Chapter 1 was the Los Angeles’ building code Division 88. The Structural Engineers of Northern California (SEAoNC) recommended that San Francisco adopt the state’s new model code. The city’s own advisory committee (Seismic Investigation and Hazards Survey Advisory Committee (SIHSAC)) generally agreed with this recommendation. However, since members of the SIHSAC represented a range of stakeholders, including engineers, architects, contractors and groups representing property and lending interests, there was a strong opposition from the owners of URM buildings, in particular from lower socio-economic parts of

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[29] Historic Buildings Committee, *Unreinforced Masonry Factsheet*, Northern California Chapter, May 2004. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ec105f53f5d40264c762f5b7e2f20726a44c37d2

[30] Robert Olshansky, *Planning for Seismic Rehabilitation: Societal Issues*, Federal Emergency Management Agency, FEMA-275, 1998

the city. While the 1989 Loma Prieta Earthquake accelerated the development of the ordinance, socio-economic issues played a role shaping the technical provisions which made retrofits more viable and helped the city protect URM buildings that often provide affordable housing and business accommodation as well as cultural and architectural resources[31].

To alleviate the financial burden of seismic retrofit, in 1992 the city authorised the issuance of USD 350 million in bonds to make loans available to URM building owners. At that time commercial loan interest rates were high and the banks perceived seismic retrofit loans high risk. From the total pool, US$ 150 million was set aside for low-interest loans at 2.5% for buildings containing affordable housing, remaining funds could be used to retrofit any other type of URM at 8.5% interest rate, which was comparable to the market rate. To access low-interest funding, the owner was required to enter into an agreement guaranteeing that the retrofitted units remain affordable. It was observed that only US$ 10.4 million was disbursed across 17 loans[32]. The low uptake was attributed to the administrative restrictions and conditions placed on borrowers and renewed interest among private banks to fund retrofits at rates competitive with the city bond programme. The experience is similar to the discontinued Residential Earthquake-Prone Building Financial Assistance Scheme administered by Kāinga Ora Homes and Communities.

Palo Alto

The city council adopted the Seismic Hazards and Identification Program (Municipal Code Section 16.42) in 1986. The ordinance established the so called “other” type of programme which established a mandatory evaluation and reporting programme and incentives for property owners to voluntary upgrade their buildings. The city identified 47 URM buildings which were in the downtown area and were primarily occupied by commercial tenants. The ordinance classified buildings into three categories and were used to record known URM buildings and other potentially structurally deficient buildings with high occupancies (Category 2 – pre-1935 structures with 100+ occupants - and Category 3 – pre-1976 structures with 300+ occupants). Since the categories captured other, non URM, buildings, the city identified 89 potentially hazardous buildings.

All owners were to be notified within six months of enactment of the ordinance, except for owners of historic buildings who received an additional 18 months to comply to allow them more time to prepare. Once notified by the city, the owners were required to contract with a structural engineer to prepare a report evaluating the potential for damage to their building in an earthquake and identifying measures to bring the building at least up to the 1973 Uniform Building Code (UBC). Within one year of submitting the engineering report, the owner also submitted a letter of intent describing plans for mitigating the identified deficiencies, albeit mandatory retrofitting was not imposed. The owner was also responsible for notifying building occupants in writing that an engineering study has been conducted and that the study is available from the city council’s Building Inspection Division. The chief building official produced semiannual reports to the council discussing the number of buildings analysed, severity of structural deficiencies and any mitigation measures taken by the owners. The September 1989 report to the city council identified that over 70% of the owners complied with

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[31] Robert Olshansky, *Planning for Seismic Rehabilitation: Societal Issues*, Federal Emergency Management Agency, FEMA-275, 1998

[32] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

the ordinance and 18 buildings were strengthened[33]. Therefore, compliance in the first three years of the programme was tracking well and the reporting and disclosure requirements served as a strong incentive.

TABLE 6. PALO ALTO URM ORDINANCE BUILDING CLASSIFICATION AND COMPLIANCE SCHEDULE

Category	Definition	Notification	Engineering report	Letter of intent	Bldgs in scope
1	Buildings constructed of unreinforced masonry (except for those smaller than 1,900 square feet with six (6) or fewer occupants)	6 months	1 ½ years	1 year	47
2	Buildings constructed prior to January 1, 1935 containing one hundred (100) or more occupants	6 months	2 years	1 year	19
3	Buildings constructed prior to August 1, 1976 containing three hundred (300) or more occupants	6 months	2 ½ years	1 year	23

The city provided development incentives for owners considering retrofits by enacting zoning changes that allowed owners to add floor area (up to 2,500 sq feet to a maximum floor area ratio (FAR) of 3:1) and exempting from on-site parking requirements. Importantly, concerned about the impacts of commercial growth, the city-imposed caps on future developments in the city centre. Most of the areas of downtown had a FAR of 1:1 (this constraints the floor area of new developments to the size of the site area).

The process of developing the ordinance for Palo Alto began in December 1981. At the time the draft ordinance proposed to impose mandatory strengthening requirements on 250 seismically deficient structures. When the ordinance was presented to the city council, it received considerable opposition from the affected building owners, businesses and the public. In April 1982, the council voted against the ordinance. Despite opposition to the ordinance, the council directed staff to convene a citizen's committee to consider cost-effective methods to reduce seismic hazards. The committee was chaired by an architect, other members included structural engineers and representative of business and property interests. Mandatory programme was perceived impractical because it did not consider the economic benefits and affordability of retrofits, lack of consideration for other circumstances faced by owners such as disruption to tenants with long term leases and challenges in establishing the full extent of structural deficiencies and therefore estimating repair costs. To overcome the concerns of the mandatory ordinance, the committee's report recommended to adopt a voluntary programme which would allow each owner to decide when and how to retrofit and require the preparation of engineering studies and the public disclosure of these findings. The city council unanimously voted to adopt the ordinance in February 1986. The outcome of the ordinance was seen as a practical compromise between the different perceptions of "acceptable" level of seismic risk (building code professionals vs building owners and developers). Another significant area of compromise was the version of the UBC used in

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[33] Timothy Beatley and Philip Berke, Seismic Safety through Public Incentives: the Palo Alto Seismic Hazard Identification Program, Earthquake Spectra, 6(1), 1990.

evaluating the structural integrity with the council adopting the 1973 version of the UBC rather than the 1985 code, the most modern available at the time. Bostrom et al (2006) reflected that the development of the Palo Alto ordinance demonstrated how the level of acceptable consequences determined by analysis alone can differ from the level acceptable by the stakeholders, emphasising that analysis requires deliberation.[34]

Beatley and Berk[35] identified several factors that led to the adoption of the Palo Alto programme:

- Stakeholder problem recognition (adopted ordinance is a compromise among different stakeholders)
- Local economic conditions (high demand for downtown properties with relatively high rents and low vacancies)
- Progressive political culture (Palo Alto is a small city with a highly educated and affluent population)
- Appointment of the citizen's committee
- Presence of seismic safety advocates
- Availability of resources

TABLE 7. STATUS OF PROPERTIES INCLUDED UNDER PALO ALTO'S CURRENT EARTHQUAKE RISK REDUCTION ORDINANCE (SEPTEMBER 2014)[36]

	Category I	Category II	Category III	Total
Retrofit	22	13	5	40
Demolished	14	2	5	21
Demo proposed	0	0	4	4
Exempt	1	0	0	1
No change	10	4	9	23
Total	47	19	23	**89**

Source: City of Palo Alto Vulnerable Buildings Seismic Risk Assessment Study Attachment D, Table 1, p.86

Berkeley

The city of Berkeley adopted its mandatory URM retrofit programme in November, 1991[37]. At the time 587 potentially hazardous URMs were identified. The ordinance specified that the technical compliance for URM buildings had to meet or exceed the UCBC requirement. In 2001 the ordinance was updated adopting 1997 UCBC Appendix Chapter 1 with certain amendments to maintain standards at least as strong as originally adopted. Prescriptive, "Bolts Plus", standards were allowed for retrofit of regular (square or rectangular) simple buildings which were 1 or 2 storeys.

Within two years of the adoption of the programme, each owner on the URM inventory was required to either demonstrate that the building meets the criteria for the prescriptive standard

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[34] Timothy Beatley and Philip Berke, Seismic Safety through Public Incentives: the Palo Alto Seismic Hazard Identification Program, Earthquake Spectra, 6(1), 1990

[35] ibid

[36] Rutherford + Chekene, *Seismic Risk Assessment Study, Final Report for the City of Palo Alto, California*, December 2016. https://www.cityofpaloalto.org/files/assets/public/v/1/agendas-minutes-reports/reports/city-manager-reports-cmrs/year-archive/2017/id-8207-seismic.pdf

[37] City of Berkeley, *Seismic Hazard Mitigation for Unreinforced Masonry Buildings*, Municipal Code, Chapter 19.38, 1991. https://berkeley.municipal.codes/BMC/19.38

or submit a seismic engineering evaluation report prepared by a structural or civil engineer. Owners then had to complete retrofits according to the compliance timeline specified in the ordinance. The programme classified buildings into six risk categories on the basis of risk to life. Up to three 6-month hardship extensions were available on the application to the city (for example, low-income housing, access to finance). In addition, owners were required to notify tenants in writing that the building is included in the URM inventory and detailing planned schedule for engaging in seismic retrofit.

TABLE 8. BERKELEY URM ORDINANCE SCOPE AND TIMELINE[38]

Risk category	**Definition**	**Compliance**
I	• Hospitals, fire and police offices/stations, emergency operation centres, buildings housing medical supplies, government administration offices, or any building with an occupancy load of one thousand (1,000) or more.	March 1, 1997
II	• Commercial buildings - Businesses, assembly buildings, educational and institutional occupancies with an occupancy load of three hundred (300) or more. • Residential buildings - Hotels, motels, apartments or condominiums containing more than one hundred (100) living units/bedrooms. • Mixed use occupancies - Any building with a combined occupancy load greater than three hundred (300).	March 1, 1997
III	• Commercial buildings-Businesses, assembly buildings, educational and institutional occupancies with an occupancy load of one hundred (100) or more. • Residential buildings-Hotels, motels, apartments or condominiums containing fifty (50) or more living units/bedrooms. • Mixed use occupancies-Any building with a combined occupancy load greater than one hundred (100).	June 30, 1997
IV	• Commercial buildings-Businesses, assembly buildings, educational and institutional occupancies with an occupancy load of fifty (50) or more. • Residential buildings-Hotels, motels, apartments or condominiums containing fewer than fifty (50) living units/bedrooms. • Mixed use occupancies-Any building with a combined occupancy load greater than fifty (50).	December 31, 1997
V	• Commercial buildings-Businesses, assembly buildings, educational and institutional occupancies with an occupancy load of fifty (50) or less. • Residential buildings-Hotels, motels, apartments or condominiums containing twenty (20) or fewer living units/bedrooms. • Mixed use occupancies-Any building with a combined occupancy load of fifty (50) or less.	December 31, 1998

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[38] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

VI	• Any non-residential building that is used less than twenty (20) hours per week, or any building with a masonry veneer of at least ten (10) feet in height or with a masonry parapet exceeding a one and one-half (1-1/2) ratio or masonry in-fill that is located in a high pedestrian traffic corridor.	December 31, 2001

By 2004, compliance rate was at 85 % with 497 buildings retrofitted and one building demolished[39]. In 2006 it was reported that the city added four building increasing the inventory to 591, nevertheless compliance rate increased to 92% with 547 retrofitted URMs and one demolished building[40]. As of January 2025, three URM buildings remain on the hazardous building inventory[41]. Since 2018, the city made available retrofit grants for owners of multi-family homes of 3+ units, non-residential buildings, hotels/motels, and mixed-use buildings. URM owners are eligible to apply for design grants (up to 75% of design costs, max USD 5,000) and construction grants (up to 40% of construction costs, max USD 25,000 – 150,000)[42].

The City of Berkeley has been successful in mandating seismic retrofitting of URM buildings on their inventory achieving a compliance rate of 99% with only 1% of building demolished as a result. It has been noted that Berkeley's approach has been one of the strictest in California from creating six compliance categories and compliance schedules to close monitoring of compliance where the city enforced regulatory laws and penalties for non-complying property owners. The city has been credited for investing in community resilience and leading by example by rebuilding or retrofitting every public school, fire station and numerous administrative buildings. Berkeley voters approved special taxes totalling more than US$ 386 to fund hazard mitigation (seismic and fire upgrades) for the municipal and school district governments[43]. In addition, in 1997 the University of California at Berkeley commissioned a seismic review of its campus buildings and in the same year launched the Seismic Action plan for Facilities Enhancement and Renewal (SAFER), a 20-year plan calling for over US$ 1 billion investment in safety improvements. By the early 2000's the university retrofitted three high-rise residence hall complexes, as well as retrofits of athletic facilities, libraries, and academic and administrative buildings[44].

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[39] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2004 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2005.

[40] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

[41] City of Berkeley, *Unreinforced Masonry Buildings in Berkely*, Progress Report, 9 January 2025. berkeleyca.gov/sites/default/files/documents/Inventory URM 5-31-22.pdf

[42] City of Berkeley, *Retrofit Grants*, n.d. https://berkeleyca.gov/construction-development/seismic-safety/funding-seismic-retrofits/retrofit-grants

[43] Jeanne B. Perkins , Arrietta Chakos, Robert A. Olson, L. Thomas Tobin, and Fred Turner, *A Retrospective on the 1906 Earthquake's Impact on Bay Area and California Public Policy*, Earthquake Spectra, 22(2), 2006. doi: 10.1193/1.2181527

[44] UC Berkeley, *Capital Strategies: At UC Berkeley, Seismic Safety is a Priority*, n.d. https://capitalstrategies.berkeley.edu/seismic-safety

Oakland

The City of Oakland enacted its URM hazard reduction programme in 1993[45]. The city established two-tiered hazard mitigation standards – mandatory and voluntary[46]. The mandatory retrofit standard adopted by the city was the prescriptive "Bolts Plus" method to reduce the risk of falling hazards including securing the roof and walls to the exterior walls, bracing parapets and removing or fixing other on-structural exterior falling hazards. Voluntary retrofit standard was established in accordance with the UCBC Appendix Chapter 1. Notably, buildings retrofitted to the mandatory standards were issued with a "Certificate of Compliance of Mandatory Requirements" but remained on the city's list of potentially hazardous URM buildings. Buildings upgraded to the voluntary standards were removed from the inventory list and were exempted from any further seismic mitigation legislation for a further period of 15 years. The ordinance specified three priority levels for compliance with the mandatory standards. Priority levels were determined by the City's Building Official based on the type of soil on which the building is located, number of stories, pedestrian and vehicle traffic adjacent to the building, use of building, number of occupants and complexity of retrofit work. Classification of buildings based on soil is similar to the categories developed in the San Francisco ordinance given their proximity, but otherwise is unique among retrofit ordinances which typically did not factored in vulnerability due to soil conditions.

TABLE 9. OAKLAND URM PRIORITY LEVELS AND COMPLIANCE TIMEFRAME FOR MANDATORY RETROFIT STANDARD

Priority level	Submission of building permit	Construction complete
I	1 year	2 years
II	2 years	3 years
III	3 years	4 years

The city identified 1,612 URM buildings. As of 2006, majority of the buildings, 1,107 (69%) complied with the mandatory, Bolts Plus, standard. A further 328 buildings (20%) were removed from the inventory with 222 buildings meeting the UCBC standards and 106 building demolished[47]. Therefore, the mitigation rate across the mandatory and voluntary standards was 89%.

The ordinance specified penalties for failure to meet the mandatory retrofit deadlines, for example, US$ 2,000 per month (max US$ 10,000 per building) for failure to complete upgrade as well as notifying parties with financial interests (e.g. lender, insurer) and tenants, placarding of the hazardous building, revoking the occupancy permit and evacuating the building three years after the construction completion deadline. After adopting the ordinance, the city

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[45] Richard Olson, Robert Olson and Vincent Gawronski, *Night and Day: Mitigation Policymaking in Oakland, California Before and After the Loma Prieta Disaster*, International Journal of Mass Emergencies and Disasters, 16(2), 1998.

[46] City of Oakland, *Chapter 15.28 Unreinforced Masonry Buildings Ordinance*, Municipal Code. https://library.municode.com/ca/oakland/codes/code_of_ordinances?nodeId=TIT15BUCO_CH15.28UNMABU

[47] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

extended deadlines for completing URM upgrades to February, 1997 for Priority I and II and February, 1998 for Priority III buildings[48].

The city deliberately chose to develop an ordinance that focused on minimal compliance with the URM law in specifying the more modest, prescriptive methods for compliance with the mandatory standard. Many of the URM buildings were in lower socioeconomic areas and there was a perception that if the mandatory bar was set high (UCBC compliance), the city would face strong opposition from businesses and property owners and very little would have been mitigated due to lack of financial resources – capital to fund retrofits and ability to pay off mortgages after the rehabilitation[49].

URM ordinances outside of California

Seattle, Washington

Seattle is located in a high seismic risk zone with the greatest risk posed by the Cascadia Subduction Zone and the Seattle Fault line. In the 1970's, the city made several attempts at addressing life safety concerns of URM buildings by introducing mandatory retrofit ordinances. At the time, the city did not back up the requirements with financial incentives to alleviate the significant cost burden. Due to prohibitive costs, the ordinances were repealed by 1978[50]. Since then, earthquake safety did not rate high on the policy agenda until the 2001 Nisqually Earthquake. While most buildings performed well from a life safety prospective, building damage was primarily concentrated in URM buildings (among 31 red tagged buildings, 20 were URM), with an estimated USD 8 million spent in repair costs to URM buildings in Seattle[51]. The earthquake prompted the city to act. Between 1993 and 2015, the city undertook multiple discrete attempts at compiling a URM list[52]. Some of the earlier studies focused on individual neighbourhoods, and it wasn't until 2009 when the city surveyed the city as a whole. In 2012 some areas were re-surveyed and in 2015 the city hired a structural engineer to validate the URM list by reviewing photographs of the buildings, visiting selected buildings to

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[48] Seismic Safety Committee, *Status of the Unreinforced Masonry Building Law: 2006 Progress Report to the Legislature*, California Seismic Safety Committee, Sacramento, CA, 2006.

[49] Richard Olson, Robert Olson and Vincent Gawronski, *Night and Day: Mitigation Policymaking in Oakland, California Before and After the Loma Prieta Disaster*, International Journal of Mass Emergencies and Disasters, 16(2), 1998.

[50] URM Policy Committee, Recommendations from the Unreinforced Masonry Policy Committee to the City of Seattle, Seattle, Washington, July 2017. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/URMFinalRecommendations.pdf

[51] Reid Middleton, City of Seattle Unreinforced Masonry Building Seismic Hazards Study, RMI Project ID# 262007.025, December 2007. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/URMSeismicHazardsStudy.pdf

[52] City of Seattle, *URM List Validation - Report to Policy Committee*, 2016. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/ReportToPolicyCommitteeURMListValidation.pdf

view the exterior construction details, and reviewing permit records[53]. The URM inventory identified 1,154 buildings. The list was finalised in 2016 and in the same year building owners on the confirmed list were notified. The list is publicly available on the City of Seattle's URM Database Viewer[54].

In 2008, to progress URM policy effort, two committees were formed, policy and technical. The 2008 Technical Advisory Committee recommended adoption of the modified Bolts Plus standard commonly used in California provided the buildings met certain criteria. Building that fell outside of the scope of the modified standard would be required to meet the more rigorous, code based standard[55]. The 2008 Policy Committee discussions did not progress due to the cost of retrofits. A new URM Policy Committee was convened in 2011 and concluded in 2017 with a set of recommendations, including that:[56]

- retrofit policy be mandatory for all URM buildings
- the URM retrofit program apply to all buildings that have unreinforced masonry bearing walls, including residential buildings with three or more units
- buildings be classified into three categories according to the building vulnerability with regard to life safety impacts (critical/high/medium risk)
- the steps in completing a retrofit include notification, assessment, permit application, permit approval and retrofit completion
- the timeline for completing a retrofit range from 7 (critical) to 13 (medium) years
- enforcement procedures are applied to non-complying owners
- the funding opportunities and financial incentives are available to assist owners with retrofits

Following the policy recommendations and recognising that retrofit costs represent the greatest barrier to compliance, an in-depth study was conducted on the funding of URM retrofits[57]. The most current estimates of the buildings on the URM inventory at the time of the study (in 2019) was 1,154[58]. To more accurately estimate the financial implications of the policy, the study used the "modified" inventory of 944 buildings which excluded buildings that have been sufficiently retrofitted (for example, substantial alterations) and publicly owned

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[53] City of Seattle, *URM List Validation - Report to Policy Committee*, 2016. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/ReportToPolicyCommitteeURMListValidation.pdf

[54] Seattle Open Data Portal, *Unreinforced Masonry Buildings*, n.d. https://data-seattlecitygis.opendata.arcgis.com/datasets/SeattleCityGIS::unreinforced-masonry-buildings-urm/about

[55] URM Technical Committee, *Final report from URM Technical Committee & Proposed Retrofit Standard*, City of Seattle, March 2012. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/URMTechnicalReportMar2012.pdf

[56] URM Policy Committee, Recommendations from the Unreinforced Masonry Policy Committee to the City of Seattle, Seattle, Washington, July 2017. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/URMFinalRecommendations.pdf

[57] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

[58] ibid

buildings which can access different sources of funding[59]. Costs of three retrofit standards are considered: Bolts +, Bolts ++Frame, and Full Seismic. Construction costs estimates ranged between US$ 5 – 95 per square foot, with buildings that qualify for Bolts+ or Bolts++Frame retrofits having a similar average cost between US$ 32-35/sqf, whereas Full Seismic retrofits come at a significant premium reaching US$ 95/sqf. It was estimated that retrofit of a hypothetical prototype 3 storey, 22,000 sqf building to Bolts+ standard would cost US$ 642,000. The estimated total costs for retrofitting privately owned URMs in Seattle were US$ 1.28 billion.[60]

TABLE 10. PROPOSED URM RETROFIT STANDARDS, NUMBER OF BUILDINGS AND AVERAGE RETROFIT COST

Retrofit Standard	Scope of work	Building count [%]	Average cost per sqf (USD)
Bolts +	1) the walls are tied to the floors and roof 2) parapets are braced 3) weak floor and roof diaphragms are strengthened 4) tall brick walls are strong backed to prevent out-of-plane bending failure	215 [23]	32.44
Bolts++Frame	As above and installation of a steel frame or shear walls to strengthen the building (due to the presence of openstore fronts at street level)	344 [36]	35.15
Full Seismic	Bespoke engineered solution	385 [41]	95.47

Source: Funding URM retrofits, 2019

Following the long history of attempting to address and developing comprehensive understanding of safety risks posed by URM buildings, the council passed Resolution 32033 on December 15, 2021 directing the City to renew efforts related to the mandatory URM retrofit programme and provide ongoing funding for any additional staff necessary to establish and maintain the program and for technical experts who can assess and approve proposed upgrade plans (at this stage the resolution is a preliminary step towards the proposal to introduce a mandatory URM retrofit ordinance). The following year the URM Technical Standard Task Group was formed to update the Technical Standard prepared by the 2008 Technical Advisory Committee. The 2023 update of the URM Retrofit Technical Standard established two pathways for retrofits – the Comprehensive (code-based) method and the Alternate Method (modelled after the California's Bolts Plus). In the same year, another resolution was passed (32111) directing the City to create a voluntary URM Retrofit Ordinance using the URM Retrofit Technical Standard. This ordinance establishes a pathway for owners to voluntarily update their status on the City's URM list and exempts buildings retrofitted to

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[59] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

[60] ibid

either retrofit method in the Technical Standard from future mandatory seismic retrofitting legislation. This voluntary ordinance was planned for adoption in November 2024.[61]

TABLE 11: TECHNICAL STANDARDS FOR URM RETROFITS

Comprehensive method	**Alternate method**
improves the life safety of the building and brings the structure into compliance with seismic retrofit performance standards consistent with the Seattle Existing Building Code	provides a minimally acceptable level of safety from collapse by requiring the installation of wall anchors, wall bracing, and parapet bracing
	Qualification criteria: • 6 stories or less; risk category IV not permitted (essential services) • No weak story irregularity • Mortar shear strength > 30psi (testing required) • Wood diaphragms all levels above grade, no straight-sheathed diaphragms • Two lines of resistance in each direction, open store front buildings may add a brace to qualify • Wall piers h:w < 2:1 and at least 40 percent of the total wall length

TABLE 12. RECOMMENDED COMPLIANCE TIMELINE FOR SEATTLE URM BUILDINGS

	Critical vulnerability	**High vulnerability**	**Medium vulnerability**
	emergency service facilities and schools	buildings over three stories in poor soil areas (i.e., liquefaction and slide areas); and buildings containing public assembly spaces with occupancies of more than 100 people	all other buildings
Count as of Sept, 2024	*75*	*183*	*882*
Notification	Year 0	Year 0	Year 0
Assessment	+1 year	+2 years	+3 years
Apply for permit	+1 year	+2 years	+2 years
Approve permit	+1 year	+1 year	+1 year
Retrofit completion	+4 years	+5 years	+7 years
Total	**7 years**	**10 years**	**13 years**

Source: URM Policy Committee Recommendations (2017); Seattle URM Retrofit Program Update (2024)

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[61] Seattle Department of Construction and Inspections, Seattle URM Retrofit Program Update, October 2024. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/2024URMShakeOutupdate.pdf

In addition to the voluntary URM retrofit codes, if a building owner is planning a substantial alteration to their property, then that triggers a seismic evaluation report detailing a prioritised list of all seismic deficiencies and recommended mitigation to comply with the Seattle Existing Building Code (section 303.4.2 - Compliance with reduced International Building Code seismic forces), in addition to meeting the fire, life safety and energy conservation requirements. A project classifies as a substantial alteration when it includes any of the following:[62]

- A significant repair (a damage ratio of 60% or more, e.g. fire or severe weather damage)
- A large addition or alteration (significant investment that extends the building's useful physical and economic life, e.g replacement of the roof and windows, installation/upgrade of mechanical systems, additional floor space)
- A change to a more hazardous occupancy (e.g. office to conference rooms)
- Occupancy of a vacant building (buildings that have been mostly vacant for more than 2 years are retrofitted when they become more fully occupied)

The mandatory programme is still several years away while the City is actively pursuing the development of supportive resources, including funding options and financial incentives, in advance of adopting this mandate[63]. Currently, there is no update of whether the voluntary ordinance has been adopted, therefore no statistics have been reported to date on the number of buildings complying with the requirements established in the 2023 update of the URM Retrofit Technical Standard.

Portland, Oregon

Similarly to Seattle, Portland has long recognised the seismic vulnerability of its URM buildings. Despite multiple studies and policy discussions, efforts to introduce mandatory retrofitting of these structures have faced significant challenges[64]. Current municipal code contains passive triggers which if exceeded will require a seismic evaluation or upgrade[65]. The list of triggers includes:

- A change in occupancy or use which results in an increase in occupant load of 150 or more occupants or where more than 1/3rd of the buildings net area has changed occupancy resulting in a higher seismic hazard classification, or
- The cost of alteration or repair exceeds certain cost triggers or
- More than 50% of the roof area is being re-roofed

Seismic design requirements for existing buildings, including URM structures, were established in 1993 and incorporated into Portland City Code Chapter 24.85 in 1994, with subsequent updates in 2004. This initiative was prompted by the reclassification of Portland

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[62] Seattle Department of Construction and Inspections, *Seattle Building Code Requirements for Existing Buildings that Undergo Substantial Alterations*, December 2021. https://www.seattle.gov/DPD/Publications/CAM/cam314.pdf

[63] Amanda Hertzfeld, City of Seattle URM Program Manager, personal communication, 19 November 2024.

[64] Amit Kumar, *Unreinforced Masonry Buildings Policy Development and Current Status –City of Portland*, Presentation to OSSPAC, May 2023. https://www.oregon.gov/oem/Documents/Kumar,%20Amit_2023_05_09.pdf

[65] ibid

and the western half of Oregon into Seismic Zone 3 in 1993, highlighting the increased earthquake risk in the region[66]. As part of this effort, the city conducted a study between 1994 and 1995 to inventory commercial-use buildings. The findings revealed that URM buildings accounted for approximately 9% of the building stock, totalling around 1,850 structures. Notably, 56% of these URM buildings were single-story. By 2014, it became evident that retrofit requirements under the passive triggers have been ineffective at mitigating hazards posed by existing buildings with less than 20% of URM buildings either upgraded or demolished (109 URMs demolished, 89 fully upgraded and 129 partially upgraded). In 2014 the city council directed its staff to develop recommendations to mitigate hazards posed by URM buildings. Three committees were formed: Retrofit Standards committee (technical standards), the Support Committee (incentives and financial support) and the Policy Committee (final policy development)[67].

TABLE 13. PROPOSED URM BUILDING CLASSIFICATION

Classification [approx. # of URMs]	Description	Upgrade level
Class 1 [10]	Critical buildings (Risk category IV buildings)	Structure will remain Operational after a Design Level Earthquake
Class 2 [88]	All school buildings and Risk category III buildings	Between Life Safety and Operational performance level for a Design Level Earthquake
Class 3 [1,345]	All other URMs not categorised as URM Class 1, 2, or 4	Modified Bolts Plus, if the building qualifies, otherwise, Life Safety under Design Level Earthquake
Class 4 [195]	1 and 2-story buildings with 0-10 occupants	Parapet bracing, wall tie in and wall bracing

TABLE 14. PROPOSED URM ORDINANCE COMPLIANCE TIMELINE

Class	Step 1 ASCE 41 Assessment	Step 2 Parapet, cornice and chimney bracing and wall to roof attachment	Step 3 All bearing and exterior wall to floor attachments and out-of-plane wall strengthening	Step 4 Seismic upgrade completed (total years)
Class 1	3 years			10 years
Class 2	3 years	10 years		20 years
Class 3	5 years	10 years	20 years	25 years (+ 5 years with demonstrable hardship)
Class 4	Not Required	10 years	10 years	

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[66] City of Portland, *Unreinforced Masonry (URM) Buildings*, n.d. https://www.portland.gov/ppd/unreinforced-masonry-urm-buildings

[67] Amit Kumar, *Unreinforced Masonry Buildings Policy Development and Current Status –City of Portland*, Presentation to OSSPAC, May 2023. https://www.oregon.gov/oem/Documents/Kumar,%20Amit_2023_05_09.pdf

Between 2014 and 2016, city staff undertook a project to update and validate the URM inventory, which was subsequently made publicly accessible online through a searchable GIS platform. When the policy recommendations were presented to council several buildings owners opposed the findings due to concerns that membership on the committees did not capture the diversity of the owners, in particular small building owners. This group of owners successfully lobbied the council and the City Council did not adopt the Policy Committee report in full[68]. In 2018, the City adopted the mandatory retrofit requirements for URM Class 1 and Class 2 such as critical facilities, schools and community centres and directed the staff to develop a financial plan to retrofit city-owned properties but not for the other URM Classes (3 and 4) which made up 85% of the stock. Instead, the City Council adopted a resolution requiring all un-retrofitted URM buildings to display placards and for tenants to be notified of the associated seismic risks. However, this ordinance was repealed in 2019 after building owners filed a lawsuit against the city and a federal judge ruled it illegal. Building on earlier efforts, a second working group was established, comprising representatives of URM owners, tenants, subject matter experts, and professionals from the finance, insurance, and actuarial sectors. The group was tasked with developing financial solutions and pairing them with standards and timelines for a mandatory retrofit program, with a report to be presented to the City Council within one year. However, due to the COVID-19 pandemic and city budget constraints, the group was disbanded in 2020. Concurrently, the URM inventory was removed from public access. At present, the development of retrofit legislation remains on hold, with seismic retrofits of URM buildings proceeding only through passive triggers in the building code. While the ordinance for the retrofit of the city-owned URMs has not been repealed, the ordinance has not been implemented and there is no timeline for that work[69].

Soft Story mitigation programmes

Most of the URM buildings in California's Seismic Zone 4 have been retrofitted or demolished between the 1980's and early 2000's. Several cities in the state moved beyond URMs to mitigate hazards of other vulnerable buildings.

California's soft story residential buildings provided cost-effective form of accommodation with ground-floor parking, commercial or open spaces and residential units above. Many of these buildings were constructed using wood-frame structures and were particularly popular during the high population growth in the 1950's and 1960's. In an earthquake, soft story buildings are prone to "pancake collapse" where the heavy mass of the upper floors collapse onto the soft or weak ground level. This type of soft story design was most typically built prior to the adoption of the 1978 building code which better addressed this specific structural deficiency. After the URM buildings, soft-story wood frame construction is the most significant risk to life safety in California[70]. Their risk became especially evident during the Loma Prieta earthquake in 1989 and then in the Northridge earthquake in 1994. In the 1989 earthquake, soft story buildings in

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[68] Amit Kumar, *Unreinforced Masonry Buildings Policy Development and Current Status –City of Portland*, Presentation to OSSPAC, May 2023. https://www.oregon.gov/oem/Documents/Kumar,%20Amit_2023_05_09.pdf

[69] Amit Kumar, personal communication, 26 November 2024.

[70] Association of Bay Area Governments (ABAG), The Problem, Loma Prieta and Northridge Were a Wake-Up Call, 1996 ABAG report updated in 2003, Oakland, CA, 2003. http://www.abag.ca.gov/bayarea/eqmaps/nightmare/problem2003.pdf

San Francisco's Marina District experienced severe damage or collapse accounting for almost half of housing lost with 7,700 housing units uninhabitable[71]. Collapse of the ground floor of the Northridge Meadow apartment building in 1994 that claimed the lives of 16 residents, especially raised attention of the experts and the public. In all, the Northridge earthquake significantly damaged or destroyed around 200 soft story apartment buildings containing 34,000 housing units in the Los Angeles area[72]. ABAG[73] estimated that without proactive retrofit programmes, soft story could account for loss of two thirds of damaged buildings in a strong earthquake. Given their prevalence, not only this can result in a serious financial loss to property but significantly disrupt recovery given that the buildings house many families who are primarily renters.

Unlike the 1986 URM law which mandated 365 cities and counties in California's Seismic Zone 4 to inventory URM and establish a loss reduction programme, the statewide mandate to address soft story risk is lacking. Assembly Bill 304, Chapter 525 (2005)[74] amended Section 19160 of the California's Health and Safety Code authorising

> *cities and counties to address the seismic safety of soft story residential buildings and encourage local governments to initiate efforts to reduce the seismic risk in vulnerable soft story residential buildings.*

In other words, while the state legislature recognises the risks of soft story buildings, local mitigation efforts are encouraged but no affirmative action is required on the part of the municipalities[75]. Programmes established prior to 2010 developed its own technical standards to meet retrofit requirements when uniform soft-story seismic retrofit standards, specifications, and plans for existing residential buildings were adopted into the Chapter A4 of the California Existing Building Code. The structural criteria are intended to apply to existing wood-frame target story where the wall configuration of such story is substantially more vulnerable to earthquake damage than the wall configuration of the story above. Target story is either (1) a basement story or underfloor area that extends above grade at any point or (2) any story above grade, where the wall configuration of such basement, underfloor area, or story is substantially more vulnerable to earthquake damage. Structural retrofit does not require mitigation of all structural deficiencies achieved in a full building retrofit therefore limiting the retrofit cost while also reducing the collapse risk and increasing the likelihood of repairability

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[71] Stephen Harris and John Harris, *Effects of Ground Conditions on the Damage to Four-Story Corner Apartment Buildings*, in The Loma Prieta, California, Earthquake of October 17, 1989 - Marina District, editor Thomas O'Rourke, Department of the Interior, 1992.

[72] Rong-Gong Lin II, In a Year of Quakes, Some Cities Forgo Retrofits of Flimsy Buildings, LA Times (Sunday), 1 December 2024. https://www.pressreader.com/usa/los-angeles-times-sunday/20241201/281487871915347?srsltid=AfmBOooRRG1Tj8_udF30l3Ah0WzksbF7aBflZ_nHkFhnO3eBwrH3Me-t

[73] ABAG, 2003.

[74] California legislation, *Assembly Bill No 304, Chapter 525, amendment of the Health and Safety Code, relating to building standards*, 2005. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060AB304

[75] Kate Baldridge, *Disaster Resilience: a Study of San Francisco's Soft-Story Building Problem*, Urban Lawyer, 44(2), 2012.

and reoccupancy[76]. Stories above the uppermost story with a soft, weak, or open-front wall line shall be considered in the analysis but need not be modified. Chapter A4 allows the use of a 75 percent factor on design loads. Modern soft story ordinances require seismic retrofit to comply with either Chapter A4 of the California Existing Building Code or the latest edition of Seismic Evaluation and Retrofit of Existing Buildings [ASCE/SEI 41] with a performance objective of Structural Life Safety with the BSE-1E hazard or Structural Collapse Prevention with the BSE-2E hazard[77].

Several cities in California have conducted or are in the process of completing inventories of soft story buildings and implementing voluntary or mandatory retrofit programmes. However, the majority of local jurisdictions in the state do not mandate retrofitting. As of 2024, only 14 jurisdictions require soft story retrofitting[78]. While this list includes major population centres such as Los Angeles, San Jose, and San Francisco, the number of municipalities with active hazard reduction programmes remains significantly smaller than those established under the URM law. There also has been a long gap since the engineering community recognised the risks of soft story wood frame buildings in the 1970’s and adoption of first mandatory retrofit ordinances[79]. Survey of soft story ordinances in California shows that most of them are less than 10 years old. Experience from early adopters of soft story mitigation programs has shown that voluntary retrofit ordinances lead to slow progress and minimal hazard reduction. For example, the City of Fremont introduced a voluntary programme in 1999, but only two property owners opted to retrofit their buildings. This lack of participation prompted the city to implement a mandatory ordinance in 2007[80]. However, even a mandatory ordinance requires robust enforcement to achieve meaningful hazard reduction. The City of Santa Monica, the first jurisdiction to develop soft story seismic retrofit plans following the Northridge earthquake, faced limited compliance under its early measures, leading the city to update and strengthen its mandatory ordinance in 2017[81].

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[76] California Existing Building Code, *Chapter A4 Earthquake Risk Reduction in Wood-Frame Residential Buildings With Soft, Weak or Open Front Walls*. https://up.codes/viewer/california/ca-existing-building-code-2016/chapter/A4/earthquake-risk-reduction-in-wood-frame-residential-buildings-with-soft-weak-or#A4

[77] For example see Mill Valey Ordinance 1343, Mandatory Retrofit Ordinance for Certain Residential Buildings, https://www.cityofmillvalley.gov/DocumentCenter/View/6855/-Signed-Ordinance-No-1343

[78] Rong-Gong Lin II, In a Year of Quakes, Some Cities Forgo Retrofits of Flimsy Buildings, LA Times (Sunday), 1 December 2024. https://www.pressreader.com/usa/los-angeles-times-sunday/20241201/281487871915347?srsltid=AfmBOooRRG1Tj8_udF30l3Ah0WzksbF7aBflZ_nHkFhnO3eBwrH3Me-t

[79] Pouria Bahmani, John van de Lindt, Steven Pryor, Gary Mochizuki et al., *Performance-Based Seismic Retrofit of Soft-Story Woodframe Buildings*, STRUCTURE Magazine, June 2014, pp.24-27. https://www.structuremag.org/article/performance-based-seismic-retrofit-of-soft-story-woodframe-buildings/

[80] Kate Baldridge, *Disaster Resilience: a Study of San Francisco's Soft-Story Building Problem*, Urban Lawyer, 44(2), 2012.

[81] Seismic Ordinances of California, *Santa Monica*, n.d. https://www.seismicordinances.com/wood-frame-soft-story-structures/santa-monica

TABLE 15. SURVEY OF CALIFORNIA'S SOFT STORY MITIGATION PROGRAMMES

Jurisdiction	Ordinance type	Scope	Complete retrofit (from notice)
Los Angeles	Mandatory retrofit (2015)	~ 12,500 buildings	7 years
San Francisco	Mandatory retrofit (2013)	~ 4,950	3-7 years (depending on tier)
Berkeley	Mandatory screening and evaluation (2005) Mandatory retrofit (2014)	~370	4 years
Beverly Hills	Mandatory retrofit (2018)	229	2 ½ years
Santa Monica	Mandatory retrofit (2017)	1,686	Complete by 2025
San Jose	Mandatory retrofit (2025)	3,000-3,500	5-7 years (depending on tier, latest by 2032)
Oakland	Mandatory retrofit (2019)	~1,480	4-6 years (depending in tier, latest by 2025)
Fremont	Mandatory retrofit (2007)	~28	5 years
Albany	Mandatory retrofit (2023)	134-164	2-5 years (depending on tier, latest by 2029)
Mill Valley	Mandatory retrofit (2023)	52-125	3-6 years (depending on tier)
Torrance	Mandatory retrofit (2023)	~985	5 years
Pasadena	Mandatory retrofit (2019)	~500	7 years
Culver City	Mandatory retrofit (2021)	~609	5 years (latest by 2029)
West Hollywood	Mandatory retrofit (2017)	~780	5 years
In progress:			
Burbank	Mandatory retrofit ordinance proposed; 1st reading passed unanimously, 2nd reading in December, 2024	~675	
Mountain View	Programme under consideration; Soft story study completed in 2018	~488	
Palo Alto	Programme under consideration; Soft story study completed in 2016	~294	

Source: Seismic ordinances; Degenkolb; Rong-Gong Lin II (2024)

All cities have certain milestones that must be met before deadlines to ensure owners do not wait until the last minute (screening, retrofit plans, building permit, complete construction). Most ordinances apply to buildings built before 1978, however some jurisdictions target wider range of construction, for example, San Jose – pre-1990 and Alamedia – pre-1985. While it is important to consider technical aspects of implementing seismic retrofits, programmes require community buy-in and must represent a balance between the economic, social and political aspects of the specific jurisdiction. Soft story retrofit ordinances have shorter compliance requirements since a targeted retrofit focuses on addressing a specific weakness - strengthening soft story - in a building's structure that is most likely to fail during an earthquake rather than requiring owners to undertake a full seismic retrofit.

Los Angeles

On January 14, 2015, Los Angeles City Council was presented with the recommendations in the *Resilience by Design* report prepared by the Mayoral Seismic Safety Task Force[82]. The report was an outcome of a formal partnership between the City of Los Angeles and US Geological Survey (USGS) to provide scientific advice to the city as it created a plan to address its seismic vulnerability. As part of this partnership, one of the report's lead authors and a geologist from USGS, Dr Lucy Jones, spent a year in the mayor's office. The Task Force also brought in structural engineers from the Structural Engineers Association of Southern California (SEAOSC). The Task Force evaluated four areas of seismic vulnerability, namely:

- Pre-1980 non-ductile reinforced concrete buildings
- Pre-1980 soft story buildings
- Water system infrastructure (including impact on firefighting capability)
- Telecommunications infrastructure

Given the strong interdependence of resilient buildings and infrastructure, the recommendations for the four areas were developed in parallel to address overlap. Recommendations that required ordinances were unanimously passed in 2015 and 2016[83]. To reduce vulnerabilities of existing buildings, the city mandated retrofits of pre-1980 nonductile concrete and soft story buildings, in addition to a mandatory evaluation and retrofit of buildings that experienced substantial damage at -lower levels of shaking. One of the notable differences in developing the ordinance was the deliberate effort to engage the stakeholders and seeking the input of owners regarding seismically retrofitting their buildings. Instead of being placed in a reactionary position after being poorly informed about the seismic issues and how to respond to the mandates, involving a wide range of stakeholders from the early stages contributes a greater chance of successful adoption[84].

The soft story ordinance created a three-step process to complete the retrofits and applied to existing wood-frame multi-story buildings with soft, weak or open front walls constructed before 1 January, 1978 and containing four or more units. Compliance with the ordinance did not require upgrade of other non-structural building systems (electrical, plumbing, mechanical,

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[82] Mayoral Seismic Task Force, *Resilience by Design*, 2014. https://www.usrc.org/wp-content/uploads/LA-Resilient-by-Design.pdf

[83] Lucile Jones, *Resilience by Design*, Engineering for Disaster Resilience, 49(2), 2019. https://www.nae.edu/19579/19582/21020/212135/212175/Resilience-by-Design

[84] Michael Cochran, Dilip Khatri, Kevin O'Connell, and Doug Thompson, *Seismic Strengthening of Buildings in Los Angeles*, STRUCTURE Magazine, November 2015, pp.20-22. https://www.structuremag.org/issues/2015-digital-issues/november-2015/

fire) unless they constituted risk to life or property. Owners were given seven years to complete construction or demolish their buildings. The soft story inventory contained over 12,000 buildings[85] and the city began issuing notices in May, 2016.

TABLE 16. LOS ANGELES SOFT STORY ORDINANCE BUILDING CLASSIFICATION AND COMPLIANCE TIMEFRAME

Priority	Building category	Order issued	Complete construction
I. 16 or more dwelling units	3-story and above	May 2016	May 2023
	2 story	July 2016	July 2023
II. 3 or more stories	< 16 units	October 2016	October 2023
III. Buildings not falling within the definition of Priority I or II	9-15 units	July 2017	July 2024
	7-8 units	August 2017	August 2024
	4-6 units	September 2017	September 2024
	Condos/commercial	November 2017	November 2024

From the receipt of the Order to Comply, building owners had:

- 2 years to submit plans to retrofit or demolish, or proof of previous retrofit
- 3.5 years to obtain permit to start construction or demolition
- 7 years to complete construction or demolition

The city staggered the issuance of retrofit orders based on building priority. However, all owners were given a 7-year compliance timeframe from the receipt of their order. Due to the large number of buildings in the inventory, implementing financial incentives and subsidies was deemed less feasible, leaving building owners responsible for covering retrofit costs.

To alleviate some financial pressures, the city enacted a cost-sharing ordinance, allowing property owners to pass through 50% of seismic retrofit costs to tenants, amortised over 120 months, with a monthly cap of USD 38. In cases where expenses exceeded the cap, collection extensions were permitted.

A 2022 study[86] estimated that targeted soft-story retrofits—such as adding ground-story shear walls, steel frames, or both—cost between USD 80,000 and USD 160,000 per building, or approximately USD 11,000 per housing unit.

The most recent data from the Los Angeles Department of Building and Safety (LADBS) indicates that as of February 2024, 76% of the buildings had either completed construction or been demolished.

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[85] Exact number varies in different publications, LADBS Feb 2024 report identifies 12,347 buildings, Rong-Gong Lin II (LA Times October 20, 2022 article) mentions 12,604 buildings

[86] Keith Porter, *ShakeOut 2022 Los Angeles Soft Story Benefits Report*, 2022. https://drive.google.com/file/d/1Yyht5ZnBHLHSV0zivCjQdZ2V_fT7dsmL/view

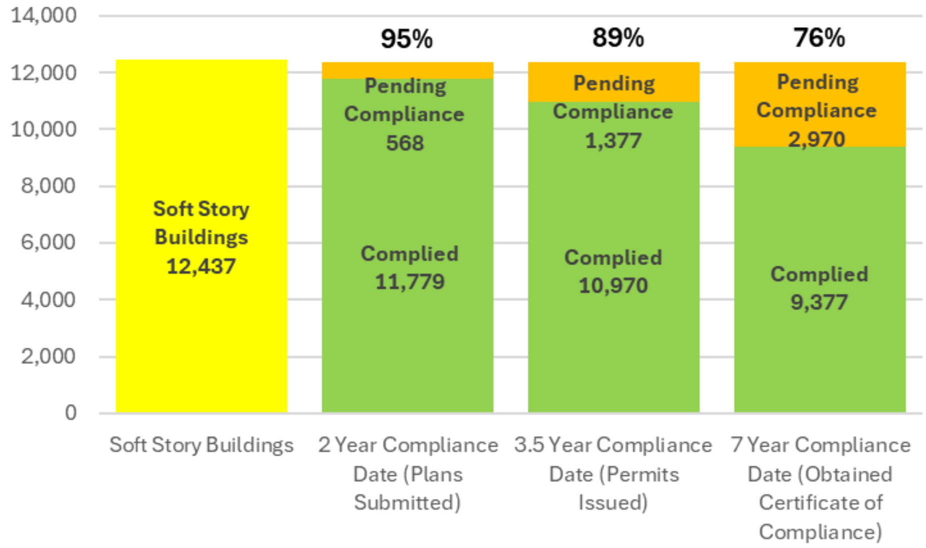

FIGURE 1. SOFT STORY RETROFIT PROGRAM STATUS AS OF FEBRUARY 1, 2024 (LADBS)

San Francisco

The 1989 Loma Prieta earthquake caused significant failure of multiunit residential soft story buildings in San Francisco's Marina District. In the district, seven buildings collapsed and another 65 were moderately to heavily damaged. Soft story failure accounted for six of the seven collapses and nearly a third of the moderately to heavily damaged buildings (18 out of 65)[87]. The earthquake had a profound impact on the affordable rental, commonly found in this type of buildings. Comerio et al.[88] found that four years after the Loma Prieta earthquake half of the units in apartment buildings that were destroyed or significantly damaged were still not repaired or replaced. Although the earthquake was less severe than the "design level" earthquake, modern structures suffered significant damage[89]. Therefore, given the possibility of a more severe event in the San Francisco Bay area resulting in large-scale repair or replacement of the housing stock, San Francisco Department of Building Inspection (DBI) formed the Community Action Program for Seismic Safety (CAPSS) in 2001. CAPSS was created to inform policy decisions and actions by DBI and other city agencies and policymakers for reducing earthquake risks in existing, privately-owned buildings regulated by DBI and also to develop repair and rebuilding guidelines that will expedite recovery after an earthquake[90]. Initially, the project was completed in 2003 but results were not published and

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[87] Stephen Harris and John Harris, *Effects of Ground Conditions on the Damage to Four-Story Corner Apartment Buildings*, in The Loma Prieta, California, Earthquake of October 17, 1989 - Marina District, editor Thomas O'Rourke, Department of the Interior, 1992.

[88] Mary Comerio, John Landis, and Yodan Rofe, *Post Disaster Residential Rebuilding*, Institute of Urban and Regional Development, University of California, Berkeley, CA., cited in Laura Samant et al., Mitigating San Francisco's Soft-Story Building Problem, ATC & SEI 2009 Conference on Improving the Seismic Performance of Existing Buildings and Other Structures, 2009.

[89] Nicholas Carino, *Chapter 4 Performance of Buildings*, in Performance of Structures During the Loma Prieta Earthquake of October 17, 1989, H.S Lew editor, NIST Special Publication 778, 1990.

[90] Laura Samant, Keith Porter, Kelly Cobeen, L. Thomas Tobin, Laurence Kornfield, Hope Seligson, Simon Alejandrino, and John Kidd, *Mitigating San Francisco's Soft-Story Building Problem*, ATC & SEI 2009 Conference on Improving the Seismic Performance of Existing Buildings and Other Structures, 2009.

the work suspended until 2006. In 2008 the Mayor of San Francisco directed the staff to expedite the study of soft story buildings under CAPSS[91]. In 2010, CAPSS made the following recommendations for the soft story programme in the City:

- Establish a mandatory programme for soft story buildings built before May 21, 1973 with three or more stories and five or more residential units;
- Develop a technical standard that will allow many of them to be occupied after a large earthquake;
- Offer immediate incentives to encourage voluntary retrofits;
- Require retrofits completed within four years of notification;
- Establish a working group to implement the recommendations.

Following this set of recommendations, the city enacted their mandatory soft story retrofit ordinance in 2013. The ordinance applies to wood-frame buildings of three or more stories and containing five or more residential dwelling units where the permit to construct was applied for prior to January 1, 1978, and where the building has not yet been seismically strengthened. Screened buildings require work be done to the lower level (only) the building (targeted retrofit), and completion of the work is determined according to the tier in which the building has been screened. Owners who do not complete the steps by the deadline are in violation of this programme and are subject to the enforcement of the San Francisco Building Code. Buildings that are in violation are posted with an "Earthquake Warning" placard noticing the building's owner, tenants, and public of the risk posed by the building. Owners that fail to abate the violation are sent to a Director’s Hearing and an assessment of compliance costs can be applied to the property. However, a 2023 investigation discovered that numerous buildings in violation of the ordinance did not display the warning placards[92].

The program screened 4,941 buildings, with the latest retrofits scheduled for completion by September 2021. This timeline applied to properties in Tier IV, which included buildings with commercial spaces on the ground floor. To address the complexities of retrofitting such properties, particularly those involving the temporary relocation of tenants, an extended compliance timeline was introduced to mitigate the additional burden on property owners.

The ordinance also triggered requirements for compliance with the Americans with Disabilities Act (ADA) for buildings with commercial uses. It was reported that finding qualified ADA specialists willing to work on smaller projects has been a significant challenge[93]. To help alleviate retrofitting expenses some owners opted to add Accessory Dwelling Units (ADUs) to generate additional rental income stream by converting some of the ground floor areas. The local planning rules allow unlimited number of ADUs on projects undergoing Mandatory or Voluntary seismic upgrades[94]. In addition, the 2010 amendment of California’s Proposition 13 provides that construction to seismically retrofit existing buildings will not trigger reassessment of property tax value, regardless of the type of building, the exclusion is not time limited and

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[91] Keith Porter and Kelly Cobeen, *Informing a Retrofit Ordinance: A Soft-Story Case Study*, Proceeding of 2012 Structures Congress, Chicago IL, March 29-31, 2012.

[92] Hilda Gutierrez, *Hundreds of San Francisco buildings are behind on earthquake retrofits, putting lives at risk*, NBC Bay Area, 6 July 2023. https://www.nbcbayarea.com/investigations/soft-story-retrofits-in-san-francisco/3267556/

[93] John A. Dal Pino, and James Enright, *The San Francisco Soft-Story Ordinance*, STRUCTURE Magazine, March 2019, pp. 8-10. https://www.structuremag.org/issues/2019-digital-issues/march-2019/

[94] San Francisco Planning, *Accessory Dwelling Units*, n.d. https://sfplanning.org/accessory-dwelling-units

applied until the building is sold (original law applied to retrofits of URM and was limited to 15 years).

The latest compliance statistics indicate that 94% of buildings have been retrofitted and 288 buildings remain in violation. The highest non-compliance rate is among Tier IV buildings which is currently around 11%. DBI regularly updates the city's map of soft story buildings and public can look up the current status of screened properties[95].

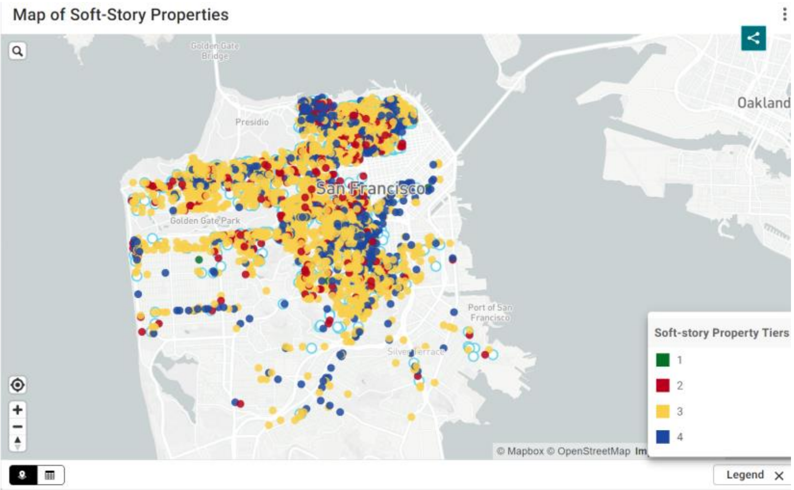

FIGURE 2. MAP OF SOFT STORY PROPERTIES - SAN FRANCISCO OPEN DATA PORTAL

TABLE 17. SAN FRANCISCO SOFT STORY ORDINANCE BUILDING COMPLIANCE TIERS AND TIMELINE[96]

Compliance tier	Property category	Permit application	Complete construction
I	Any building containing educational, assembly, or residential care facility uses	September 2015	September 2017
II	Any building containing 15 or more dwelling units	September 2016	September 2018
III	Any building not falling within another tier	September 2017	September 2019
IV	Any building containing ground floor commercial uses, or any building in a mapped liquefaction zone	September 2018	September 2021

TABLE 18. SOFT STORY INVENTORY AND COMPLIANCE STATUS AS OF DECEMBER 2024

Status	**Tier**				**Total**
	I	**II**	**III**	**IV**	
Work complete	7	496	3227	921	**4651**
Non-compliant		18	166	104	**288**
Newly added			1	1	**2**
Total	**7**	**514**	**3394**	**1026**	**4941**

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[95] San Francisco Open Data Portal, Map of Soft-Story Properties, n.d. https://data.sfgov.org/Housing-and-Buildings/Map-of-Soft-Story-Properties/jwdp-cqyc

[96] San Francisco Department of Building Inspection, *Mandatory Soft Story Program*, n.d. https://wayback.archive-it.org/20246/20221105001800/https://sfdbi.org/softstory

Berkeley

In 1996 the City of Berkeley conducted a survey of soft story buildings containing five or more units that were designed prior to adoption of the 1997 Uniform Building Code and identified nearly 400 such buildings. A side-walk assessment by professional engineers of 150 identified properties estimated that 46% would suffer severe damage in a major earthquake and another 49% would have moderate vulnerability. After establishing the scale of the vulnerability, the city implemented a two-phased soft story ordinance.

In 2005 the city passed Phase 1 of the ordinance which established the Inventory of Potentially Hazardous Buildings, provided for the notification of owners and tenants of buildings on the inventory and required mandatory evaluations of buildings' seismic adequacy. The ordinance adopted Chapter 4 of the 2003 International Existing Building Code for voluntary retrofits and provided a 15-year exemption for retrofitted buildings to be identified as potentially hazardous. Between February and October 2016, the city sent out notices to 321 buildings[97]. Within two years of receiving the notice, the owners were required to submit engineering analysis of their building, notify tenants in writing of the building listing on the inventory and submit a copy of the letter to the city, and post a clearly visible earthquake warning sign until the building is removed from the inventory. The ordinance included penalties for non-compliance, however, in practice enforcement was handled at the discretion of the city's Building Inspection Division (BDI) that managed the programme. Although the BDI sent out initial letters of non-compliance between 2009-10, as of 2011 no penalties were issued[98]. Surprisingly, while past experience of voluntary programmes resulted in low retrofit rates, as the result of the 2005 mandatory screening and evaluation ordinance, 40% of buildings were retrofitted according to a 2013 report[99].

To evaluate the feasibility of Phase 2, the city conducted an economic analysis of building owners to determine their financial capacity to fund retrofits without incentives or subsidies. The estimated retrofit cost was approximately US$50,000 per building[100]. The study found that most owners would be able to afford retrofits[101]. The mandatory retrofit ordinance took effect in January 2014 and added 47 buildings to the inventory. Owners were required to apply for a building permit by December 31, 2016, and complete the seismic retrofit work within two years after submitting their permit application by December 31, 2018.

The city offered one-year extensions to complete retrofit work for owners in financial hardship. Design and Construction Grants are also available through the city's Retrofit Grants Scheme. For owners of soft story buildings with 5 or more residential units, owners can receive up to US$5,000 in design grant (capped at 75% of design costs) and US$25,000-150,000 in construction grant (capped at 40% of construction costs).

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[97] Sharyl Jean Marie Rabinovici, *Motivating Private Precaution with Public Programs: Insights from a Local Earthquake Mitigation Ordinance*, Thesis, Doctor of Philosophy in Public Policy, University of California, Berkeley, 2012.

[98] ibid

[99] Berkeleyside, *Berkeley renews focus on retrofitting soft-story buildings*, 26 July 2013. https://www.berkeleyside.org/2013/07/26/berkeley-renews-focus-on-retrofitting-soft-story-buildings

[100] ABAG, *Soft Story Retrofit Program Development*, ABAG Publication #P16001EQK, March 2016.

[101] ABAG, Soft-Story Housing Improvement Plan for the City of Oakland, October 2014.

As of December 2024, the inventory listed 369 buildings. The only remaining non-compliant buildings were not on the original inventory and were newly added.

TABLE 19. BERKELEY SOFT STORY BUILDINGS STATUS AS OF DECEMBER 2024[102]

Retrofit completed	**Retrofit**	**284**
Removed:	< 5 units	38
	Not soft story	22
	Newer building	1
	Demolished	1
Applied for permit:	Permit issued	6
	Permit in review	11
Out of compliance:	Newly added	6
Total		**369**

As discussed in Weizer[103], California's approach to soft-story retrofitting has evolved through regional influences, with jurisdictions often adapting and refining ordinances based on neighbouring cities' policies. A distinct pattern emerges between Northern and Southern California, where larger cities lead in implementing seismic resilience measures, prompting smaller jurisdictions to follow suit. For example, in Northern California, Oakland's 2019 ordinance closely mirrors San Francisco's 2013 priority tier system, demonstrating how cities leverage existing frameworks to streamline retrofits. Similarly, Southern California saw Los Angeles spearhead a major ordinance in 2015, followed by Long Beach (2016), Santa Monica and West Hollywood (2017), Beverly Hills (2018), and Pasadena and Burbank (2019). Larger cities like San Francisco and Los Angeles, with greater resources and expertise, set the precedent, while smaller cities benefit from their research and guidance. Collaboration and communication among jurisdictions are key, as earthquake resilience must extend beyond city boundaries to ensure a coordinated and efficient recovery effort. Though regional trends shape policy, each city adapts ordinances to fit local priorities and constraints rather than applying a one-size-fits-all approach.

Non-ductile concrete buildings

Non-ductile concrete (NDC) buildings are common type of construction in California. Their presence is also widespread internationally and they represent one of the greatest life safety hazards because of their collapse potential in earthquakes. The poor performance of NDC buildings has been repeatedly observed in the moderate 1994 Northridge earthquake and more recent earthquakes in Mexico, Taiwan, New Zealand and Türkiye. Many NDC buildings have high occupancies. In the LA city, while 1-3 story buildings are the most common, high-rise buildings with 8 stories or more represent approximately 40% of space[104] . In California,

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[102] City of Berkeley, Mandatory Earthquake Retrofit Programs, https://berkeleyca.gov/construction-development/seismic-safety/mandatory-earthquake-retrofit-programs#:~:text=If%20you%20own%20an%20unreinforced%20masonry%20or%20soft,for%20these%20improvements%20through%20seismic%20retrofit%20financing%20programs.

[103] Griffin Weizer, *Ensuring Resilience: Efforts to Retrofit Soft-Story Housing in California*, Thesis Quality Research Project Submitted in Partial Fulfilment of the Requirements for the Master of Public Administration, San Jose State University, May 2020.

[104] Mary Comerio and Thalia Anagnos, *Los Angeles Inventory: Implications for Retrofit Policies for Nonductile Concrete Buildings*, 15th World Conference on Earthquake Engineering, Lisboa, 2012.

NDC buildings were built between late 1800's and mid-1970's when codes for ductile concrete were enforced. Mitigating hazards posed by NDC buildings is challenging due to the number of potentially vulnerable buildings[105] and the variety of structural systems and configurations. The size and complexity of buildings drive the cost of retrofitting significantly, often exceeding several million dollars. While life safety risks are well known among structural engineers and building officials, addressing these risks with mitigation policies exist in isolated cases within California.

Currently, only four mandatory NDC programmes operate in California, all in the greater Los Angeles area, for pre-1980s construction. In addition, LA County is considering a move to mandatory retrofit for pre-1977 high-rise (more than 75 feet above the lowest access level) NDC buildings. Proposed ordinance would require owners to submit structural analysis and retrofit or demolition plans within 7 years of notice, complete demolition, if opting for demolition, within 10 years or otherwise complete retrofit work within 20 years. The ordinance was expected to be presented to council in 2024. Since 2021 the city of Long Beach has been developing a Building Resiliency Program and conducting a seismic resilience study for vulnerable buildings including NDC. While the city is preparing the inventory, owners are encouraged to complete voluntary retrofits. Similarly, the city of Berkeley encourages voluntary retrofits for NDC buildings with assistance of design and construction grants. Lastly, the City of San Francisco is developing a programme to identify and strengthen vulnerable concrete buildings and established Stakeholder Engagement Group. The group published its report in April 2024 for the Concrete Building Safety programme[106]. While the programme is more comprehensive, extending to pre-2000s construction, at the moment there are no plans to introduce mandatory retrofit requirements limiting the scope of proposed ordinance to screening of vulnerable structures.

In 2015 the City of West Hollywood conducted a study to identify seismic safety issues in the existing buildings and develop a framework for a seismic retrofit programme (WEHO). Consequently, in 2017 the city adopted mandatory retrofit ordinances for wood frame soft story buildings (effective April 2018) and NDC and Pre-Northridge Steel Moment Frame buildings (effective August 2018). The NDC ordinance prioritised the buildings based on the number of stories which is used for issuing of notices. From receiving the notification letter, building owners follow a two-phase approach for compliance. A set of expected deliverables are set for each phase as outlined below. The West Hollywood NDC ordinance has two notable differences from the Los Angeles Ordinance – allowance for the phased approach and exclusion of condominiums (also referred to as **Residential Common Interest Development** (CID) which involves individual ownership of a residential unit along with shared ownership or responsibility for common areas and amenities within the development; CIDs are conceptually similar to New Zealand's Unit Title properties which would include apartments).

1. Phase I
    a. 3 years from notification – submit engineering report and determination of all structural deficiencies. Engineering report is a combination of the Screening Form and Feasibility Study prepared by a civil or structural engineer.
    b. 5 years from notification - submit retrofit plans for major deficiency mitigation.

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[105] California Seismic Safety Committee estimates that there are 40,000 NDC buildings in CA as cited in Craig Comartin et al., *The Concrete Coalition: Building a Network to Address Nonductile Concrete Buildings*, 14th World Conference on Earthquake Engineering, Beijing, 2008.

[106] City and County of San Francisco, Concrete Building Safety Program, n.d. https://onesanfrancisco.org/concrete-building-safety-program

   c. 7 years from notification – obtain major deficiency retrofit building permit.
   d. 10 years from notification - complete major deficiency construction.
2. Phase II
   a. 13 years from notification - Submit Retrofit Plans for Remaining Structural Deficiencies.
   b. 15 years from notification - Remaining Deficiency Retrofit Building Permit.
   c. 20 years from notification - Complete Remaining Deficiency Construction.

TABLE 20. SURVEY OF LOCAL MANDATORY NON-DUCTILE CONCRETE BUILDINGS RETROFIT PROGRAMMES

Jurisdiction	Retrofit	Scope	Compliance date
Los Angeles	Mandatory (2015)	~1,200 buildings	Complete retrofit or demolish within 25 years of service of order by 2041
Santa Monica	Mandatory (2017)	~ 70	Complete retrofit within 10 years from notice by 2027
West Hollywood	Mandatory (2017) (effective 2018)	~55; Prioritisation: I – 8 or more stories II – 3 – 7 stories III – 2 or less stories	Two-phase approach **Phase 1:** Engineering report and major deficiency mitigation – within 10 years from notice (major deficiencies include: load path, weak or soft story, vertical irregularity, torsion, captive column); Phase 2: complete retrofit – 20 years from notice (10 additional years from Phase 1)
Torrance	Mandatory (2023)	~50 Prioritisation: I – 3 or more stories II - 2 stories and 7 or more units III – not in I & II	Two-phase approach as in West Hollywood

Los Angeles

Reducing the risk of NDC buildings[107] was one of the recommendations in the *Resilience by Design* report prepared by the Mayoral Seismic Safety Task Force to improve the resilience of Los Angeles following a major earthquake[108]. The mandatory NDC ordinance was enacted at the same time with the soft story retrofit ordinance. The purpose of the Non-Ductile Concrete

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[107] Applies to any existing concrete building built pursuant to a permit application for a new building that was submitted before January 13, 1976, or, if no permit can be located, the structure is determined by the Department of Building and Safety to have been built under building code standards enacted before January 13, 1976

[108] Mayoral Seismic Task Force, *Resilience by Design*, 2014. https://www.usrc.org/wp-content/uploads/LA-Resilient-by-Design.pdf

(NDC) Ordinance[109] is to reduce the seismic risk of existing non-ductile concrete buildings and requires all concrete buildings designed prior to January 13, 1977 to complete retrofit to achieve the minimum engineering standard outlined in the ordinance by 2041 within 25 years of receiving the "Order to Comply" notice from the City, or be demolished. The ordinance requires the retrofit design to meet one of the following criteria:[110]

1. Strength of the lateral-force resisting system shall meet or exceed 75% of the seismic base shear specified in "The Equivalent Lateral Force Procedure" of the current Los Angeles Building Code. Elements not designated to be part of the lateral-force resisting system shall be adequate for gravity load effects and seismic displacement due to the full (100%) of the design story drift specified in the current Los Angeles Building Code seismic provisions.
2. Meet or exceed the requirements specified for "Basic Performance Objective for Existing Buildings" of ASCE 41, using a Tier 3 procedure and the two level performance objective for existing buildings (BPOE) in Table 2-1 of ASCE 41 for the applicable risk category, and using ground motions and procedures established by the Department.

Building owners within the scope of the programme are required:

- Within three years after service of the order submit on the form provided by the Department of Building and Safety a completed checklist for the Department to review and approve
- If the building is determined to be a non-ductile concrete building, within ten years after service of the order, submit a detailed evaluation of the building documenting whether the building meets or exceeds the requirements set in the ordinance
- Within 25 years after service of the order, complete all necessary retrofit work on the building or demolition.

The inventory of NDC buildings contained 1,194 active buildings.

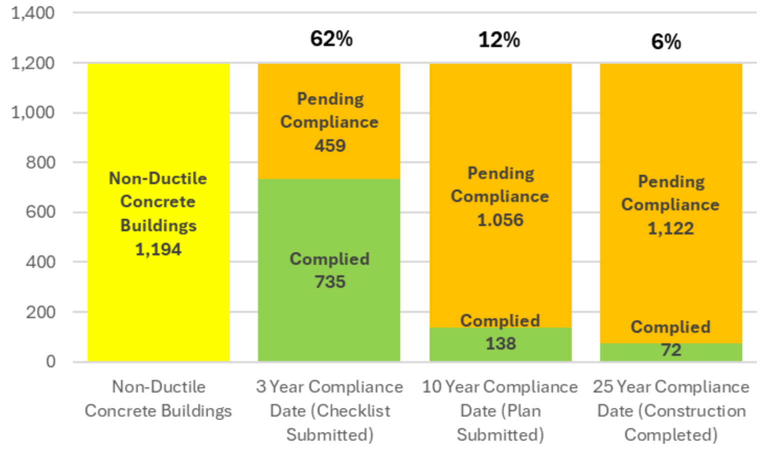

FIGURE 3. STATUS OF THE LOS ANGELES NDC BUILDINGS ORDINANCE COMPLIANCE AS OF FEBRUARY 2024

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[109] Los Angeles Municipal Code, Division 95, *Mandatory Earthquake Hazard Reduction in Existing Non-Ductile Concrete Buildings*, 2015. https://codelibrary.amlegal.com/codes/los_angeles/latest/lamc/0-0-0-182349

[110] Ibid, Section 91.9508. Engineering Analysis

Several years into the LA's mandatory NDC building ordinance, NDC Working Group was formed under the initiative of the Mayor's Office. The group was set up to analyse the retrofit programme implementation and provide recommendations for improvement of unforeseen impacts of the ordinance. Following meetings with a range of stakeholders including property owners, developers, engineers, contractors, advocacy groups and city officials, the group published a white paper in October 2021[111]. At six years into the NDC programme, only 31% of owners completed the 3-year compliance goal of submitting a checklist. It was noted that although the ordinance does state that it is unlawful to occupy buildings that fail to meet ordinance requirements, there is no explicit penalty for not meeting the time limit for compliance. Due to lack of enforcement and penalties, owners may be taking a "wait and see" approach to understand the consequences of missing the 25-year time limit. Retrofit cost remains a significant impediment to retrofits. With evidence from a small sample of completed retrofits under the ordinance, it was found that retrofit costs alone range between US$ 30-50 per sqf, however when combined with peripheral works such as partial demolitions, building systems upgrade, tenant relocation, interior fitouts, accessibility etc, the cost of comprehensive seismic retrofit is pushed to US$50-100 per sqf. For an average 7-story, 68,000 sqf (~6,300 sqm) building in the programme, total retrofit work can range from US$2.1m to US$6.8m. It was also observed that it was difficult for property owners or developers to secure bank lending to fund retrofits because presently the retrofitted buildings do not generate increased rents. Therefore, in the current environment retrofits are not financially feasible for most owners without alternative mechanisms to offset retrofit cost or increased income stream after retrofit. The group found that enabling conversion of NDC buildings to housing through planning incentives (e.g. allowing greater density) can be an important way to encourage property owners to retrofit their buildings while at the same time making a positive difference in the housing shortage and neighbourhood revitalisation.

The Los Angeles experience reinforces earlier observations about the URM programmes when mandatory ordinances lack enforcement, the program can lose momentum and become stagnant as some property owners choose to miss deadlines if they feel that there are no repercussions[112].

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[111] Omgivning, White Paper: Non-Ductile Concrete Buildings, NDC Working Group, Los Angles, California, October 2021. https://www.bing.com/ck/a?!&&p=54b81c56110c13e0d8a704a1f5fd4fa4838d50bfd170116d3ffeaf50af6e25a4JmltdHM9MTczODM2ODAwMA&ptn=3&ver=2&hsh=4&fclid=37fb3471-711d-69b8-3f1e-2172708d68a5&psq=White+Paper%3a+Non-Ductile+Concrete+Buildings&u=a1aHR0cHM6Ly9hc3NldHMuY3RmYXNzZXRzLm5ldC96Nzg0NzVvcjZpM2QvNnU1WmIzZEpocWoxSGFXZTYxVlIwRS8yOWZjNzZhOTcxZTAzYTYzOWIwNGIwZjZmYjJlYTU2Ny8yMTEwMjVfTkRDX1doaXRlX1BhcGVyX18xXy5wZGY&ntb=1

[112] National Development Council, *Funding URM Retrofits: Report to the City of Seattle*, May 2019. https://www.seattle.gov/documents/Departments/SDCI/Codes/ChangesToCodes/UnreinforcedMasonry/FundingURMRetrofits.pdf

Part II: Seismic Risk Mitigation for Existing Buildings in Other International Jurisdictions

Taiwan

Over the past few decades, Taiwan has experienced several catastrophic earthquakes, including the 1999 Chi-Chi earthquake and more recent events such as the 2016 Meinong, 2018 Hualien and the 2024 Hualien earthquakes. These events have underscored the need for robust building resilience, especially in older reinforced concrete structures, the dominant form of construction in the country, with over three quarters of the existing stock built before 1999[113].

Since the 1999 Chi-Chi earthquake, the central government implemented seismic retrofit policies for public buildings and schools and privately-owned buildings. During the Chi-Chi earthquake approximately 4,600 public buildings were damaged. In June 2000, the Taiwan Government established the "Building Seismic Assessment and Strengthening Programme"[114]. The programme targets public buildings (31,146 buildings), such as government offices, hospitals, schools and other essential service buildings built prior to May 1997 to ensure their functionality during and after an earthquake[115]. There are 3 stages of this program: preliminary assessment (30,348), detailed assessment (16,207) and retrofitting (9,369) or demolition (2,179) (if considered not suitable for retrofitting). As of 2022, out of 31,146 public buildings, 97% completed preliminary assessments. It was found that 10,143 buildings required retrofitting and 2,445 buildings required demolition. As a result, 9,369 buildings completed retrofitting while 2,179 properties were demolished[116] (these statistics include mitigated public schools discussed below).

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[113] Shyh-Jiann Hwang, Seismic retrofitting for school buildings in Taiwan, Thailand Symposium on Earthquake Research, keynote presentation, 2023. http://www.earth-th.org/TSER2023/assets/docs/Keynote_ProfHwang_abstract.pdf

[114] Richard Henry, Bo-Yao Lee, David McGuigan, John Finnegan and Gordon Ashby, *The 2016 Meinong Taiwan Earthquake: Learning from Earthquakes Report*, Bulletin of the New Zealand Society for Earthquake Engineering, 50(3), 2017.

[115] Guy Carpenter, Chi-Chi Earthquake: Resilience After 24 Years, 2024. https://www.guycarp.com/insights/2024/09/chi-chi-earthquake-resilience-after-25-years.html

[116] ibid

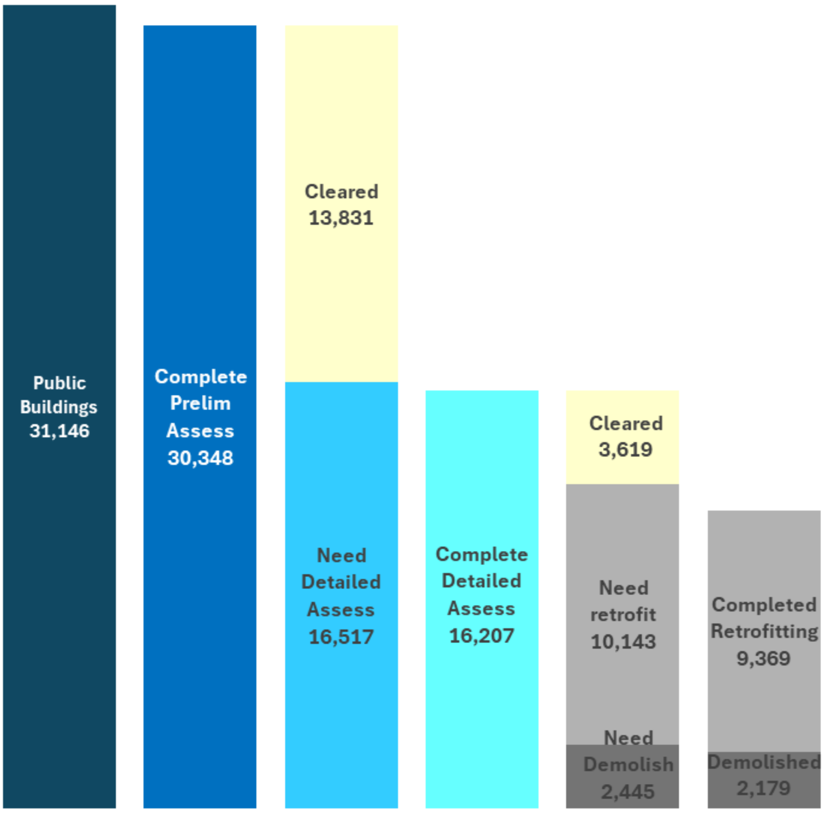

FIGURE 4. ASSESSMENT STAGES OF PUBLIC PROPERTIES[117]

The retrofitting of public schools has been a significant priority of the central government to ensure the safety of students and staff during earthquakes. In the Chi-Chi earthquake, more than half of the school buildings in Nantou County were either partially or fully destroyed[118]. Soon after the earthquake, National Centre for Research on Earthquake Engineering (NCREE) was engaged to develop technologies for the seismic evaluation and retrofit. NCREE conducted laboratory and on-site experiments which led to the development of seismic technologies including the evaluation procedures and retrofit design methods. At the conclusion of the project in 2008, NCREE published the output of its research in “Technology Handbook for Seismic Evaluation and Retrofit of School Buildings”[119]. From 2009 to 2022, the government funded NTD 128.4 billion for seismic assessments and retrofitting of schools. Retrofits were prioritised based on risk assessments and building age. In this period, the seismic capacities of 9,550 school buildings were upgraded, which accounts for about 37% of

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[117] Guy Carpenter, Chi-Chi Earthquake: Resilience After 24 Years, 2024. https://www.guycarp.com/insights/2024/09/chi-chi-earthquake-resilience-after-25-years.html

[118] Shyh-Jiann Hwang, Seismic retrofitting for school buildings in Taiwan, Thailand Symposium on Earthquake Research, keynote presentation, 2023. http://www.earth-th.org/TSER2023/assets/docs/Keynote_ProfHwang_abstract.pdf

[119] Shyh-Jiann Hwang, Fu-Pei Hsiao, Lap-Loi Chung et al., Strategy for Seismic Upgrading of Public School, Australian Earthquake Engineering Society 2010 Conference, Perth, Western Australia, 2010.

the total school buildings in Taiwan[120]. The effectiveness of school building retrofitting was demonstrated in subsequent events. Retrofitted buildings experienced only minimal damage in the 2010 Jiaxian earthquake, the 2016 Meinong earthquake and the 2018 and 2024 Hualien earthquakes. NCREE has been assisting the Ministry of Education with the implementation of the school retrofit programme by establishing a School Project Office for the purposes of technical and administrative support, as well as training and workshops for school management staff and engineers[121].

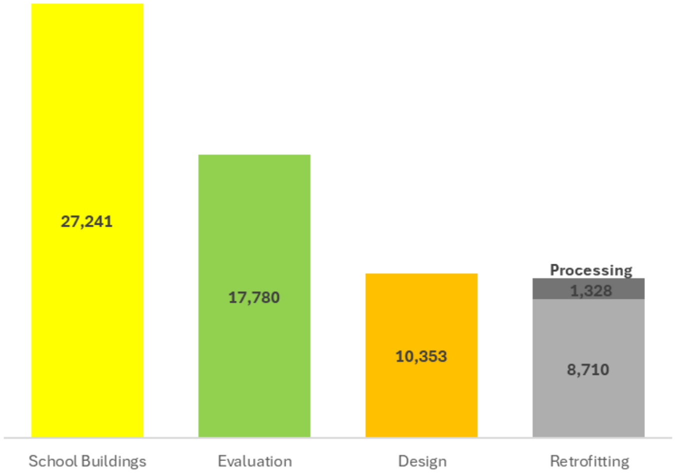

FIGURE 5. TAIWAN'S SCHOOL RETROFITTING PROJECT[122]

Retrofitting private buildings is more challenging due to complexities of multiple ownership, financial burden of permitting and construction costs. Since many of vulnerable buildings used for residential accommodation, there is an additional burden of housing cost for temporary relocation. To address these challenges, the government approved the Nationwide seismic assessment and retrofit plan in 2018[123]. In 2019, the national “Private Building Seismic Weak Story Retrofit Program” was launched to address structural vulnerabilities in privately-owned buildings. This program represents a significant policy initiative aimed at improving public safety and minimising loss of life and property during earthquakes. NCREE has been commissioned by the Ministry of the Interior’s Construction and Planning Agency to set up an office to provide technical support for the private building retrofitting program. NCREE provides technical oversight and assistance as well as public outreach and education to raise public awareness about earthquake safety and inform homeowners about the importance of seismic

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[120] Shyh-Jiann Hwang, Seismic retrofitting for school buildings in Taiwan, Thailand Symposium on Earthquake Research, keynote presentation, 2023. http://www.earth-th.org/TSER2023/assets/docs/Keynote_ProfHwang_abstract.pdf

[121] Shyh-Jiann Hwang, Fu-Pei Hsiao, Lap-Loi Chung et al., Strategy for Seismic Upgrading of Public School, Australian Earthquake Engineering Society 2010 Conference, Perth, Western Australia, 2010.

[122] Shyh-Jiann, *Seismic Retrofitting Program of School Buildings in Taiwan*, Recent Advances in Increasing the Resilience and Sustainability of the School Infrastructure presentation, virtual workshop, February 2021. https://www.resilienciasismica.unam.mx/docs/Presentaciones/1-Hwang-Feb24.pdf

[123] Ministry of the Interior, Nationwide seismic assessment and retrofit program, 2018. https://english.ey.gov.tw/News3/9E5540D592A5FECD/461891fc-dd6d-48d4-ab94-26ba3ea0f8cb

retrofitting. The programme maintains its official site (in Chinese): https://privatebuilding.ncree.org.tw/.

The program focuses on retrofitting private multi-story buildings that exhibit weak storey - commonly referred to as soft-story buildings - which are particularly vulnerable to collapse during earthquakes. With approximately 36,000 buildings identified as at-risk structures across Taiwan, the program aims to systematically strengthen these buildings through targeted retrofitting strategies, categorised into three distinct plans to address a range of vulnerabilities and ownership models[124].

The programme primarily targets buildings constructed before the implementation of modern seismic codes which were significantly revised in 1999 after the Chi-Chi Earthquake. Many of these structures feature soft-story designs, due to the fact that the lower floors are open spaces for public use with fewer structural and non-structural walls such as open ground floors used for parking or commercial purposes. The programme focuses on developing phased retrofitting strategies that are economically feasible and prioritise the prevention of collapse. Recognising the challenges faced by private property owners, such as financial constraints and lack of awareness, the programme lacks mandatory evaluation and retrofitting requirements, relying instead on voluntary compliance facilitated by incentives.

The program offers three distinct plans, each tailored to address different levels of structural vulnerabilities and ownership models as below.

TABLE 21. TAIWAN'S SEISMIC RETROFIT OPTIONS

	Plan A	**Plan B**	**Plan C**
	Addressing Weak/Soft-Story Vulnerabilities	**Achieving 80% Seismic Code Compliance**	**Targeted Structural Repairs from Earthquake Damage**
Focus	Targets buildings with **soft-story weaknesses**, usually caused by open ground floors used for parking or commercial spaces	Comprehensive retrofitting to ensure buildings meet at least **80% of modern seismic code standards**	Designed for **single-ownership buildings** requiring localised structural repairs
Retrofit techniques	Shear wall installation, steel bracing systems, column reinforcement, and wing wall enhancements	Foundation strengthening, installation of shear walls, structural bracing, and real-time seismic monitoring systems	Epoxy crack injection, column reinforcement, carbon fiber wrapping, and localised repairs
Goal	Improve immediate safety and prevent catastrophic collapse during moderate to severe earthquakes	Provide holistic structural improvements for long-term resilience	Address specific structural weaknesses without requiring full-scale retrofitting

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[124] Seismic Retrofit Program Office for Private Buildings, Newsletter, Issue 13, July 2024 (in Chinese). https://privatebuilding.ncree.org.tw/wp-content/uploads/2024/07/%E7%AC%AC13%E6%9C%9F%E9%9B%BB%E5%AD%90%E5%A0%B1.pdf

Financial subsidies	Subsidies cover **up to 45% of retrofit costs**, capped at **NTD 4.5 million**	Subsidies cover **up to 45% of retrofit costs**, capped at **NTD 4.5 million**	Subsidies are capped at **NTD 500,000**, focusing on localised repairs
Retrofit cost range (from completed projects)	Retrofit costs typically range from **NTD 3 million to NTD 4.5 million**	Comprehensive projects can cost up to **NTD 6.2 million**	Smaller targeted repairs average around **NTD 1.1 million to NTD 1.2**

The programme is gaining momentum. As of January 2025, 120 projects have been approved through the programme including 20 buildings where retrofit has been completed or under construction, 51 projects where subsidies have been approved and remaining projects in the various stages of design and construction[125]. Majority of projects are located in Taiwan's Taipei and New Taipei districts[126].

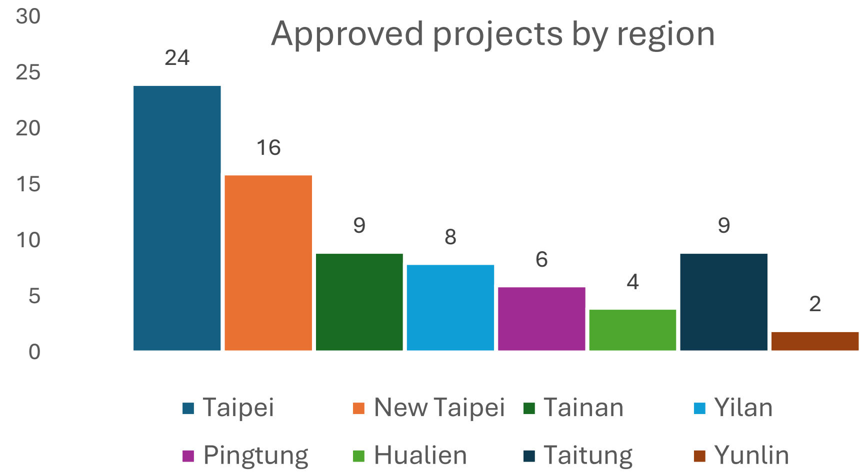

FIGURE 6. LOCATION OF APPROVED PROJECTS BY REGION[127]

The issue of mandatory retrofit requirements for private buildings remains a topic of ongoing policy discussion and refinement. The Ministry of the Interior and NCREE have been actively evaluating the feasibility of introducing mandatory retrofit requirements for private buildings[128]. In parallel, some of the cities have launched pilot programmes aimed at exploring the feasibility of mandatory seismic retrofit requirements for private buildings. These pilot programmes focus on high-risk municipalities and multi-story reinforced concrete buildings, especially with soft story vulnerabilities, to understand the challenges and refine implementation strategies before

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[125] Seismic Retrofit Program Office for Private Buildings, Newsletter, Issue 14, January 2025 (in Chinese). https://privatebuilding.ncree.org.tw/wp-content/uploads/2025/01/%E7%AC%AC14%E6%9C%9F%E9%9B%BB%E5%AD%90%E5%A0%B1.pdf

[126] Seismic Retrofit Program Office for Private Buildings, Newsletter, Issue 13, July 2024 (in Chinese). https://privatebuilding.ncree.org.tw/wp-content/uploads/2024/07/%E7%AC%AC13%E6%9C%9F%E9%9B%BB%E5%AD%90%E5%A0%B1.pdf

[127] ibid

[128] ibid

broader enforcement. The pilots aim to evaluate the effectiveness of different retrofit plans (A, B, C) in real-world scenarios by identifying technical, financial, and social challenges faced during mandatory implementation, developing best practices and refining regulations for broader enforcement.

In 2024, the central government (Legislative Yuan) received a draft proposal titled “Seismic Assessment and Retrofit of Existing Buildings Promotion Act” from one of its legislators. The draft Act aims to promote the routine seismic assessment and retrofit of existing buildings. The Act would apply to buildings as defined under the Building Act that were issued construction permits on or before December 31, 1999. These buildings are divided into two categories: Specific Buildings and Other Buildings:

TABLE 22. CATEGORIES OF BUILDINGS UNDER TAIWAN'S PROPOSED "SEISMIC ASSESSMENT AND RETROFIT OF EXISTING BUILDINGS ACT"

Category I: Specific Buildings	Category II: Other Buildings
Public Buildings: Government offices, public service buildings, and facilities managed by public institutions.	**Residential Apartment Complexes:** Multi-story residential buildings where ownership is divided among multiple individuals.
Privately-Owned Public Use Buildings: Shopping malls, theatres, hotels, hospitals, and educational institutions.	**Commercial Buildings:** Private commercial properties that do not fall into the first category.
Potentially Hazardous Buildings Identified by Local Authorities: Buildings flagged by local building authorities as structurally vulnerable or high-risk based on seismic evaluation.	**Miscellaneous Structures:** Other structures not classified as public buildings or identified as high-risk but still require periodic assessments

The act proposes a systematic approach that mandates completion of:

- Preliminary seismic assessment;
- Detailed seismic assessment, if preliminary assessment raised concerns;
- Seismic retrofit design and strengthening, if detailed assessment indicated the need for retrofit.

Phased seismic reinforcement is allowed for Category II buildings when technical constraints or ownership complexities prevent the completion of a full structural retrofit project in one phase. Phased approach allows owners to address safety concerns without requiring unanimous consent for full structural reinforcement upfront.

Buildings that undergo detailed seismic assessment and are deemed unsafe must be demolished and reconstructed. Local authorities will be responsible for supervising and facilitating this process under the Urban Renewal Act.

Local authorities develop zoning and phased plans for the investigation, seismic assessment, and retrofit of buildings under this Act. All plans are submitted to the central government for approval. Local authorities establish a Seismic Review Committee to oversee seismic retrofit. The Act specifies fines for non-compliance which accrue until the requirement of the Act are met.

Local authorities will issue seismic certification marks for buildings meeting the criteria listed below. These marks are required to be displayed in a prominent place:

- Completed Seismic Diagnosis Mark: For buildings that pass preliminary or detailed seismic assessments without requiring reinforcement.
- Completed Weak Story Retrofit Mark: For buildings that have undergone targeted reinforcement for weak layers.
- Completed Seismic Retrofit Mark: For buildings that meet seismic safety standards after full reinforcement.

Due to the public nature and higher use, Specific Buildings are prioritised for higher seismic resilience with capacity set for a 475-year return period earthquake, as defined in the 2011 seismic design codes. Whereas Second Category Buildings are given more flexibility in meeting seismic standards, including phased implementation and incremental reinforcement strategies which aim to eliminate weak-story failures and address critical structural vulnerabilities.

The draft legislation serves as a comprehensive framework to systematically address seismic vulnerabilities in existing buildings across Taiwan. The proposal establishes clear guidelines for seismic assessment and reinforcement processes for both Specific Buildings and Second Category Buildings. Where technical, financial, or ownership challenges prevent immediate full reinforcement, phased reinforcement approach is allowed. The act also provides frameworks for demolition and reconstruction when retrofit is not feasible. Similar to New Zealand’s Earthquake-prone Buildings framework, the central government will set national standards and oversee policy implementation while local authorities are responsible for enforcement, oversight, and community engagement.

While mandatory seismic retrofitting requirements for private buildings are not yet implemented in Taiwan, significant policy groundwork is being laid, in particular through the “Private Building Seismic Weak Story Retrofit Program”. Taiwan’s government's approach emphasises a balance between mandatory enforcement and financial support, ensuring that property owners can comply without facing challenging financial or logistical barriers.

Japan

Japan's development of seismic building codes dates from the consequences of the 1923 Great Kantō earthquake and, until the 1960s, focussed almost exclusively upon building standards for new buildings. The limits of these early attempts at the development of seismic building codes were exposed by the damage experienced in the Niigata (1964) and Tokachi-oki (1968) earthquakes, and from examples outside Japan (particularly the 1971 San Fernando quake).[129] This led to fundamental changes to Japanese building codes in the 1980s, particularly the introduction of ductility into the seismic building standards in 1981. Buildings constructed prior to this are described as "insufficiently [seismically] engineered" with those constructed prior to the 1920s being referred to as "non-[seismically] engineered". These codes have seen further improvements in line with global improvements around seismic engineering. As a result of these developments, by the latter part of the 20th Century, new buildings in Japan were subject to some of the strictest seismic building codes in world and, unusually, these codes are enshrined in primary legislation.

However, this focus upon new buildings as a means of driving seismic resilience was challenged by the events of 17th January 1995. On this date a 7.3 magnitude earthquake on the Nojima fault led to the 1995 Great Hanshin-Awaji Earthquake (often referred to outside Japan as the Kōbe earthquake). This disaster saw the collapse of over 100,000 buildings and resulted in 6,434 deaths, 43,792 injuries and the displacement of over 300,000 people. Studies shortly after the event showed that the vast majority of collapsed buildings (97%) had been constructed prior to 1981 with 76% dating from before 1971.[130] One consequence of this event was a decision to focus upon the seismic resilience of existing buildings (particularly those constructed pre-1981) to improve Japan's resilience to future seismic events.

This approach continues to apply in Japan today and many of the principles established at this point remain in place. As the following study shows, the Japanese model employs a combination of strong requirements around seismic assessments and a degree of mandatory requirements around remediation or demolition complemented by strong financial incentives to encourage improved levels of seismic resilience. The package of measures that achieve this are centrally managed but locally implemented with significant variation between prefectures as to delivery practice. Some mandatory requirements do exist but these tend to focus upon requirements to assess and publicise assessments rather than require remediation be undertaken. A degree of mandatory control does exist around public buildings where central government has required local authorities improve seismic resilience. However, much of this central government intervention is undertaken through the creation of mandatory targets rather than specific requirements.[131] The details of this framework are explored below.

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129 Tsuneo Okada, Development and present status of seismic evaluation and seismic retrofit of existing reinforced concrete buildings in Japan, Proceedings of the Japanese Academy, Series B 97 (2021), p404.

130 Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar (2022) Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States, Journal of Earthquake Engineering, 26:12, p6216; Thomas Moullier and Keiko Sakoda, Building Regulation for Resilience, Converting Disaster Experience into a Safer Built Environment - The Case of Japan, World Bank/GFDRR, 2018, p6. available at: http://documents.worldbank.org/curated/en/674051527139944867/Building-regulation-for-resilience-converting-disaster-experience-into-a-safer-built-environment-the-case-of-Japan

[131] Thomas Moullier and Keiko Sakoda. *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan (English),* Washington, D.C. : World Bank Group, available

The regulatory framework for seismic resilience in Japan

The current approach to the management of seismic risk amongst existing buildings in Japan is primarily founded upon the 1995 Act for the Promotion of Seismic Retrofit of Buildings (APSRB). This Act, provides a series of tools to promote and support seismic retrofit of buildings, particularly those constructed before 1981.[132] These are of three types:

1. Requirements around seismic assessments
2. Expectations around retrofitting/demolition
3. Financial and Tax incentives

These three elements are explored in more detail below.

Seismic evaluation/assessment

All buildings in Japan designed prior to the year 1981 are assumed to have been "insufficiently" seismically engineered. These are the focus of Japanese policies towards seismic risk for existing buildings.[133] One of the key aims of the 1995 Act was to establish the level of vulnerability in the existing building stock. Key to this was the requirement that all three storey (or above) multi-user buildings of more than 1,000m^2 (specifically including schools, gymnasiums, hospitals, theatres, stadiums, multi-household buildings and office blocks), required to undergo a seismic assessment.[134] In addition, the Act provides for specific timeframes for specific levels of seismic resilience to be achieved using the mechanisms provided within the legislation (75% of such buildings by 2003 and over 90% by 2015).

These seismic assessments are primarily incorporated within the periodic safety assessment processes which are carried out every six months to three years. This applies to "strategic" buildings mentioned above (e.g. hospitals, hotels, department stores, theatres, multi-residence buildings and office blocks) and those which are utilised by people with limited mobility .[135] The APSRB has seen two amendments since its inception. The most significant occurred in 2013 when the requirement for seismic assessments was extended to include all residential properties, including "single-family houses".[136]

Mandatory Requirements

The APSRB utilises a decentralised model of seismic regulation with the central government formulating the overall policy and local authorities acting to deliver the centrally mandated

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at: http://documents.worldbank.org/curated/en/674051527139944867/Building-regulation-for-resilience-converting-disaster-experience-into-a-safer-built-environment-the-case-of-Japan

[132] Shoichi Ando, *Evaluation of the Policies for Seismic Retrofit of Buildings*, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), p 391-402

[133] Cameron Eade, *From Disaster to Resilience: A Comparative Study of Legal Frameworks for Managing the Seismic Risk of Existing Buildings*, LLM thesis (2021), University of Canterbury, at p55, available at https://ir.canterbury.ac.nz/server/api/core/bitstreams/832d2e7b-b037-4002-8988-d475b91bcdb4/contentp

[134] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan*), Washington, D.C.

[135] ibid

[136] Tsuneo Okada, *Development and present status of seismic evaluation and seismic retrofit of existing reinforced concrete buildings in Japan*, Proceedings of the Japanese Academy, Series B 97 (2021), p414.

seismic resilience requirements.[137] The key tool utilised by the central government is the creation of a series of mandatory numerical targets for seismic resilience which local authorities (the prefectures) are expected to achieve. These targets vary but have included raising the proportion of designated buildings (e.g. schools and hospitals) to 75% and 80% by 2003 and 2008, respectively.[138] In 2006 the APSRB was amended to require that local governments develop seismic retrofitting plans. These plans set out the actions being undertaken by the prefectures (both regulatory and through incentives, etc) to achieve the required targets and ensure the safety of designated emergency routes.[139]

Local governments will publish the "seismic capacity index", *Is* (the index used by the Japanese building code to indicate seismic resilience) of "strategic" buildings (including large occupancy buildings, hospitals, schools and those located on designated emergency routes).[140] In addition, the plans and timetable for retrofitting/demolition of these buildings have, since 2013, been made publicly available.[141]

Although the APSRB is the key framework within which the Japanese system operates, it should not be assessed in isolation. In reality it is part of a wider series of government frameworks to ensure seismic safety. For example, the Ministry of Education, Culture, Sports, Science & Technology has established specific policies for the structural and non-structural retrofit of schools in Japan which are not only important for the safety of school children but the use of such buildings as evacuation centres.[142] This policy has resulted in all schools being rated as "seismic resistance" by 2016.[143] The level of retrofitting required is high, with the buildings identified expected to be retrofitted to a level close to 100% of current requirements.[144]

Retrofitting Incentives and Owner Engagement

Although Japan's approach to strengthening seismic performance of existing buildings has a strong legislative underpinning, its practical operation is based upon two other policy elements mandated by the APSRB. These include a package of financial incentives mandated by the

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[137] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan* (English), Washington, D.C., p47

[138] Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar, *Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States*, Journal of Earthquake Engineering, 26(12), pp6208-6235, 2022. DOI: 10.1080/13632469.2021.1911889, p6216

[139] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan* (English), Washington, D.C.

[140] Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar, *Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States*, Journal of Earthquake Engineering, 26(12), pp6208-6235, 2022. DOI: 10.1080/13632469.2021.1911889, p6216

[141] Tsuneo Okada, *Development and present status of seismic evaluation and seismic retrofit of existing reinforced concrete buildings in Japan*, Proceedings of the Japanese Academy, Series B 97 (2021), p414.

[142] Shoichi Ando, *Evaluation of the Policies for Seismic Retrofit of Buildings*, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), p 391-402

[143] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan* (English), Washington, D.C.

[144] Correspondence with Japanese seismic engineering pracitioners

APSRB and a focus upon capacity building and engagement with building owners.[145] Such policies aim to encourage building owners to carry out the required retrofit measures and utilise the financial incentives to do so.[146] These schemes, initially focussed upon strategic (public) buildings now extend to standalone residential homes. This aspirational approach to improving national seismic resilience is a key feature of the Japanese model.

Financial Incentives in Japan

It is accepted as a central tenet of Japanese government policy that the state (at both local and central government levels) needs to provide financial incentives to private owners to reduce the vulnerability of existing buildings to seismic events. This consensus comes both from community expectations but is also driven by the financial liabilities that arise for Japanese authorities in post-disaster events. These arise from a combination of the duty which Japanese governments have to provide housing (significantly reduced in recent years) and legislation introduced in 1998 which requires the government to provide financial assistance to building owners in the wake of disasters. Thus, Japanese governments have a financial incentive to improve the resilience of existing residential buildings in particular.[147] The costs of seismic assessment of a building is shared between government (both central and local) and the building owner. The exact nature of the cost sharing depends upon a variety of factors, including the policies of prefecture. However, the costs are usually shared equally between the central government, the local authority and the building owner. The central government has also utilised specific incentives to increase knowledge around seismic vulnerabilities, such as a limited time offer during 2018 where the central government subsidies were increased to 50%.[148] Local governments are not required to provide funding. When this is not forthcoming the central government is responsible for 33.3% of the assessment costs, with the owner being responsible for the remainder.[149] Local government also has access to subsidies and additional funding for the seismic assessment and retrofit of schools.[150]

Japan provides a different set of financial incentive schemes for retrofitting. These operate through tax incentives, loans and subsidies.[151] These arrangements place a lot more responsibility on the building owner. In this case, central and local government contributes only 23% (11.5% each), leaving the owner responsible for the remaining 77%. Prefectures are

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[145] ibid

[146] Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar, *Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States*, Journal of Earthquake Engineering, 26(12), pp6208-6235, 2022. DOI: 10.1080/13632469.2021.1911889, p6217.

[147] Shoichi Ando, Evaluation of the Policies for Seismic Retrofit of Buildings, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), p391

[148] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan,* Washington, D.C., World Bank Group, 2018, pp46 onwards; Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar (2022) Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States, *Journal of Earthquake Engineering*, 26:12, 6208-6235, DOI: 10.1080/13632469.2021.1911889.

[149] Moullier and Sakoda, 2018, ibid

[150] Shoichi Ando, *Evaluation of the Policies for Seismic Retrofit of Buildings*, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), pp 391-402.

[151] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience: converting disaster experience into a safer built environment - the case of Japan,* Washington, D.C. : World Bank Group, p48.

not required to pay these incentives and in such circumstances the owners contribution rises to 88.5%. In addition, various time limited promotions have been offered by the central government. For example, one scheme (which ended in 2019) offered subsidies of up to 100% for seismic assessments and up to 66.7% for retrofit costs.[152] More recent schemes have seen the central government responsibility increased to 33.3% while the building owner's financial responsibility decreased to 55.2%. The local government's financial responsibility remained the same at 11.5%.[153]

In addition to the above, both central and local governments have incentivised the seismic retrofitting of buildings on evacuation routes as well as those buildings designated by local governments as emergency management hubs. In these cases the subsidy from central government is up to a maximum of 40%, with further subsidy of up to 40% available from local government. The remainder is covered by the building owner.

In addition to the incentives mentioned above, the Japanese Housing Financing Agency also supports a mortgage incentive scheme (the so called Flat 35 scheme) which provides for 35 year fixed rate mortgages for those purchasing houses which exceed building code standards (which include but are not limited to seismic resilience elements).

Capacity Building and Seismic Risk Awareness

Capacity building and engagement are an integral part of improving seismic safety of existing buildings in Japan. The need for both is mainly due to a lack of public understanding of the benefits of investing in seismic assessment/strengthening work. This has been cited as a barrier for building owners taking preventative measures.[154]

Local government in Japan has been at the forefront of efforts to raise awareness about such issues by undertaking public communication efforts such as holding seminars for local communities, financial support schemes (see above) and the provision of consultancy services for seismic assessment.[155]

To improve public and professional awareness, Japan has also implemented training and licensing programs for building professionals as well as loan initiatives and tax breaks for homes that exceed the minimum safety standards.[156]

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[152] Yating Zhang, Juan F. Fung, Katherine J. Johnson & Siamak Sattar, *Review of Seismic Risk Mitigation Policies in Earthquake-Prone Countries: Lessons for Earthquake Resilience in the United States*, Journal of Earthquake Engineering, (2024) 26:12, 6208-6235.

[153] For more details on all these figures, see the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), http://www.mlit.go.jp/common/001123670.pdf (in Japanese), as cited in Moullier and Sakoda, see p47/48

[154] Xijun Yao, His-Hsien Wei, Igal M Shohet and Miroslaw J Skibniewski, *Public-Private Partnership for Earthquake Mitigation Involving Retrofitting and Insurance*, Technological and Economic Development of Economy, 23 (2017) 810.

[155] Shoichi Ando, *Evaluation of the Policies for Seismic Retrofit of Buildings*, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), p 391-402.

[156] Thomas Moullier and Keiko Sakoda, *Building regulation for resilience : converting disaster experience into a safer built environment - the case of Japan*, Washington, D.C., World Bank Group, 2018.

Conclusions

The key feature of the Japanese model is its aspirational nature with policy shifting from strategic buildings to other properties over time. The APSRB thus acts as a framework, which requires the monitoring and assessment of seismic resilience and provides a number of tools for its achievement. This multi-modal regulatory model of seismic resilience thus utilises a limited level of regulatory requirements with a significant level of financial incentives.

Overall, the Japanese model is defined by a long-term monitoring of seismic resilience in the wider building stock, long term policy targets and regular policy changes to deliver what is needed to achieve the levels of seismic resilience desired in Japan. This aspirational approach to seismic resilience aims for 95% of all buildings being “seismically resistant” by 2020. In 2018 around 87% of the building stock was earthquake resistant by Japanese standards. This is testament to the success of the Japanese approach.

Nevertheless, the Japanese framework still faces challenges. For example, while encouraging homeowners to strengthen their building has been successful overall, the success has not been consistent across all sectors. For example, elderly residents have generally been reluctant to invest in such actions and not all homeowners are convinced of the importance of improving the seismic safety of their properties.[157]

However, it should also be noted that the Japanese context is significantly different from New Zealand. State ownership of buildings (including residential housing) remains high which provides the ability for the state to drive seismic improvement. In addition, the culture in Japan would appear to make soft regulatory instruments (such as publicity around seismic vulnerability) particularly effective. Finally, the use of financial incentives has been a long-term policy achieved by public consensus. This is partly due to the stability of Japan’s political system and partly due to the widespread acceptance of seismic resilience as a community good. It is not clear that either condition currently exists in Aotearoa New Zealand at the present time.

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[157] Shoichi Ando, *Evaluation of the Policies for Seismic Retrofit of Buildings*, Journal of Civil Engineering and Architecture, Apr. 2012, Volume 6, No. 4 (Serial No. 53), p 391-402.

Italy

Italy's approach to the reduction of seismic risk in existing buildings is focussed primarily upon economic incentives within limited mandatory requirements. This reliance upon financial incentives to encourage improving the seismic performance of existing buildings has been widely seen as problematic in the absence of sufficient funding.[158] The following provides an overview and assessment of the current schemes.

Mandatory Requirements

The current mandatory requirements around seismic residence in Italy are focussed upon the 2003 Ordinance of the President of the Council of Ministers n. 3274 (OPCM), which was introduced in response to the Molise Earthquake (Mw 5.8) of 2002.[159] This required the owners of strategic buildings (primarily hospitals, schools and buildings used in emergencies) to complete a seismic assessment within a five-year period. This assessment period was later extended due to lack of compliance.[160] The assessment scheme was accompanied by a financial incentive scheme to fund strengthening work. This amounted to approximately €200 million, with most of the funds provided to schools.[161]

Heritage values also play a significant role in the management of seismic risk of existing buildings in Italy. Around 50% of the building stock is regarded as having significant heritage value.[162] This creates challenges for seismic risk reduction. Many of these buildings are covered by laws requiring the retention of their heritage values which provide an extra layer of complexity when it comes to risk reduction.[163] This complexity provides a significant barrier in a regulatory model which is largely voluntary and relies upon financial incentives to achieve its goals.

Tax Incentives

Italy's limited regulatory framework for improving the seismic performance of existing buildings is largely based upon financial incentives.[164] Tax incentives provide a significant part of this this model. Italy first introduces tax incentives to encourage seismic strengthening in 1997.

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[158] Fabio Sabetta, Seismic Risk Assessment and Risk Reduction In Italy, NED University Journal of Research (2019). DOI: 10.35453/NEDJR-STMECH-2019-0005

[159] Cameron Eade, From Disaster to Resilience: A Comparative Study of Legal Frameworks for Managing the Seismic Risk of Existing Buildings, LLM thesis (2021), University of Canterbury, available at: https://ir.canterbury.ac.nz/server/api/core/bitstreams/832d2e7b-b037-4002-8988-d475b91bcdb4/content

[160] Ibid, p45.

[161] Mauro Dolce "The Italian National Seismic Prevention Program" (paper presented to 15th World Conference on Earthquake Engineering, 2012). Available at: http://www.civil.ist.utl.pt/~mlopes/conteudos/SISMOS/DOLCE.pdf

[162] National Council of Engineers in Italy, 2013, as cited Cameron Eade, From Disaster to Resilience: A Comparative Study of Legal Frameworks for Managing the Seismic Risk of Existing Buildings, LLM thesis (2021), University of Canterbury, p13.

[163] Alessandra Bellicoso "Italian Anti-Seismic Legislation and Building Restoration" (2011) 35 International Journal for Housing Science 137, p140.

[164] Cameron Eade, From Disaster to Resilience: A Comparative Study of Legal Frameworks for Managing the Seismic Risk of Existing Buildings, LLM thesis (2021), University of Canterbury.

Under Financial law n.449 of that year, private property owners were offered a reduction of up to 50% on the VAT (GST) costs for strengthening and renovating buildings in “high” seismic risk zones. This category applies to a majority of the land area of the state by area, with over 3000 (out of a total of 7,900) municipalities being included in this category.[165]

Italy’s current tax incentive scheme for seismic resilience (known as *Sismabonus*) dates from 2013 (Decree Law 63/2013). Originally the scheme only applied to main dwellings and commercial buildings, but this has now been extended to all residential buildings.[166] The scheme was originally limited to those buildings located in seismic zones 1 and 2 (“high” risk seismic zones), with a maximum discount of 96,000 Euros. However, in 2016 the scheme was expanded to cover “medium” risk areas (seismic zone 3) and extended until 2021 (Law 232/2016). In 2021, the scheme was again modified and extended (Sisma Bonus 2024) and in 2025 a further extension was introduced.

The tax incentives are capped at a limit of 96,000 Euros which has remained constant throughout the various schemes, although the most recent versions have introduced a degree of means testing into the scheme for households with incomes over 75,000 Euros.[167]

The original *Sismabonus* scheme provided a tax deduction of 65% (payable over 5 years) for all seismic reduction measures but more recently, the scheme has targeted funding at more effective retro-fitting. Thus, post-2017, the tax deduction was reduced to 50% but if the retrofit leads to the risk category of the building being reduced by one or two classes (under the Italian seismic risk categorisation model) the tax deduction available was increased to 70-80% (and for apartments 85%).

Part of the resources for the *Sismabonus* scheme are provided by an Italian Superannuation Fund, with a budget of 47.5 billion Euros, to promote infrastructural and development investments in Italy during the period 2017–2032 (Law 232/2016). The government budgeted for 11.6 billion Euros being spent on seismic risk reduction (and energy efficiency renovation) of buildings during the period of the plan.[168]

Other Financial Incentives

In 2009, Italy established the National Plan for Seismic Risk Prevention with a total budget of 965 million Euros over the period 2010–2016 (Law 77/2009). This plan and its associated funding was primarily used to reduce the seismic vulnerability of existing public and private buildings.[169] Various initiatives have also been funded by the private sector.[170]

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[165] Fabio Sabetta, Seismic Risk Assessment and Risk Reduction In Italy, *NED University Journal of Research*, 2019, p10.

[166] Susanna Paleari “Natural Disasters in Italy: Do We Invest Enough in Risk Prevention and Mitigation?” (2018) 75 International Journal of Environmental Studies, p679.

[167] www.windowo.co.uk/blog/sismabonus.

[168] Susanna Paleari “Natural Disasters in Italy: Do We Invest Enough in Risk Prevention and Mitigation?” (2018) 75 International Journal of Environmental Studies.

[169] Ibid, p679.

[170] Ibid.

The limits of the Italian incentive model

Although the financial resources provided to improve seismic resilience in Italy are significant, they represent a relatively small contribution to what is needed to reduce the vulnerability of Italian building stock to the level expected. The National Council of Engineers estimated that to guarantee the seismic safety of all dwellings (in medium intensity earthquakes requires an investment of at least 93 billion Euros.[171] Thus although the Italian schemes are widely regarded as a positive step, far more financial resources need to be provided if the risk is to be effectively managed.[172]

In addition, the current schemes have tended to be introduced in response to specific seismic events (and other disasters) and/or through the initiatives of specific political leaders. They thus lack overall coherence and the overall the financial measures are somewhat fragmented.[173]

Given these limits, the current focus of the government has been on high-risk areas. Currently official estimates have calculated the costs of improving the seismic safety of the load-bearing masonry buildings located in the 648 "highest risk" Italian municipalities at around 36.8 billion Euros. However, it is not entirely clear how the financial resources required to achieve this will be provided.[174]

The incentive-based schemes also suffer from a lack of public understanding around the seismic risk of existing buildings.[175] There is also low public awareness of seismic risk in Italy,[176] particularly among children.[177] Given the limited perception of the risks and the limited nature of the financial incentives, it can come as no surprise that their overall impact has been disappointing.

Conclusion

As the above report briefly discusses, seismic regulation in Italy is primarily voluntary and based upon incentives. These incentives have not been widely taken up in Italy but even if they had been, the finances required to achieve the goals of seismic resilience are insufficient to address the problem. When this is coupled with a lack of public awareness, it can come as

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[171] Susanna Paleari, *Natural Disasters in Italy: Do We Invest Enough in Risk Prevention and Mitigation?* (2018) 75 International Journal of Environmental Studies.

[172] Fabio Sabetta, *Seismic Risk Assessment and Risk Reduction in Italy*, NED University Journal of Research (2019).

[173] Susanna Paleari, *Natural Disasters in Italy: Do We Invest Enough in Risk Prevention and Mitigation?* (2018) 75 International Journal of Environmental Studies.

[174] Ibid, p680.

[175] Martelli A, Clemente P, Benzoni G. (2017). "State-of-the art of development and application of anti-seismic systems in Italy". Proc. of the Joint 2017 NZSEE and ASSISi Conference, New Zealand, Wellington 2017, New Zealand Society for Earthquake Engineering & ASSISi, Invited Lecture.

[176] Mauro Dolce, Elena Speranza, Giuseppina De Martino, Chiara Conte and Francesco Giordano, The implementation of the Italian National Seismic Prevention Plan: A focus on the seismic upgrading of critical buildings (2021) International Journal of Disaster Risk Reduction 62, August 2021, 102391.

[177] A.E. Bandecchi, V. Pazzi, S. Morelli, L. Valori, N. Casagli, *Geo-hydrological and seismic risk awareness at school: emergency preparedness and risk perception evaluation*, International Journal of Disaster Risk Reduction 40 (2019) 101280.

no surprise that the impact of current efforts to improve seismic resilience in Italy remain limited.

Türkiye

Türkiye is situated in one of the world's most seismically active regions. Majority of the country's land mass – 96% - is under earthquake risk, with 42% in the highest risk zone[178]. Over the last several decades, several devastating earthquakes hit the country with the most recent event in 2023. The 2023 Kahramanmaras Earthquake resulted in more than 50,000 deaths and more than 250,000 heavily damaged and collapsed buildings.

Although Türkiye's building codes have evolved significantly, generally following major, damaging earthquakes, the 2023 Kahramanmaraş Earthquake exposed ongoing challenges with consistent enforcement, public awareness, and addressing legacy issues in older structures. A recent study reports that in Kahramanmaraş, about 97% of the collapsed buildings were constructed prior to the significant 1997 seismic code updates[179] (Binici et al., 2023 – in Turner, 2024). In contrast, modern buildings that are ductile and were built after 2000 were less likely to collapse, although some still did[180] (Turner, 2024). Poor design and construction practices became increasingly apparent, in part due to "construction amnesty", a practice which existed since 1960's and allowed property developers to bypass safety certification by paying a fee. It was found that at least 75,000 buildings in the 2023 earthquake zone were found to have received construction amnesties. Moreover, the country lacks a professional institution that would establish competence of design practitioners (structural engineers, architects) and offer continuing professional development.

The 1999 Marmara Earthquake, one of the deadliest and most destructive earthquakes in Türkiye's history. Recognition of these risks triggered the government to develop a comprehensive hazard management strategy for the country.

Following the 1999 event, the government established Compulsory Earthquake Insurance (DASK) managed by the Turkish Catastrophe Insurance Pool. The insurance is mandatory for all registered residential properties. Premiums are calculated based on regional risk zone group (seven groups) and construction type (reinforced concrete or steel and other). A cap is set on the maximum coverage which may not be sufficient to cover reconstruction costs (especially in high-value areas). As of 2024, around 11.2 million properties are insured under DASK which represents approximately 56% of Türkiye's housing stock. Nevertheless, informal housing is common in many regions. Some estimates predict that a quarter of Türkiye's urban population lives in such informal settlements[181]. Such structures are typically built without any engineering oversight, using substandard construction materials. While informal housing provides affordable housing for low-income families, this represents some of the country's most vulnerable building stock. Informal housing are ineligible for DASK coverage, leaving a significant portion of vulnerable buildings uninsured.

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[178] S. Gundes, N. Atakul, F. Buyukyoran, B. Balaban-Okten, *Earthquake Preparedness: Evaluation of Urban Transformation Law in Türkiye*, 16th World Conference on Earthquake Engineering, Santiago, 2017.

[179] Baris Binici, Ahmet Yakut, Koray Kadas et al., *Performance of RC buildings after Kahramanmaraş Earthquakes: lessons toward performance based design*, Earthquake Engineering and Engineering Vibration, 22(4), 2023. https://doi.org/10.1007/s11803-023-2206-8

[180] Alice Turner, After the earthquakes: Experts discuss building codes in Türkiye and the U.S., Temblor, 2024. http://doi.org/10.32858/temblor.334

[181] HOFINET, Country Profile: Türkiye, Housing Finance Information Network, n.d. https://www.hofinet.org/countries/description.aspx?regionID=3&id=169

DASK was able to reduce the financial burden on the government during disaster relief. However, financing risk reduction at scale would not have been possible without external assistance. International support has played a role in Türkiye's efforts. For instance, the World Bank has been involved in projects aimed at improving the resilience of public buildings. Istanbul is the centre of the country's economic life, generating more than half of Türkiye's trade and home to nearly 1/5 of the total population. The 1999 earthquake triggered one of the largest economic shocks to the city, leaving it highly vulnerable to any future seismic event, especially since most of the buildings were built before the modern construction practices which would minimise earthquake risk. In 2006 the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP) was established. The project focussed on mitigating seismic risk in public buildings. World Bank financing for the project was US$ 563 million. While the World Bank financing ended in 2015, the project remains active after securing additional financing from international financial institutions including European Investment Bank, Council of European Development Bank, Islamic Development Bank and German Development Bank (KfW). By 2018, the total amount of committed financing was in excess of EUR€ 2 billion[182]. The project included four components:

- Component A supported enhanced emergency preparedness through establishing an emergency communication system, an emergency management information system, and an emergency management centre
- Component B supported seismic risk mitigation for public buildings through retrofits and reconstruction of priority public buildings, and providing technical assistance for cultural heritage buildings.
- Component C supported indirect efforts to mitigate seismic risks in private buildings, through awareness programs, training of engineers, and pilot efforts to digitise municipal permitting processes.
- Component D supported project management

Approximately 70% of the World Bank lending was allocated to seismic risk mitigation (retrofit and reconstruction). At the beginning of the project, public buildings were inventoried and prioritised for retrofitting or reconstruction based on such criteria as access post disaster, technical features, seismic vulnerability, capacity load, distance to fault line etc. The project applied a simple cost benefit approach where a decision is made to retrofit if the cost of retrofitting does not exceed 40% of the cost of reconstruction. Under ISMEP, there has been a significant reduction in seismic vulnerability in 1,624 of Istanbul's public buildings, especially school and hospital buildings, significantly improving their seismic resilience. A 2018 report estimated that 88% of Istanbul's schools built before 1998 were retrofitted or reconstructed[183].

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[182] IEG, *Istanbul Seismic Risk Mitigation and Emergency Preparedness Project*, Project Performance Assessment Report, June 2018.

[183] ibid

TABLE 23. NUMBER OF RETROFITTED AND RECONSTRUCTED PUBLIC BUILDINGS UNDER ISMEP

Building type	Status	Completed	Ongoing	Total
Schools	Retrofitted	968	47	1,015
	Reconstructed	422	17	439
Hospitals	Retrofitted	48		48
	Reconstructed	6		6
Health care centres	Retrofitted	59		59
	Reconstructed	2		2
Administrative buildings	Retrofitted	43		43
	Reconstructed	14		14
Dormitory	Retrofitted	28		28
	Reconstructed	11		11
Social services	Retrofitted	16		16
	Reconstructed	7		7
Total			**Completed:**	**1,624**
			Ongoing:	**64**

Informed by the successes and insights gained from ISMEP, a new project targeting buildings across Türkiye. The current project combines structural strengthening with energy efficiency measures, aiming to create safer and more sustainable public buildings. The Seismic Resilience and Energy Efficiency in Public Buildings Project is operational from 2022-2027 and is supported by a US$ 265 million loan from the World Bank. Similar to ISMEP, the project funding is allocated to retrofitting, reconstruction, technical assistance and project management and implementation support. Retrofitting is deemed feasible where retrofitting costs do not exceed 40% of the reconstruction costs. It is anticipated that approximately 80 large public buildings could be retrofitted or reconstructed[184]. The project defined clear eligibility and prioritisation criteria for public buildings.

Despite the country's history of devastating earthquakes and efforts to improve resilience of public buildings, retrofitting private commercial and residential buildings remains a significant challenge. Most housing stock built before the introduction of the modern seismic building codes (pre-2000) suffer from significant structural vulnerabilities making them prone to damage and collapse during earthquakes. It is estimated that around 6.7 million residential buildings across Türkiye require retrofitting or reconstruction. The period following the 1999 earthquake is described as the earthquake awakening period[185]. Right after the earthquakes, all construction in the affected areas were suspended until new regulations were provided. Construction permits nearly halved between 1999 – 2002[186]. The government pledged to implement long term solutions to prevent future losses. It wasn't until the 2011 Van earthquake that the government implemented the Law on the Regeneration of Areas Under the Risk of Disaster, no. 6306 in 2012. Known as the Urban Transformation Law, the law introduced the

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[184] World Bank Group, Türkiye - Seismic Resilience and Energy Efficiency in Public Buildings Project (English), 2021. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/738871623549676664/Türkiye-seismic-resilience-and-energy-efficiency-in-public-buildings-project

[185] Dicle Kizildere, Earthquake disaster-induced urban policies: paradoxes and challenges in Türkiye, Urban Research & Practice, 2024. doi:10.1080/17535069.2024.2422627

[186] S. Gundes, N. Atakul, F. Buyukyoran, B. Balaban-Okten, *Earthquake Preparedness: Evaluation of Urban Transformation Law in Türkiye*, 16th World Conference on Earthquake Engineering, Santiago, 2017.

framework for earthquake-focused urban transformation through the rehabilitation, demolition and renewal of areas at risk, as well as plots of land where risky buildings exist. To initiate the process of retrofitting or reconstruction under the Urban Transformation Law, property owners commission a risk assessment to determine the building's structural integrity (the request for assessment does not require the majority consensus and can be initiated by any one owner). If deemed risky, the building becomes subject to urban transformation procedures. Evidence suggests that any building that was constructed before 1999 would get a “Risky Building Report” since seismic codes were significantly revised after the 1999 earthquake[187]. Once the building is deemed “risky”, the owners are notified of the building's status and the need for evacuation. The period for evacuation is 90 days. Decisions to retrofit or reconstruct requires consensus from absolute majority owners (50% +1). Upon application, permits for construction must be issued within 30 days. The primary responsibility for funding the retrofitting or reconstruction of properties identified as "risky" falls on the property owners. The government provides limited financial incentives to alleviate the burden by providing access to low interest loans, tax exemptions and rental assistance for temporary relocation. It appears that demolishing and reconstructing buildings is favoured over retrofitting, particularly when existing structures are deemed too vulnerable or when redevelopment offers economic benefits, especially in high value areas. This approach is evident in Istanbul's plan to reconstruct 242,000 dwellings by 2035 under the Urban Transformation Plan[188].

The country’s seismic resilience strategy combines transformative building code reforms and large scale urban transformation projects. The country’s building codes are regularly updated to incorporate advancements in engineering and risk mitigation. Notably, the 2007 and the 2018 revisions introduced rigorous design criteria for new buildings and retrofitting of older structures. Efforts to build more seismically resilient schools that follow the 2018 seismic code is showing stepped improvement in the building stock. Only about 5% of the 20,000 education buildings in the 2023 earthquake-affected areas collapsed or were either severely or moderately damaged[189]. Buildings constructed under the World Bank funded projects (ISMEP, Seismic Resilience and Energy Efficiency in Public Buildings Project) have set a new benchmark for public construction in Türkiye. The projects benefitted from customised design and close monitoring during construction. Designs introduced some new technologies to Türkiye. ISMEP hospitals brought the first use of seismic base isolation in Türkiye. This has been standardised, and adopted for all large new hospitals[190]. Since 2018, Electronic Concrete Monitoring System (EBIS) has been implemented in approximately 432,797 buildings across

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[187] CVG Hukuk, Urban Transformation In Türkiye: Opportunities For Foreign Investors, 10 October, 2024. https://cvghukuk.com/urban-transformation-in-Türkiye-opportunities-for-foreign-investors/?utm_source=mondaq&utm_medium=syndication&utm_content=articleoriginal&utm_campaign=article

[188] NetZero Cities, *Istanbul's Pilot City Activity: Green and Carbon Neutral Building Transition Guide*, n.d. https://netzerocities.eu/istanbuls-pilot-city-activity-green-and-carbon-neutral-building-transition-guide/#:~:text=In

[189] Alice Turner, After the earthquakes: Experts discuss building codes in Türkiye and the U.S., Temblor, 2024. http://doi.org/10.32858/temblor.334

[190] IEG, *Istanbul Seismic Risk Mitigation and Emergency Preparedness Project*, Project Performance Assessment Report, June 2018.

Türkiye[191]. The technology utilises electronic chips embedded within concrete to monitor and verify the quality of materials used in construction. There are ongoing efforts to strengthen regulatory oversight and ensure adherence to established standards as well as reforms to establish stricter inspection protocols, including mandated independent inspections during construction. These initiatives demonstrate the country's commitment to risk reduction.

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[191] Barnes International Realty, Revolutionizing Building Safety and Construction Quality with EBIS Technology, 5 March 2024. https://www.barnes-Türkiye.com/en/news/2024/revolutionizing-building-safety-and-construction-quality-with-ebis-technology-197.html

Mexico

Earthquakes represent an ever-present threat in Mexico. The country sits atop the intersection of five tectonic plates. Mexico City is the country's capital and most populous region. Several natural hazards contribute to increased earthquake risk and amplify earthquake effects in Mexico City. The city is partially built on a lakebed of compressible clay soils and is responsible for the city's ongoing subsidence of up to 40 centimetres per year in some areas[192]. Soft soils may compromise structural stability of foundations and amplify seismic waves in comparison with firmer soils. In the 1985 earthquake, the highest level of damage was experienced in the areas located directly on the lakebed[193]. Man-made hazards intensify earthquake risks. In Mexico City, "irregular" settlements[194] occupy approximately half of the urban area and house 60% of the city's population. Irregular, also known as non-engineered, housing is built without following housing code regulations and lacks professional oversight, construction permitting and code compliance. Irregular housing is not eligible for insurance. However, even with regular housing, residential insurance is rare. For instance, nationwide in 1998, 150,000 houses out of 16 million were insured[195]. Following the 2017 earthquake, an insurance scheme was developed between Swiss Re and Mexico City government. The insurance automatically covers owners who meet certain criteria, such as being registered and fully paid property taxes at the time of event[196].

Being a federal republic, Mexico lacks a model building code, instead building codes are to be issued by each of the more of 2400 municipalities[197]. Most code development efforts in Mexico have been made for Mexico City. In most cases, local building codes are adaptations or sometimes copies of the Mexico City Building Code (MCBC). MCBC is regarded as the model code for the country. The first structural building code for Mexico City was issued in 1920. However, it wasn't until 1942 edition that the codes incorporated requirements for seismic design, albeit limited. The 1942 MCBC and the further updates in 1957 and 1966 were Working Stress Design Codes[198]. The first collapse-prevention seismic code for Mexico City is the 1976 code introducing a set of performance-based requirements. The 1976 code considered was considered as a very advanced code, with criteria not adopted anywhere in the world at the time[199]. However, by the end of 1984, the 1976 MCBC entered a major revision. The 1985 Mexico City earthquake accelerated this process. The 1985 Emergency

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[192] Rachel Nadelman, Caroline Nichols, Sara Rowbottom, Sarah Cooper, *Learning from the Mexico City Earthquake: Dynamics of Vulnerability and Preparedness The Case of Housing*, Global Report on Human Settlements, 2007. http://www.unhabitat.org/grhs/2007

[193] ibid

[194] ibid

[195] ibid

[196] UNDRR, *Mexico earthquake, 2017- Forensic analysis, Case Study*, 11 September 2024. https://www.undrr.org/resource/mexico-earthquake-2017-forensic-analysis

[197] Mario Ordaz and Roberto Meli, *Seismic Design Codes in Mexico*, in Proceedings of 13th World Conference on Earthquake Engineering, Vancouver, Canada, paper 4000, 2004.

[198] Arturo Tena-Colunga, Eber Alberto Godínez-Domínguez, Hector Hernandez-Ramírez, Seismic retrofit and strengthening of buildings. Observations from the 2017 Puebla-Morelos earthquake in Mexico City, Journal of Building Engineering, 2022.

[199] Sergio M. Alcocer and Vıctor M. Castano, *Evolution of codes for structural design in Mexico*, Structural Survey, 26(1), 2008. doi 10.1108/02630800810857417

Building Regulations considerably raised the elastic design seismic shear coefficients. The 1987 MCBC preserved most of the requirements of the 1985 Emergency Regulations[200]. Major updates were introduced in the 2004 MCBC. This was in response of research advances made since the 1985 earthquake, both related to structural behaviour and to strong-motion estimation in Mexico City[201]. The code is composed of complementary technical norms for all materials, plus design norms for earthquake and wind loads. The 2004 code remains the foundational regulatory framework, however, regular updates are issued though Complementary Technical Norms (CTNs) to address specific aspects of construction and design. For example, in the aftermath of the 2017 Mexico City Earthquake, the local government developed a new CTN for Evaluation and Rehabilitation of Existing Buildings and established a process to update CTNs every six years.

It is evident that MCBC has evolved in complexity in response to new knowledge, especially after the 1985 earthquake. All buildings, except for one, that collapsed in the 2017 earthquake were built before the 1987 building code. Collapse factors included insufficient transverse steel reinforcement in concrete columns, construction on soft soils and land subsidence[202]. The 2017 earthquake showed that improved codes can protect lives and reduce damage. For example, in the 1985 earthquake between 10,000 and 30,000 people lost their lives and caused US$ 4.1 billion economic losses (2.7% of GDP) while in the 2017 earthquake 326 people died and the earthquake caused US$ 2.5 billion in economic losses (.15% of GDP)[203]. A case study of four concrete buildings retrofitted after the 1985 earthquake showed that rehabilitation techniques improved the performance of these buildings in the 2017 earthquake. The rehabilitated structures experienced limited or no damage[204]. Nevertheless, structures damaged in the 2017 earthquake shared common features that contributed to their poor performance such as issues with the quality of concrete mix design, inadequate casting and curing, shortage of reinforcement and corrosion of steel reinforcement[205]. Therefore, despite rigorous regulations, inadequate enforcement and implementation, lack of maintenance that leads to corrosion and pounding are the weak links in improving earthquake resilience[206]. Street surveys indicate that that lack of compliance with technical standards and adequate design and construction practices are becoming problems in Mexico City and other parts of the country[207]. One significant reason is that building code requirements are not understood

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[200] ibid

[201] Mario Ordaz and Roberto Meli, *Seismic Design Codes in Mexico*, in Proceedings of 13th World Conference on Earthquake Engineering, Vancouver, Canada, paper 4000, 2004.

[202] UNDRR, *Mexico earthquake, 2017- Forensic analysis, Case Study*, 11 September 2024. https://www.undrr.org/resource/mexico-earthquake-2017-forensic-analysis

[203] ibid

[204] Juan Murcia-Delso, Sergio M Alcocer, Oriol Arnau,, Yaneivy Martınez, and David Muria -Vila, Seismic rehabilitation of concrete buildings after the 1985 and 2017 earthquakes in Mexico City, Earthquake Spectra, 36(S2), 2020. doi: 10.1177/8755293020957372

[205] ibid

[206] Jelena Pantelic, *The link between reconstruction and development*, Land Use Policy, October 1991.

[207] Sergio M. Alcocer and Vıctor M. Castano, *Evolution of codes for structural design in Mexico*, Structural Survey, 26(1), 2008. doi 10.1108/02630800810857417

and correctly applied by all design professionals[208]. There is a big gap between the level of expertise of a small group of well-informed specialists and that of the most professionals and builders[209]. Moreover, local governments lack the technical knowledge to identify code deficiencies in proposed designs[210].

Most commonly structural retrofits are because of earthquake damage. Instances of proactive retrofit are rare. For example, strengthening may be required for change of use or other significant modifications to the building (personal communication, Alcocer). There are no national seismic risk mitigation measures since each municipality develops its own building codes. In Mexico City, there are no voluntary or mandatory requirements for evaluation and/or strengthening of private buildings. More than a quarter of population in the city live in poverty[211] and many owners lack financial resources to fund retrofits. The 2023 version of MCBC's Complementary Technical Norm ("Norma Técnica Complementaria para Evaluación y Rehabilitación Estructural de Edificios Existentes") establishes the minimum requirements for the evaluation and structural rehabilitation of existing buildings in Mexico City. The triggers for evaluation include moderate or severe damage due to seismic events, change of use and remodelling or modifications that involve changes to the structural systems. The minimum performance level of retrofit is for collapse prevention. Examples of acceptable strategies include localised repairs for damage, strengthening of key structural elements and addition of energy dissipators, dampers, or base isolation systems. Depending on the building's vulnerability level and geotechnical zone, structural evaluation must be completed within 6-24 months and project construction, including the design and necessary works, must be completed within 6-36 month following the evaluation phase. The norms allow for older construction to evaluate and rehabilitate buildings with more recent norms than the original code used in design (i.e. they are not required to meet the requirements of the 2023 NTC version). In the past, owners were required to use the most current standard, causing the process to fail because many owners lack the financial strength to meet the demand of a more rigorous code, or in some cases, demands require foundations to extend beyond the physical boundaries of the building site[212].

In post-disaster response, rehabilitation and reconstruction of housing is typically covered with public funds and support from private foundations. In the 2017 earthquake, by 2020, out of 11,880 damaged single-family masonry houses, 9,050 were under rehabilitation and 2,830 were rebuilt or being relocated[213]. In addition, 525 multi-story residential buildings (with more than 11,000 apartments) were rehabilitated. Typical retrofit cost was approximately 30% of the replacement cost. Whereas if the retrofit costs exceed 60% of reconstruction cost, then the structure was replaced. The municipal government covered the cost of retrofit and

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[208] Mario Ordaz and Roberto Meli, *Seismic Design Codes in Mexico*, in Proceedings of 13th World Conference on Earthquake Engineering, Vancouver, Canada, paper 4000, 2004.

[209] Sergio M. Alcocer and Vıctor M. Castano, *Evolution of codes for structural design in Mexico*, Structural Survey, 26(1), 2008. doi 10.1108/02630800810857417

[210] ibid

[211] UNDRR, *Mexico earthquake, 2017- Forensic analysis, Case Study*, 11 September 2024. https://www.undrr.org/resource/mexico-earthquake-2017-forensic-analysis

[212] Sergio M. Alcocer, personal communication, 5 December 2024.

[213] Juan Murcia-Delso, Sergio M Alcocer, Oriol Arnau,, Yaneivy Martınez, and David Muria -Vila*, Seismic rehabilitation of concrete buildings after the 1985 and 2017 earthquakes in Mexico City*, Earthquake Spectra, 36(S2), 2020. doi: 10.1177/8755293020957372

reconstruction. The government was able to recover part of the reconstruction costs through densification by increasing the floor area of new builds by 35%[214]. Similarly, the government's response to recovering residential losses in the 1985 earthquake was swift and involved a massive reconstruction programme. Insurance coverage was absent and the responsibility for reconstruction was borne by the government and affected residents. Two types of residential accommodation suffered the most damage – large multi-storey apartment complexes housing hundreds of people and smaller apartment buildings called *viviendas* which were typically poorly built and lacked basic services. Most of viviendas were "irregular" being built illegally. The presidential decree established *Renovacion Habitacional Popular* (Housing Renovation Program) (RHP). Over a two-year period, RHP delivered 48,800 housing units of which 42,090 were new or rebuilt units[215]. The cost of the RHP was around US$ 392 million of which about 55% came from the Mexican government and the rest from the World Bank[216]. RHP received international recognition for the speed and extent of reconstruction and the improved housing outcomes. The key aspects of improvement were the shift in tenure from renting to ownership and physical upgrading of the housing such as greater living spaces (RHP housing had an average size of 40 m2 which nearly doubled available space for a family) and incorporation of the latest seismic design[217].

Another initiative worth mentioning is the school rehabilitation programme. After the 1985 earthquake, more than 2,000 school buildings in Mexico City and other high-seismic hazard regions were rehabilitated. Simplified and unobstructive methods that could be executed over summer holidays to minimise disruption to education activities were developed. External strengthening was favoured to avoid disturbance to internal finishes and equipment. An example of such technique was external posttensioned diagonal bracing. In addition, emergency evacuation stairs were added and regular evacuation drills were practiced to ensure orderly evacuation[218]. In contrast, other critical facilities such as hospitals and healthcare buildings required more expensive retrofit solutions and temporary relocation of services. Unlike schools, because of higher costs and more elaborate rehabilitation, only a fraction of hospitals in the city were upgraded even 15 years after the 1985 earthquake. Damage assessment of public school buildings caused by the 2017 earthquakes showed that damage intensity in seismically designed post-1985 buildings was significantly lower than that observed in the pre-1985 structures. Load bearing and infill masonry walls were the most damaged structural elements[219]. From the 19,194 school campuses damaged in 2017 (representing 28% of all campuses exposed to these earthquakes), 12,014 were reported with minor damage, 6970 with moderate damage, and 210 with severe damage. Although design

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[214] Sergio M. Alcocer, Strengthening Urban Resilience: Mexico City's Response to the 2017 Earthquake, unpublished paper for QuakeCoRE, December 2024.

[215] Rachel Nadelman, Caroline Nichols, Sara Rowbottom, Sarah Cooper, *Learning from the Mexico City Earthquake: Dynamics of Vulnerability and Preparedness The Case of Housing*, Global Report on Human Settlements, 2007. http://www.unhabitat.org/grhs/2007

[216] Aseem Inam, *Post-earthquake housing recovery in Mexico City and Los Angeles*, Cities, 16(6), 1999.

[217] Ibid and Jelena Pantelic, *Post-Earthquake Housing Reconstruction in Mexico City: Making a New Paradigm*, Proceeding of the 9th World Conference on Earthquake Engineering, Tokyo-Kyoto, 1988.

[218] Roberto Meli and Sergio M. Alcocer, Implementation of Structural Earthquake-Disaster Mitigation Programs in Developing Countries, Natural Hazards Review, 5(1), 2004.

[219] Sergio M Alcocer, David Muria-Vila, Luciano R Fernandez-Sola, Mario Ordaz,and Jose C'Arce, Observed damage in public school buildings during the 2017 Mexico earthquakes. Earthquake Spectra, 36(S2), 2020.

regulations implicitly expect critical facilities, such as school buildings, to attain an Immediate Occupancy performance level, moderately to severely damaged buildings (including post-1985 construction) did not meet this performance objective[220].

Seismic Alert System of Mexico (SASMEX) has been instrumental in mitigating the impact of earthquakes in Mexico by providing early warnings that allow for timely evacuations and the implementation of safety measures. The system began operations in August 1991 and in August 1993 it became the first seismic early warning system in the world to openly broadcast seismic alerts to the general population via subscribing radio and television stations[221]. Regular alerts and public education about the system's use have conditioned people to respond appropriately, minimising panic during real emergencies. Since its inception the system issued only one false alert. The consistency and reliability of SASMEX have encouraged public trust and compliance during alerts, further amplifying its life-saving impact.

Mexico's efforts in mitigating earthquake risks and addressing their aftermath highlight the importance of proactive measures and rigorous building codes. Nevertheless, challenges remain in enforcement, retrofitting, and financial affordability of seismic resilience, especially for vulnerable populations. Strengthening enforcement and bridging knowledge gaps will be key to long-term earthquake preparedness.

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[220] Sergio M Alcocer, David Muria-Vila, Luciano R Fernandez-Sola, Mario Ordaz,and Jose C’Arce, Observed damage in public school buildings during the 2017 Mexico earthquakes. Earthquake Spectra, 36(S2), 2020.

[221] Gerardo Suárez, *The Seismic Early Warning System of Mexico (SASMEX): A Retrospective View and Future Challenges*, Frontiers in Earth Science, 10(February), 2022.

Part III: Review of select technical standards and building codes

International Existing Buildings Code (IEBC)

The International Existing Building Code (IEBC) was developed in the United States of America by the International Code Council (ICC) to encourage the use and reuse of existing buildings by achieving appropriate levels of safety without requiring full compliance with new construction requirements. The IEBC is distinct but aligned with the International Building Code (IBC)[222] also developed by the ICC, which is a model code that provides minimum requirements to safeguard the public health, safety and general welfare of the occupants of new buildings. Where appropriate the IEBC refers to criteria in the IBC.

In the IEBC distinction is made between additions and alterations, with additions being required to comply with requirements for new construction whereas alterations shall be made such that the existing building is no less compliant than it was previously[223]. The IEBC is organized around three primary compliance methods: Prescriptive, Work Area, and Performance. The Prescriptive Method is defined by a series of prescriptive measures that must be met to achieve compliance and is frequently conservative because the method must apply to a broad range of items without in-depth professional analysis. The Performance Method prioritises life safety, including fire safety and means of egress and the Work Area Method categorises projects by the amount of existing fabric that is impacted, separating projects into three alteration levels, where Alteration Level 1 corresponds to projects limited to finishes and fixtures, Alteration Level 2 includes projects involving the reconfiguration of spaces or systems with a work area of less than 50 percent and Alteration Level 3 includes all projects for which the work area is greater than 50 percent[224].

The IEBC was first released in 2003 and is maintained via a standardised procedure[225] where proposed changes are submitted by code enforcement officials, industry representatives, design professionals and other interested parties. Proposed changes are carefully considered through a process in which all interested and affected parties may participate. The document is revised every 3 years, with the 2024 version having been recently released[226].

The IEBC may be adopted by the governing body of a jurisdiction through a state or local ordinance and because of the need to pass laws that are accessible to the public the IEBC is freely available online. In 2006 the Californian Seismic Safety Commission recommended that the IEBC be adopted as California's model building code for existing buildings so that future alterations to existing buildings trigger seismic retrofits to the latest standards. The 2021 edition of the IEBC was adopted by Alabama, Alaska, California (Los Angeles County, **Los**

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[222] https://codes.iccsafe.org/content/IBC2024P1/preface#IBC2024P1_FmPREFACE_FMSecINTRODUCTIONTOTHEINTERNATIONALBUILDINGCODE

[223] https://codes.iccsafe.org/content/IEBC2024V1.0/chapter-5-prescriptive-compliance-method#IEBC2024V1.0_Ch05_Sec502

[224] Ferriss, L., & Auren, A. J. (2018). A Road Map to Structural Alterations in the International Existing Building Code. *APT Bulletin: The Journal of Preservation Technology*, *49*(1), 1-8.

[225] https://www.iccsafe.org/products-and-services/i-codes/code-development/

[226] https://codes.iccsafe.org/content/IEBC2024V1.0

Angeles City, San Diego, San Jose, **San Francisco**), Colorado (Denver), Connecticut, Florida, Illinois (DuPage County), Louisiana, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New Mexico, North Dakota, Ohio, **Oregon (Portland)**, South Carolina, South Dakota (Sioux Falls), Texas (Austin, Dallas, Fort Worth, Houston, San Antonio), Utah, Virginia, **Washington (Seattle)**, and Wyoming. In most cases jurisdictions adopted the 2021 IEBC with amendments. Currently the 2024 edition of the IEBC has been adopted by Illinois, Kansas (Wichita-Sedgwick), and Wyoming.

Chapter 5 of the IEBC provides details for the prescriptive compliance method. Section 502 refers to additions to existing buildings and section 503 refers to alterations to existing buildings. Section 506 addresses change of occupancy and section 507 addresses Historic Buildings. Chapter 5 has further relevance because of the amendments to this chapter that various jurisdictions apply, as described later.

Chapter 12 of the IEBC provides exceptions for the preservation of historic buildings, where the historic status of the building must be accredited by a state or local authority after careful review of the historical value of the building. To meet the requirements of IEBC Chapter 12 a written report must be prepared and filed with the code official by a registered design professional. The report shall identify each required safety feature that is in compliance and where compliance to the IEBC would be damaging to the contributing historic features. For each feature that is not in compliance with the IEBC provisions it is necessary to demonstrate how the intent of the provisions is complied with to provide an equivalent level of safety.

Appendix A of the IEBC provides guidelines for the seismic strengthening of unreinforced masonry bearing wall buildings (Chapter A1[227]), earthquake hazard reduction in existing reinforced concrete and reinforced masonry wall buildings with flexible diaphragms (Chapter A2[228]), prescriptive provisions for seismic strengthening of cripple walls and sill plate anchorages of light, wood-frame residential buildings (Chapter A3), and earthquake risk reduction in wood-frame residential buildings with soft, weak or open front walls (Chapter A4).

Technical insights pertaining to the IEBC

Section 304 of the IEBC provides details for structural design loads and evaluation and design procedures, with section 304.3 providing details for seismic evaluation and design procedures. Section 304.3.1 describes full seismic criteria, with compliance to either the IBC or to ASCE 41[229] . Section 304.3.2[230] describes reduced seismic criteria, where seismic evaluation or design shall comply to either 75 percent of the prescribed forces in the IBC or applicable chapters of Appendix A of the IEBC. Note that although it is not possible to make definitive statements, the implication of Section 304.3.2 is that the criteria of Appendix A of the IEBC (and specifically sections A1 and A4 that have most relevance for New Zealand) can be compared to 75% of the full design requirements of the IBC for equivalent new buildings and

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[227] https://codes.iccsafe.org/content/IEBC2024V1.0/appendix-a-guidelines-for-the-seismic-retrofit-of-existing-buildings#IEBC2024V1.0_AppxA_ChapterA1

[228] https://codes.iccsafe.org/content/IEBC2024V1.0/appendix-a-guidelines-for-the-seismic-retrofit-of-existing-buildings#IEBC2024V1.0_AppxA_ChapterA2

[229] https://ascelibrary.org/doi/10.1061/9780784416112

[230] https://codes.iccsafe.org/content/IEBC2024V1.0/chapter-3-provisions-for-all-compliance-methods#IEBC2024V1.0_Ch03_Sec304

hence are analogous to 75%NBS, or more generally the earthquake-risk classification of approximately 67%NBS that is commonly used in New Zealand.

Section 405.2.2 and 405.2.3 of the IEBC refer to repairs to buildings due to disproportionate earthquake damage[231]. The building shall be evaluated by a registered design professional and the evaluation findings shall be submitted to the code official. The evaluation shall establish whether the lateral force-resisting system of the damaged building, including its foundation, if repaired to its predamaged state, would comply with the IBC and the reduced seismic criteria of section 304.3.2 as described above[232].

Section 502.1.1 of the IEBC refers to Risk Category Assignment. The Risk Category of buildings is reported in Table 1604.5 of the IBC[233] and identifies four risk categories based upon the function and usage of the building. Consequently, the IBC Risk Category is analogous to the building Importance level as applied in New Zealand. Where an addition to an existing building has different occupancies, the risk category of each existing and each added occupancy is to be determined, and where the risk category for the existing building is now higher than before the addition then the addition is to be deemed a change of occupancy. Similar procedures apply in New Zealand when an addition to an existing building may have a different Importance Level than that of the existing building.

Appendix A[234] associated with guidelines for the seismic retrofit of existing buildings is a comprehensive and extensive appendix that is intended as minimum standards for structural seismic resistance, and are established primarily to reduce the risk of life loss or injury. The opening to the appendix clarifies that the provisions will not necessarily prevent loss of life or injury, or prevent earthquake damage to retrofitted buildings.

Chapter A1 is limited to unreinforced masonry (URM) building wall buildings not more than six stories in height (which would describe all or almost all URM buildings in New Zealand). Criteria are provided for discerning whether masonry walls may be treated as solid, cavity, or veneer based on wall cross-section characteristics, and details are provided for testing procedures for masonry materials and anchors in URM walls. Prescribed material strength limits are provided for existing materials. In general the procedures described are consistent with New Zealand New Zealand Seismic Assessment Guidelines, but are more prescriptive. Section A113.6 notes that parapets and exterior wall appendages not conforming to this chapter shall be removed, stabilised or braced to ensure that the parapets and appendages remain in their original position. The height of a URM parapet above any wall anchor shall not be less than 12 inches (305 mm). Section A110 reports General Procedures and Section A111 reports Special Procedures, but clause A111.2 of the Special Procedures refer back to the General Procedures. Section A110.1defines minimum design loads of $0.5D_{DS}W$ where D_{DS} is the Design Spectral Acceleration at short period and is dependent on a location. The ASCE Hazard Tool can be used to obtain detailed seismic demand at a location, but Table 1613.2.5(1) from the City of Los Angeles Existing Building Code was used to identify that D_{DS} can be quantified as 0.167g for minor ground shaking, as 0.33g for moderate ground shaking,

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[231] https://codes.iccsafe.org/content/IEBC2024V1.0/chapter-4-repairs

[232] https://codes.iccsafe.org/content/IEBC2024V1.0/chapter-4-repairs#IEBC2024V1.0_Ch04_Sec405

[233] https://codes.iccsafe.org/content/IBC2024P1/chapter-16-structural-design

[234] https://codes.iccsafe.org/content/IEBC2024V1.0/appendix-a-guidelines-for-the-seismic-retrofit-of-existing-buildings#IEBC2024V1.0_AppxA_ChapterA1

0.5g for severe ground shaking. The resulting evaluation of the design earthquake loading is presented in the table below.

Level of ground shaking	Seismic Demand
Minor	0.835W
Moderate	0.165W
Severe	0.25W

Legacy codes prior to the 2003 IEBC

Prior to the formation of the International Existing Building Code the following codes for existing building were available in USA[235]:

1) An organisation named the Southern Building Code Congress International (SBCCI) had a Standard Existing Building Code. The first edition was dated 1988. The SBCCI had their headquarter office in Birmingham, Alabama. The document did not address earthquake risk.
2) An organisation named Building Officials and Code Administrators (BOCA) had a National Existing Structures Code. The first edition was dated 1984.
3) An organisation named the International Conference of Building Officials (ICBO) had a document named Uniform Code for Building Conservation (UCBC). The first edition was dated 1985. The ICBO revised the Uniform Code for Building Conservation in 1988, 1991, 1994, 1997, and 2000. This timeline leads into the first release of the IEBC in 2003.

In addition to the above, the California Seismic Safety Commission (CSSC) released a draft model ordinance for the seismic retrofit of hazardous URM buildings in 1990[236], which was an update to an earlier Draft Model Ordinance in 1985 (SSC Report No. 85-06) and was based on retrofit standards from the City of Los Angeles and the Structural Engineering Association of Southern California. The 1990 Draft Model Ordinance incorporated the ABK method of seismic strengthening that was developed via a grant from the US National Science Foundation (NSF)[237]. In the opening to the 1990 CSSC draft ordinance it is noted that the ABK method is referred to as the “Special Procedures” in the proposed revised model ordinance and that conventional design is called “General Procedures”. In the opening notes it is also reported that for buildings with 100 occupants or fewer the earthquake force requirements using the general procedures have increased from 0.1W to 0.13W.

The ABK Methodology

ABK were a joint venture consisting of three firms from the Los Angeles area, who secured a grant from the National Science Foundation (NSF) to develop a methodology for the mitigation of seismic hazards in existing unreinforced masonry buildings. The 1984 ABK Methodology refers to effective peal accelerations of 0.1g, 0.2g and 0.4g (corresponding to design

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[235] https://www.youtube.com/watch?v=r2cMdHka-IU

[236] State of California Seismic Safety Commission (1990). A draft model ordinance for the seismic retrofit of hazardous unreinforced masonry buildings. Report No. SSC 90-1. Accessed from: https://ssc.ca.gov/wp-content/uploads/sites/9/2020/08/cssc_90-01_draft_model_ordinance_for_urm.pdf

[237] ABK (1981). Methodology for mitigation of seismic hazard in existing unreinforced masonry buildings: The methodology. Topical Report 08. Accessed from: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB85194371.xhtml

earthquake forces of 0.1W, 0.2W, and 0.4W. Topical Report 02 of the ABK Methodology notes that the design spectra were developed for 5% damping[238].

ASCE 41 Seismic Evaluation and Retrofit of Existing Buildings

As noted previously, clause 304.3.1[239] of the IEBC refers to ASCE 41 as one means of compliance for full seismic criteria. ASCE/SEI 41-23[240] Seismic Evaluation and Retrofit of Existing Buildings describes deficiency-based and systematic procedures that use performance-based principles to evaluate and retrofit existing buildings to withstand the effects of earthquakes. The standard presents a three-tiered process for seismic evaluation according to a range of building performance levels by connecting targeted structural performance and the performance of nonstructural components with seismic hazard levels. The deficiency-based procedures allow evaluation and retrofit efforts to focus on specific potential deficiencies deemed to be of concern for a specified set of building types and heights. The systematic procedure, applicable to any building, sets forth a methodology to evaluate the entire building in a rigorous manner.

This ASCE 41 standard establishes analysis procedures and acceptance criteria, and specifies requirements for foundations and geologic site hazards; components made of steel, concrete, masonry, wood, and cold-formed steel; architectural, mechanical, and electrical components and systems; and seismic isolation and energy dissipation systems. Checklists are provided for a variety of building types and seismicity levels in support of the Tier 1 screening process.

ASCE 41-23 is a primary reference for structural engineers addressing the seismic resilience of existing buildings and for building code officials reviewing such work. It also will be of interest to architects, construction managers, academic researchers, and building owners.

Technical insights pertaining to ASCE 41

ASCE 41 is not a code but instead a standard. The document is written by structural engineers for use by structural engineers, and is analogous to the Seismic Assessment Guidelines developed in New Zealand. A number of relationships exist between engineers involved in the preparation of ASCE 41 and engineers involved in the preparation of Eq-Assess documents. Content from ASCE 41 has been adopted within the Eq-Assess documents and some research from New Zealand has influenced ASCE 41.

California Existing Building Code

The California Existing Building Code (CEBC) outlines regulations for the repair, alteration, change of occupancy, addition, and relocation of existing buildings to ensure they comply with current safety and efficiency standards. The California Existing Building Code 2022 is based on the International Existing Building Code 2021 (IEBC 2021) with amendments and additions[241]. The CEBC document is part of the California Building Standards Code, which is Title 24 of the California Code of Regulations[242]. Part 8 of Title 24 is the California Historical

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[238] ABK (1984). Methodology for mitigation of seismic hazard in existing unreinforced masonry buildings: Seismic Input. Topical Report 02.

[239] https://codes.iccsafe.org/content/IEBC2024V1.0/chapter-3-provisions-for-all-compliance-methods

[240] https://ascelibrary.org/doi/10.1061/9780784416112

[241] https://up.codes/viewer/california/ca-existing-building-code-2022

[242] https://www.dgs.ca.gov/BSC/About/History-of-the-California-Building-Standards-Code---Title-24

Buildings Code (CHBC) and Part 10 of Title 24 is the California Existing Building Code (CEBC).

The CEBC and CHBC first came into effect in the 1995 edition, with the specific date of effect being January 1, 1996, with Part 10 being based on the 1994 UCBC and being named the California Code for Building Conservation (CCBC). The 1998 edition of CEBC/CCBC was based on the 1997 UCBC and the 2001 edition of the CEBC was also based on the 1997 UCBC. Since 2007 the CEBC has been based on the corresponding version of IEBC, with release dates typically trailing by one year.

Technical insights pertaining to the CEBC

Whereas the IEBC has 9 sections in Chapter 3, the CEBC has 23 sections in Chapter 3[243]. Section 312 pertains to Hospital Structural Performance categories (see below). Section 317 refers to earthquake evaluation and design for retrofit of existing buildings and provides sub-categories for state-owned buildings (including the University of California and California State University), public school buildings, and community college buildings. Section 319[244] refers to seismic criteria selection for existing buildings and describes the technical approach to be used for the seismic evaluation and design of existing buildings, including the role of peer review. Section 322[245] provides details on Peer Review Requirements, including the timing of the selection of the independent reviewer, the qualifications and terms of employment, the scope of the review, the content required in the review report, and procedure for resolution of conflicts. The CEBC also contains an additional Chapter 3A[246] for existing buildings regulated by the Office of Statewide Health Planning and Development (OSHPD), including section 313A for earthquake monitoring for existing buildings.

Appendix A of the CEBC is analogous to Appendix A of the IEBC.

California Historical Building Code

The California Historical Building Code 2022 is found in Title 24, Part 8 of the California Code of Regulations and provides guidelines for preserving, rehabilitating, and restoring historic buildings while allowing for necessary upgrades to meet current safety standards and accessibility requirements[247]. The CHBC governs for all qualifying historical buildings or properties in the state of California. The CHBC is intended to save California’s architectural heritage by recognizing the unique construction issues inherent in maintaining and adaptively reusing historic buildings. The CHBC provides alternative building regulations for permitting repairs, alterations and additions necessary for the preservation, rehabilitation, relocation, related construction, change of use, or continued use of a “qualified historical building or

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[243] https://up.codes/viewer/california/ca-existing-building-code-2022/chapter/3/provisions-for-all-compliance-methods#3

[244] https://up.codes/viewer/california/ca-existing-building-code-2022/chapter/3/provisions-for-all-compliance-methods#319

[245] https://up.codes/viewer/california/ca-existing-building-code-2022/chapter/3/provisions-for-all-compliance-methods#322

[246] https://up.codes/viewer/california/ca-existing-building-code-2022/chapter/3A/provisions-for-all-compliance-methods#3A

[247] https://up.codes/viewer/california/ca-historic-building-code-2022

structure.” The CHBC is a performance-based code as opposed to the more prescriptive approach contained within the IEBC.

Section 18955 of the California Health and Safety Code defines a "qualified historical building or structure” as “any structure or property, collection of structures, and their associated sites deemed of importance to the history, architecture, or culture of an area by an appropriate local or state governmental jurisdiction. This shall include structures on existing or future national, state or local historical registers or official inventories, such as the National Register of Historic Places, State Historical Landmarks, State Points of Historical Interest, and city or county registers or inventories of historical or architecturally significant sites, places, historic districts, or landmarks. This shall also include places, locations, or sites identified on these historical registers or official inventories and deemed of importance to the history, architecture, or culture of an area by an appropriate local or state governmental jurisdiction.”

Gilmartin and Dreyfuss (2015)[248] note that there is a common source of confusion regarding the definition of a ‘qualifying building’, with design professionals often assuming that a building must be landmarked, whereas the intent is that a building that would be historically significant and yet is not landmarked is still eligible for use of the CHBC. The CHBC allows for the reality that not all historically significant structures have been formally recognized. On a local level, city and county preservation planners can be very helpful in terms of providing the information (local inventories or cultural heritage surveys) to facilitate an understanding of whether or not the building in question can be deemed a qualified historical building. By using the word “future” in its definition, the CHBC allows for situations in which historic buildings for which surveys have not yet been performed to be assessed, and if appropriate, designated, thereby classifying them as a qualified historical building.

Enforcing agencies in California are required to allow the use of the CHBC for pertinent work on qualified historical buildings when a private property owner elects to use the CHBC. Unfortunately, many owners are not advised that their buildings are eligible to use the CHBC by their design professionals, and the scopes of work put forth in these situations are beyond that which is necessary. Conversely, State Agencies are required to apply the CHBC “in permitting repairs, alterations and additions necessary for the preservation, restoration, rehabilitation, safety, relocation, reconstruction or continued use of qualified historical buildings or properties.”

The CHBC’s standards and regulations are intended to facilitate the rehabilitation or change of occupancy so as to preserve their original or restored elements and features, to encourage energy conservation and a cost effective approach to preservation, and to provide for reasonable safety from fire, seismic forces or other hazards for occupants and users of such buildings, structures and properties and to provide reasonable availability and usability by the physically disabled.

In order to provide for interpretation of the provisions of the CHBC and to hear appeals, the State Historical Building Safety Board (SHBSB) shall act as an appeal and review body to state and local agencies or any affected party.

In Section 8-102 it is noted that it is the intent of the CHBC to allow nonhistorical expansion or addition to a qualified historical building or property, provided nonhistorical additions shall conform to the requirements of the regular code. When a qualified historical building or

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[248] Gilmartin, U. M., & Dreyfuss, A. R. (2015). Introduction to the California Historical Building Code. In *Improving the Seismic Performance of Existing Buildings and Other Structures 2015* (pp. 208-215).

property is determined to be unsafe as defined in the regular code, the requirements of the CHBC are applicable to the work necessary to correct the unsafe conditions. Work to remediate the buildings or properties need only address the correction of the unsafe conditions, and it shall not be required to bring the entire qualified historical building or property into compliance with regular code. In Section 8-104 it is noted that where an emergency is declared and a qualified historical building or property is declared an imminent threat to life and safety, the state agency assessing such a threat shall consult with the SHBSB before any demolition is undertaken, per Section 18961 of the Health and Safety Code.

In Section 8-105 it is noted that repairs to any portion of a qualified historical building or property may be made in-kind with historical materials and the use of original or existing historical methods of construction, subject to conditions of the CHBC. Further details are provided in chapter 8-8 named ‘Archaic materials and methods of construction’.

In Section 8-702 it is noted that the CHBC shall not be construed to allow the enforcing agency to approve or permit a lower level of safety of structural design and construction than that which is reasonably equivalent to the regular code provisions in occupancies which are critical to the safety and welfare of the public at large, including, but not limited to, public and private schools, hospitals, municipal police and fire stations and essential services facilities and that the CHBC regulations shall prevent voluntary and partial seismic upgrades when it is demonstrated that such upgrades will improve life safety and when a full upgrade would not otherwise be required.

Searer et al. (2015)[249] note that the California Building Code refers to “unsafe” and “dangerous” whereas the CHBC refers to “distinct life safety hazard” and “imminent threat”. Searer et al. (2015) also note that the CHBC is often misunderstood or misused, and Gilmartin and Dreyfuss (2015) note that despite the genesis of the CHBC deriving from Volume 1 of the 1973 California History Plan[250], many engineers and architects are unaware of the CHBC, and that those who are aware of the document are sometimes prone to misconceptions regarding its content and use. Gilmartin and Dreyfuss (2015) provide comprehensive details regarding the legislative procedures associated with the formation of the CHBC. Gilmartin and Dreyfus (2015) also emphasise that the stated intent of the CHBC is to “facilitate the preservation and continuing use of qualified historical buildings or properties while providing reasonable safety for the building occupants and access for persons with disabilities.” The phrase “reasonable level of safety” is an important one. It is not a guarantee that a building is free from all risk.

Specific CHBC criteria for seismic forces

Section 8-706.1 of the CHBC addresses seismic forces. Four exceptions are listed: (1) forces need not exceed 75 percent of the seismic forces for regular code requirements, (2) for other than the high risk category near fault effects can be neglected, (3) for low risk categories (I and II) the seismic base shear need not exceed 0.3W and (4) for high risk categories (III and IV) the seismic base shear force need not exceed 0.4W.

Section 8-706.1.2 provides two exceptions for unreinforced masonry bearing wall buildings: (1) Strength values may exceed the values given in the CEBC when test data and building

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[249] Searer, G. R., Cobeen, K. E., & Sasaki, K. A. (2015). Beneficial Uses and Misuses of the California Historical Building Code. In *Improving the Seismic Performance of Existing Buildings and Other Structures 2015* (pp. 198-207).

[250] California Department of Parks (1973). The California History Plan, Sacramento, CA.

configuration support higher values, and (2) scope criteria in the CEBC for regulated elements shall not apply for Risk category III buildings with an occupancy load greater than 300.

Further comments related to the CHBC

Currently there is nothing parallel to an Historic Buildings Code in New Zealand. One challenge in the New Zealand context is that throughout the country, both in major urban centres and in more rural towns, old (often URM) buildings are located on ‘main street’, and whilst these buildings may not constitute listed Heritage Buildings, they do make an important contribution to the historic character of the township. Extending from the principles of the CHBC, the viability of protecting New Zealand ‘character precincts’ in some way via less demanding criteria for seismic response may merit consideration.

Los Angeles retrofit ordinance - Division 88 (City of Los Angeles Existing Building Code)

The City of Los Angeles Building Code (Amended Jan 3 2014) lists Article 1.2 associated with Existing Buildings (Amended Dec 30 2016). The Basic Provisions note that “The Los Angeles Existing Building Code adopts by reference portions of the 2022 California Existing Building Code (CEBC)”. The City of Los Angeles Existing Building Code differs from other documents because it contains ‘divisions’ for the treatment of different building systems as further described below.

Division 88[251] is titled Earthquake Hazard Reduction in Existing Buildings. In Clause 91.8808.1 it is noted that the minimum total lateral seismic force need not exceed the values given in the table below:

Rating Classification	Seismic demand
I, Essential Buildings	0.186W
II, High Risk Buildings	0.133W
III & IV, Medium Risk and Low Risk Buildings	0.100W

San Francisco Existing Building Code (SFEBC)

San Francisco Building Codes are amendments to the California Building Standards Codes[252]. San Francisco Building Codes were released in 1948, 1952, 1988, 1992, 1995, and then from 1998 were amendments of the California Building Code. A monograph of an abridged history of San Francisco’s Bureau of Building Inspection between 1944 and 1992 is available[253].

Chapter 5B of the San Francisco Existing Buildings Code[254] is titled Earthquake Hazard Reduction in Unreinforced Masonry Bearing Wall Buildings. Chapter 5C is titled Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings and Chapter 5D it

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[251] https://codelibrary.amlegal.com/codes/los_angeles/latest/lamc/0-0-0-180358

[252] https://sfpl.org/locations/main-library/government-information-center/san-francisco-government/san-francisco

[253] https://avelar.net/articles_publications/an-abridged-history-of-san-franciscos-bureau-of-building-inspection-1944-to-1992/

[254] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5B/earthquake-hazard-reduction-in-unreinforced-masonry-bearing-wall-buildings#new_5B

titled Parapet and Appendages – Retrospective Provisions. Consequently, the format of the San Francisco Existing Building Code follows the CEBC but additional sections appear.

In Chapter 5B it is noted that the time limits for compliance with the provisions of the chapter have passes, but that the ordinance are still in effect. The time periods are in years measured from February 15, 1993, and the longest time period was 13 years, therefore expiring in February 2006.

In the San Francisco Existing Buildings Code, Bolts-Plus is defined in section 503B[255] as:

“the installation of shear and tension anchors at the roof and floors and, when required, the bracing of the unreinforced masonry bearing walls upon evaluation of the height-to-thickness ratio of these walls.”

Section 504B.2.3 notes an owner shall engage a registered civil or structural engineer or licensed architect to prepare an engineering report on the building when: (A) An owner desires to demolish a qualified historical building or any building containing a nonexempt Group R Occupancy rather than retrofit the building, and a report is requested by the Building Official or the Building Official of the Planning Department; or (B) The Bolts-plus level of strengthening is proposed; or (C) Strengthening to comply with the State Historical Building Code is proposed; or (D) The owner believes the building complies with Chapters 5B and 5C without any further alteration. The engineering report shall detail applicable retrofit requirements of the least restrictive retrofit procedure for which the building qualifies. The required retrofit measures shall be developed schematically, and a conceptual construction cost estimate shall be included. If the Bolts-plus level of strengthening defined above and described in Exception 1 to Section 509C.2 is proposed, the necessary measures for compliance with the Special Procedure of Section 511C shall also be designated, and a second cost estimate for this option shall also be included in the report.

Chapter 5C provides the seismic strengthening provisions for unreinforced masonry bearing wall buildings. Clause 510C.1 addresses General Procedures and requires that buildings be designed to resist 0.10W. Clause 511C.6 addresses Special Procedures and requires that buildings without crosswalls be designed to 0.132W and buildings with crosswalls be designed to 0.1W. A crosswall is defines as wood-framed wall oriented in the direction of consideration.

Bolts-Plus

In Section 509C.2[256] of the San Francisco Existing Buildings Code it is noted that a building may be strengthened to the Bolts-Plus level by complying only with the requirements for wall anchorage (tension bolts), diaphragm shear transfer (shear bolts) and out-of-plane wall and parapet and appendage bracing, provided the entire building complies with all of the following requirements:

1. The building does not have any vertical irregularities of Types 1a or 1b (Soft Story), 4 (In-Plane Discontinuity) or 5a or 5b (Weak Story) as defined in ASCE 7-16 Table 12.3-2 or horizontal irregularities of Types 3 (Diaphragm Discontinuity) or 4 (Out-of-Plane Offset) as defined in ASCE 7-16 Table 12.3-1 or those irregularities are corrected.

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[255] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5B/earthquake-hazard-reduction-in-unreinforced-masonry-bearing-wall-buildings#new_503B

[256] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5C/seismic-strengthening-provisions-for-unreinforced-masonry-bearing-wall-buildings#new_509C.2

2. The building does not contain any Group A Occupancies with an occupant load of 300 or more, or Group E, Group I or Group H-1, H-2 or H-4 Occupancies.
3. The building has a mortar shear strength, vt, as determined by Section 506C.3.3, of 30 psi (206.843 kPa) or more for all masonry classes.
4. The building has wood or plywood diaphragms at all levels above the base of building.
5. The building contains a maximum of six stories above the base of the building. The base shall be the ground level and basement or basements shall be excluded from the story count.

EXCEPTION: In an otherwise qualifying building of greater than six stories, a maximum of six of the uppermost contiguous stories may be retrofitted using the Bolts-Plus Procedure, providing the building is not located on poor soil as defined in Section 503B. The masonry walls required by Item 7 below shall occupy not less than 50 percent of the wall length in the lowest two of the uppermost six stories. Nonqualifying stories and stories below the uppermost six shall be retrofitted to any other procedure for which they qualify.

6. The building has or will be provided with crosswalls as defined in Section 511C.3 at a spacing that does not exceed 40 feet (12.192 m) on center. Any story which does not have or is not provided with complying crosswalls and all stories below that story shall be analysed using the General Procedure of Section 510C or, where applicable, the Special Procedure of Section 511C. The floor structure that separates the Bolts-Plus and General or Special Procedure stories shall be investigated for its adequacy to act as a diaphragm in accordance with Section 510C.1 or, where the Special Procedure is applicable, Section 511C.4.
7. The building has or will be provided with a minimum of two lines of vertical elements of the lateral force resisting system parallel to each axis. Masonry walls shall have wall piers with a height-to-width ratio that does not exceed 2 to 1 and shall occupy not less than 40 percent of the wall's length in order to be considered as providing a line of resistance. Existing moment frames and other lines of resistance added or altered to comply with this requirement shall fully comply with Section 512C. At least one line in each direction shall be a masonry or concrete shear wall.
8. In buildings containing one or more party walls, the Bolts-Plus Procedure shall not be used unless each building sharing a party wall individually complies with all of the limitations set forth above and the owner of each such building consents to the use of the procedure in writing.

When the Bolts-Plus Procedure is applicable, the forces to be used for diaphragm shear transfer and irregularity correction shall be those specified in Sections 511C.5[257] and 511C.6[258] and h/t ratios shall be evaluated in accordance with Section 511C.7. When the intersection of the diaphragm span and demand capacity ratio falls outside the three regions of Figure 5C-1, the h/t ratios for "all other buildings" in Table 5C-B shall be used. The measures used to comply shall be part of, and be coordinated with, the complete strengthening scheme described in the engineering report required by Section 504B.2.3.

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[257] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5C/seismic-strengthening-provisions-for-unreinforced-masonry-bearing-wall-buildings#new_511C.5

[258] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5C/seismic-strengthening-provisions-for-unreinforced-masonry-bearing-wall-buildings#new_511C.6

The requirements for the design of wall anchorages are contained in section 513C.1.1[259], the design of diaphragm shear transfer is detailed in section 513C.2[260] .

The Bolts-Plus criteria were adopted by the City of San Francisco and a few other Californian local governments in the early 1990s. The procedure was not used extensively and it has been estimated that well under 10% of URM retrofits in California followed the Bolts-Plus approach, largely because the procedure did not comply with the minimum performance requirements of either IEBC Appendix A1 or ASCE 41. Whilst the procedure remains in the SFEBC it is noted that the procedure can only be used in regions with low seismicity, which effectively makes the method obsolete in California. Additionally, following the 1989 Loma Prieta earthquake the performance of retrofitted URM buildings was evaluated and it was concluded that partial retrofits such as resulting from the Bolts Plus procedure did not perform markedly better than parapet bracing alone[261].

In several cases the descriptor Bolts-Plus has been incorrectly applied to refer to the general concept of non-specific seismic upgrading rather than the specific criteria of the official Bolts-Plus ordinance. The Bolts-Plus procedure arose from an Environmental Impact Report developed by the engineering company Rutherford and Chekene in the early 1990s and the procedure was opposed by the Structural Engineering Society of Northern California (SEAONC) in a letter to the City of San Francisco because the method provided an insufficient level of strengthening. Also, the Bolts-Plus method was considered but not incorporated into either UCBC Appendix A1 or IEBC Appendix 1.

It has been suggested that parapet bracing would be a more logical first level intervention (rather than the Bolts-Plus procedure) and that parapet bracing is recognised in local ordinances, state regulations, and national standards in the US, which aligns with the amendment to the Building Act 2004 in response to the 2016 Hurunui/Kaikōura earthquakes.

Seattle Existing Building Code 2021 and Oregon Existing Building Code 2021

The Seattle Existing Building Code 2021[262] is based on the IEBC 2021[263] and was adopted on 15 Nov 2024. From a general review it appears that there are no noteworthy additions pertaining to earthquake assessment or improvement beyond those contained in the IEBC.

The Oregon Existing Building Code 2021 is based on the International Existing Building Code 2021 (IEBC 2021) with amendments and additions[264]. The date of adoption was 1 October 2022. In the Oregon Existing Building Code the IEBC requirements for Appendix A Guidelines

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[259] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5C/seismic-strengthening-provisions-for-unreinforced-masonry-bearing-wall-buildings#new_513C.1

[260] https://up.codes/viewer/san_francisco/ca-existing-building-code-2022/chapter/new_5C/seismic-strengthening-provisions-for-unreinforced-masonry-bearing-wall-buildings#new_513C.2

[261] Kustu, O., Bruce, R.A., & Rojahn, C. (1993). Report and Summary of ATC-31—Evaluation of the Performance of Seismically Retrofitted Buildings. Structural Engineering in Natural Hazards Mitigation, 337-342.

[262] https://up.codes/viewer/seattle/iebc-2021

[263] https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/existing-building-code#2021seattleexistingbuildingcode

[264] https://up.codes/viewer/oregon/iebc-2021

for the Seismic Retrofit of Existing Buildings has been omitted. The Portland City Code contains Chapter 24.85 for the seismic design requirements for existing buildings[265]. Specific criteria for the seismic strengthening of unreinforced masonry bearing wall buildings are contained in section 24.85.065[266]. The criteria are less prescriptive than in California as reproduced below:

When any building alterations or repairs occur at an Unreinforced Masonry Bearing Wall Building, all seismic hazards shall be mitigated as set forth in Subsections 24.85.065 A. and B. A previously permitted seismic strengthening scheme designed in accordance with FEMA 178/310/ASCE 31 may be submitted for consideration by the Bureau Director as equivalent to the ASCE 41 improvement standard.

A. Roof Repair or Replacement. When a roof covering is repaired or replaced, as defined in 24.85.020, the building structural roof system, anchorage, and parapets shall be repaired or rehabilitated such that, at a minimum, the wall anchorage for both in-plane and out-of-plane forces at the roof and parapet bracing conform to the ASCE 41-BPOE improvement standard. In-plane brick shear tests are not required as part of the ASCE evaluation under this subsection.

B. Additional Triggers.

1. Building alterations or repair. When the cost of alteration or repair work which requires a building permit in a 2-year period exceeds the following criteria, then the building shall be improved to resist seismic forces such that the entire building conforms to the ASCE 41-BPOE improvement standard.

Table 24.85-C

Building Description	Cost of Alteration or Repair
Single Story Building	$40 per square foot
Buildings Two Stories or Greater	$30 per square foot

2. Special building hazards. Where an Unreinforced Masonry Building of any size contains any of the following hazards, the building shall be seismically improved if the cost of alteration or repair exceeds $30 per square foot:

a. The Building possesses an Occupancy Classification listed within the Relative Hazard Category 5 as determined in Section 24.85.040 of this Chapter; or

b. The building is classified as possessing either vertical or plan irregularities as defined in the OSSC.

3. Exclusions from cost calculations. Costs for site improvements, eco-roofs, mandated FM41 agreements, mandated ADA improvements, mandated non-conforming upgrades under Title 33, mandated elevator improvements and mandated or voluntary seismic improvements or work exempted from permit as described in

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[265] https://www.portland.gov/code/24/85

[266] https://www.portland.gov/code/24/85#toc--24-85-065-seismic-strengthening-of-unreinforced-masonry-bearing-wall-buildings-

Chapter 1 of the OSSC will not be included in the dollar amounts listed in Subsections 24.85.065 B.1. and 2.

4. Live/Work spaces in Unreinforced Masonry buildings. See Section 24.85.040 B for requirements when a Unreinforced Masonry building is converted to contain live/work spaces.

5. Automatic cost increase. The dollar amounts listed in Subsections 24.85.065 B.1. and 2. shall be modified each year after 2004 by the percent change in the R.S. Means of Construction Cost Index for Portland, Oregon. The revised dollar amounts will be made available at the Development Services Center.

Interpreting design level earthquake loading

The extensive development of seismic hazard criteria in New Zealand and the US since the 1980s results in comparisons between US past-practice and NZ current-practice being questionable. It is also noted that most retrofits to URM building in California were installed more than two decades ago. The following analysis is provided in the hope that it may prove constructive but it is emphasised that close scrutiny is unmerited.

As noted previously, in the City of Los Angeles Existing Building Code Clause 91.8808.1 it is reported that the total lateral seismic force to be resisted need not exceed the values given in the table below:

Rating Classification	**Seismic demand**
I, Essential Buildings	0.186W
II, High Risk Buildings	0.133W
III & IV, Medium Risk and Low Risk Buildings	0.100W

In the San Francisco Existing Building Code the General Provisions refer to 0.1W and the Special Provisions refer to 0.132W when there are no crosswalls.

More generally, the IEBC provides the following values for the design earthquake force.

Level of ground shaking	**Seismic Demand**
Minor	0.084W
Moderate	0.165W
Severe	0.25W

In New Zealand the US Risk Categories I and II correspond to Importance Levels 1 and 2 that can be described as ordinary, such that the Risk Factor in NZS 1170.5[267] is R=1. For a URM building the first mode period is typically 0.2-0.4 seconds and therefore near-fault effects are not considered when using NZS 1170.5. Adopting Wellington as a building location for the purpose of comparison the seismic zone factor would be Z=0.40. Adopting soil class C the Spectra Shape factor C_h(T=0.2-0.4)=2.36. The design seismic load would then be 2.36x0.4x1x1x1=0.944W.

Section C8 allows for the elastic design force to be reduced by a factor of 3 when non-brittle modes are developed, which is common. This reduction is justified by the observation that URM buildings are highly damped, which significantly influences the design spectra when compared with normal 5% damping. Consequently the resultant earthquake demand on a

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[267] NZS 1170.5:2004 Structural Design Actions Part 5: Earthquake Actions – New Zealand. Standards New Zealand.

regular (non-brittle) URM building in Wellington would be 0.315W and the demand from both Los Angeles and San Francisco of 0.1W would equate to 32%NBS.

The analysis above indicates that when using the California Historic Building Code the design level loading would be approaching 100%NBS for a URM building. For buildings composed of other materials where a 5% spectra was appropriate a more detailed analysis would be required before comparisons could be made.

Conclusions

The following conclusions are presented:

1. The formation of a single national document for existing buildings (the IEBC) has resulted in harmonisation of procedures across the United States. This point is perhaps less relevant for New Zealand.
2. The practice of individual jurisdictions in the US adopting the IEBC with amendments is perhaps something worthy of consideration in New Zealand, if there was to be an opportunity for individual New Zealand Territorial Authorities to exercise a level of discretion about certain aspects of a national earthquake prone buildings policy.
3. The engineering practices pertaining to seismic assessment and improvement of existing buildings of West Coast USA and New Zealand are similar, with frequent exchange of information between the two regions. ASCE 41 is a technical document analogous to the Seismic Assessment Guidelines used in New Zealand.
4. Despite the similarities referred to above, there is no simple parameter used in the US that is analogous to the %NBS term that is central to the current New Zealand earthquake prone building methodology.
5. The non-specific procedures of Appendix A of the IEBC can be approximated as offering 75%NBS protection, or more generally matching the 67%NBS earthquake risk category used in New Zealand.
6. The criteria provided in Appendix A1 for the seismic retrofit provisions of existing URM buildings are analogous to 33%NBS. This statement assumes that the seismicity of Los Angeles, San Francisco and Wellington are comparable.
7. Currently there is no document or procedure in New Zealand that compares to the California Historic Building Code. The development of New Zealand procedures for the protection of designated heritage buildings merits consideration. The seismic demand criteria of CHBC indicate that when using this code a URM building would be strengthened to approximately 100%NBS.
8. The Bolts-Plus method that was developed in San Francisco has had limited uptake and is now effectively obsolete. The Californian experience would instead be in favour of a 3-tiered system such as:
    a. Parapet securing analogous to the ordinance enacted in the lower North Island and upper South Island following the 2016 Hurunui/Kaikōura earthquakes.
    b. Non-specific procedures that prescribe a reduced level of strength capacity, such as 75% of New Building Strength (as implied in USA) or perhaps 67% using the existing procedures in New Zealand. Note however that IEBC criteria for URM buildings is more analogous to 33%NBS.
    c. Full engineering design using the New Zealand Seismic Assessment Guidelines.
9. In the existing building codes of San Francisco and Seattle there is reference to the estimated costs for seismic upgrading. The requirement to submit cost estimates may merit consideration.

Part IV: Regulatory Approaches to Life Safety - A Preliminary Guide

Introduction

Regulation is a hugely complex and contested topic. This is particularly true when it comes to applying such regulatory models to life safety issues. The follow is a very brief overview of the main varieties of regulatory approaches utilised globally with a focus upon life safety and personal injury examples. Given the time constraints of the project, it is, by necessity, far from comprehensive and the examples provided are a little eclectic. A more nuanced study with a better coverage of overseas examples, particularly relevant to the issue of seismic resilience in existing buildings would be possible but would require a longer timeframe to complete. Nevertheless, the following does provide an accurate if high level overview of the topic and the issues that exist around it.

There are a variety of different types of regulatory approaches available for policymakers to use when attempting to control a particular activity or behaviour relating to personal safety. These range from approaches which require a high level of state intervention (such as prior approval licensing) to those which involve little or no state intervention (such as self-regulation). Unfortunately, there is no academic consensus on how to categorise these different approaches. However, the following provides a synthesis of the main regulatory categories as drawn from some of the key writers in the field.[268] As a result the following divides these approaches into the four following categories:

1. command and control
2. self-regulation
3. voluntarism
4. economic approaches.

In reality these are ideal types and most jurisdictions utilise a variety of mechanisms in delivering life safety within their jurisdictions.

In most, if not all, jurisdictions, state regulatory models are complemented by some form of legal liability for actions which infringe the life safety of individuals and groups. This is achieved in Common Law systems, (such as New Zealand), through the medium of tortious liability for personal injury. This operates as a form of economic incentive to encourage responsibility for the health and safety of others through the "good neighbour" principles, with financial redress available for those who harm others through negligent actions. In some jurisdictions, such as the United States, the damages awarded can be punitive, with large compensation payments possible to discourage disregard for the safety of others.

New Zealand, by contrast, is unique in providing no incentive to individuals to reduce personal injury risk through the operation of the civil law. Instead, the ACC scheme bars the courts from entertaining personal injury claims. Thus formal regulatory frameworks play a disproportionately important role in the management of life safety in New Zealand than in equivalent regimes overseas. This is important to bear in mind when considering overseas examples and their application in New Zealand.

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[268] The report particularly draws upon Ogus, Baldwin and Cave, and Gunningham, Grabosky and Sinclair.

Command and Control Approaches to Life Safety Regulation

Command and control regulations are defined as rules which impose standards that are backed by sanctions (criminal and administrative) for breaching the standard.[269] Ogus identifies three forms of command and control regulation: information; standards; and prior approval.[270] These are examined below:

Information Regulation

Of the three types of command and control regulation, information regulation requires the least amount of state intervention.[271] Information regulation does not control the action itself or the supply of a particular good or services. Rather it regulates the provision of information about actions, products or service to the public.[272] This form of regulation can be divided into two broad categories: mandatory disclosure and ‘negative’ information regulations.

Mandatory Disclosure Regulation

Mandatory disclosure regulation requires actors to provide information to the public where the market fails to offer an incentive to do so voluntarily.[273] The information disclosed can include issues relating to risk and safety.[274] This information allows consumers to make informed decisions on the acceptability of the particular good or service.

This model is used in the case of car safety in New Zealand and Australia. All models of cars are rated using one of the three rating schemes (ANCAP, UCSR and VSRR). However, with some exceptions, the consumer is free to purchase the vehicles they wish, even if the safety rating is low. The Food standards code (applicable in Australia and New Zealand) takes a similar approach. Such information allows the public to determine the different risks posed by different brands of the same product. In the field of seismic safety this is an approach has been utilised in Japan. In New Zealand this approach can also be seen under the Earthquake

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[269] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 35; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 39. Anthony Ogus Regulation: Legal Form and Economic Theory (Oxford University Press, New York, 1994) at 5.

[270] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 150.

[271] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 49; Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 121.

[272] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 121.

[273] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 49; Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 144. For information on the processes and effectiveness of voluntary disclosure see: Even Fallan and Lars Fallan “Voluntarism versus Regulation: Lessons from Public Disclosure of Environmental Performance Information in Norwegian Companies” (2009) 5 Journal of Accounting and Organizational Change 472; Josephine Maltby “Setting its Own Standards and Meeting those Standards: Voluntarism versus Regulation in Environmental Reporting” (1997) 6 Business Strategy and the Environment 83.

[274] It can of course, also include information unrelated to safety, such as price, quantity, composition and quality. Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 121; Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 49.

Prone Building requirements of the Building Act, currently under review. The EPB requirements mandate that buildings which fall within the legal definition of an EPB must be listed on the public register and provide a public notice to this effect on the building itself.

However, although mandatory disclosure can be useful to drive health and safety, this model has recognised issues. For example, the system will fail to deliver the life safety goals desired if consumers/users fail to understand the implications of the information disclosed; incorrectly assess the risks; or lack the resources to research the risks effectively.[275] There is also a potential for actors to make inaccurate claims and for those that do so to gain market benefit. Thus strong policing of a mandatory information scheme is necessary if it is to work effectively. This thus increases the cost of regulation.[276] In addition, when a risk is such that it cannot be reduced by individual action, or the consequences for the state are too high, it may not be appropriate to simply inform the public of the existence of the risk. In such instances it may be necessary for further regulation involving higher levels of state intervention.[277] Thus in Japan, local authorities have intervened directly in relation to buildings deemed to be seismically vulnerable along emergency routes as the economic and social costs of their failure is too great.

‘Negative’ Information Regulation

‘Negative’ information regulation provides a much lighter form of life safety regulation. This involves the state controlling or prohibiting the supply of false or misleading information rather than requiring the provision of specific information.[278] Such a regime still requires the state to ensure that the regulations are followed (although civil law principles around fraud or passing off may also play a role). In practice such approaches are utilised as part of wider safety regimes, which can either require mandated or voluntary behaviours. An example of such a regime in practice can be found in the regulation of health claims for food safety in New Zealand. For example, although the use of the Health Star Rating is not compulsory, when it is used, it must be in accordance with the requirements of the scheme as enforced by MPI. Such a regime could play some role in seismic resilience and has already been seen in the Wellington property market in particular. However, it is not clear that those using %NBS as a means of providing evidence of seismic resilience are aware of the how the system works.

Standards Regulation

Standard based regulation requires an actor to meet certain life-safety requirements when it is carrying out its activities. These requirements will be established by state sponsored agencies. There are three main categories of standards used in this form of regulation:

- target standards
- performance-based standards

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[275] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 49.

[276] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 50.

[277] Robert Baldwin and Martin Cave Understanding Regulation (Oxford University Press, New York, 1999) at 50.

[278] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 144-145; Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 49.

- specification/process-based standards.[279]

Target standards set out the types of harm an actor is prohibited from causing when conducting an activity, for instance, an individual or company is barred from causing specific amounts of pollution[280] Performance-based standards set specific requirements that must be met. These can include specific life-safety requirements. However, such standards focus upon the performance and not the method that is used to meet this standard. Such standards have become more common in building practice since the 1980s and are the basis of the current EPB model.[281] They are also a key component of the Health and Safety at Work Act which requires those responsible under the Act to ”eliminate” or ”minimise” risks but in most cases does not specify how this is to be achieved. Finally, process-based standards set the specific procedures or methods that must be used to manage a particular risk.[282] The latter example is utilised around the regulation of adventure sports in New Zealand (in addition to their wider responsibilities under the HSWA).[283]

Standards and command and control regulations can provide a degree of certainty surrounding the standards that apply but this type of regulation has been criticised for the potential to produce “unnecessarily complex and inflexible rules”, the need for regulators to have comprehensive knowledge of the industry, difficulties setting appropriate standards and the lack of incentives to go beyond the minimum standards required.[284] In addition, such models rely heavily upon the regulator to ensure enforcement of life safety requirements and provide clarity around the standards required. In the EPB context heavily utilised in relation to new buildings across most developed states and as the above shows, there is some use of mandatory requirements alongside other mechanisms in other states. However, New Zealand remains an outlier in the emphasis it places upon such models in the EPB environment.

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[279] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 150-151; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 40. Gunningham, Grabosky and Sinclair also refer to another type of standard: technology-based standards.

[280] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 40; Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 166.

[281] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 166-167; Wendell Pritchett “Types of Regulation” The Regulatory Review (5 April2016) <https://www.theregreview.org/2016/04/05/pritchett-types-of-regulation/>; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 40.

[282] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 40; Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 167-168.

[283] See Health and Safety at Work (Adventure Activities) Regulations 2016

[284] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 35-39; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 39-47; Chibuike Ugochukwu Uche “The Theory of Regulation: A Review Article” (2000) 9 Journal of Regulation and Compliance 67 at 70.

Prior Approval Regulation

Under prior approval regulation, actors are required to get authorisation from a regulatory body before being permitted to carry out a particular activity.[285] This authorisation is usually in the form of a permit or a licence, which would be granted if the applicant satisfies, or can prove that they would be able to satisfy, the standards set by the regulatory agency. Prior approval regulation is utilised in New Zealand in relation to building consents under the Building Act.[286] Prior approval regulation is considered to be a highly interventionist form of regulation due to its particularly severe sanction as, without a permit/licence, an actor is prohibited from carrying out the activity.[287]

Prior approval allows the state to control the types of activities that can be carried out in its jurisdiction but the level of intervention it utilises has led to criticism that it risks restricting competition (and thus consumer choice);[288] has the potential to make regulatory bodies cautious when they make decisions[289] and can be both costly and difficult to enforce.[290] It has also been criticised for creating a false sense of security around the safety of approved activities.[291] This is because although prior approval can minimise risk, it will not necessarily eliminate it. However, in knowing that an activity has been approved, some may fail to recognise the remaining risk. Furthermore, prior approval only requires the actor to meet a minimum set of standards, and does not encourage improved practices beyond these standards.[292] Nevertheless, prior approval remains an important method in cases when the safety risk is well established and the public has little ability to reduce the individual risk that they are exposed to. Applying this model to earthquake vulnerable buildings is problematic, however, as such buildings are likely in use and unless there is a requirement to actively apply for a retrospective permission, there is no opportunity for a prior approval model to engage with the issue. The exception is when buildings require permissions to be utilised for specific

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[285] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 214.

[286] Building Performance "Apply for Building Consents" Ministry of Business, Innovation and Employment <www.building.govt.nz/projects-and-consents/apply-for-building-consent>.

[287] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 214.

[288] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 214; Peter Cartwright "Risks and Returns of Prior Approval by Licensing: The Case of Banking" (2007) 7 Journal of Banking Regulation 298 at 301-302.

[289] Peter Cartwright "Risks and Returns of Prior Approval by Licensing: The Case of Banking" (2007) 7 Journal of Banking Regulation 298 at 303.

[290] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 45.

[291] Peter Cartwright "Risks and Returns of Prior Approval by Licensing: The Case of Banking" (2007) 7 Journal of Banking Regulation 298 at 303-304.

[292] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 45.

purposes. This has been utilised in New Zealand by some local Councils (notably Wellington) around change of use requirements.[293] This model could be expanded.

Self-Regulation

Self-regulation offers an alternative to a command and control model. Although there is no one agreed definition of self-regulation, it is generally described as a process whereby an organisation/association develops its own system of rules which it then enforces against its own members.[294] This approach already exists in the building sector in Aotearoa New Zealand through the Registered Master Builders Association (amongst other Associations), and Engineering New Zealand which collaborates with the building sector and the state to develop and enforce standards against its members.[295]

Self-regulation is a quicker and more flexible form of regulation,[296] which is sensitive to the market and requires less state intervention than command and control regulation.[297] However, it often leads to weak standards, ineffective enforcement, and the ability of some actors to avoid accountability (by removing themselves from the regulatory regime for example). In addition, this model can lack visibility, credibility and accountability.[298] It is thus rarely used in alone in life safety situations. However, some jurisdictions, notably in the United States, has used this approach to regulate various industries. This has, at times, had catastrophic results.[299]

Self-regulation can be used in addition to the other types of regulatory approaches mentioned in this paper (as in the examples of engineering and building work).[300] However, such models tend to be ineffective unless there is a threat of direct state intervention or where there are external reasons for the industry to uphold high standards (e.g. credibility, legitimacy or

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[293] Hopkins, Safe as Houses? The Limits of Seismic Building Regulation in Aotearoa New Zealand, *New Zealand Law Review*, [2023] p339.

[294] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 39; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 50; Cary Coglianese and Evan Mendelson "Meta-Regulation and Self-Regulation" in Robert Baldwin, Martin Cave and Martin Lodge (eds) *The Oxford Handbook of Regulation* (Oxford University Press, New York, 2010) 146 at 147.

[295] Master Builders "About Us" <www.masterbuilder.org.nz//RMBA/About_Us/About_Us.aspx>.

[296] Chibuike Ugochukwu Uche "The Theory of Regulation: A Review Article" (2000) 9 Journal of Regulation and Compliance 67 at 70.

[297] Neil Gunningham, Peter Grabosky and Darren Sinclair Smart Regulation: Designing Environmental Policy (Oxford University Press, New York, 1998) at 52.

[298] Robert Baldwin and Martin Cave Understanding Regulation (Oxford University Press, New York, 1999) at 40-41; Chibuike Ugochukwu Uche "The Theory of Regulation: A Review Article" (2000) 9 Journal of Regulation and Compliance 67 at 71; Neil Gunningham, Peter Grabosky and Darren Sinclair Smart Regulation: Designing Environmental Policy (Oxford University Press, New York, 1998) at 53.

[299] This has been most visible in the Theme Park industry. The death of Caleb Schwab in 2016 brought this issue to the public eye. https://www.motleyrice.com/news/amusement-parks-law-federal-regulation. However, the problem had long been recognised in the US. See, for example. Avery, Brian & Dickson, Duncan. (2010). Insight into amusement park ride and device safety in the United States. Worldwide Hospitality and Tourism Themes (2), 299-315 10.1108/17554211011052221.

[300] Allen and Clarke "Guide to Regulation" (2021) <https://www.allenandclarke.co.nz/wp-content/uploads/2016/03/50346-AC-A-Guide-to-Regulation.pdf> at 3.

market pressure).[301] In the context of seismic regulation of existing buildings, where the risk to the state is significant, it is not clear how this model could be applied without significant levels of state oversight.

Voluntarism

In contrast to command and control which requires control by the state and self-regulation which requires control by an organisation, there is no such control under the voluntary regulation. Instead, such models require actors to engage in a desired behaviour of their own accord, without fear of a penalty.[302] The state can act as a co-ordinator or facilitator under this approach, offering support to projects that sees actors attempt to meet certain standards voluntarily, while knowing that there are no formal consequences if they do not adopt the required standards (other than the loss of state support).[303] Voluntarism only works as a tool of regulation where there is strong self-interest in an actor achieving the standard sought by the state.[304] Voluntarism is not a model deployed in life safety environments unless there is a lack of external oversight. For example, the international aid sector operates international good practice models through voluntary codes of conduct in the absence of effective international and, at times, domestic regulation.

Economic Approaches to Regulation

The third model of life-safety regulation is the use of economic incentives or “nudges”.[305] The model provides for the use of positive and/or negative financial incentives to encourage the desired behaviour.[306] There are many types of economic regulation, including, but not limited to: the creation of property rights; financial instruments; creation of liability; deposit refund schemes and public compensation schemes. A brief overview of some of the more relevant models for life-safety regulation are provided below.

Property Rights / Liability

Under the property rights approach to regulation, the state creates or allocates property rights in order to encourage desirable behaviours.[307] Property rights can be used to encourage

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[301] Neil Gunningham, Peter Grabosky and Darren Sinclair Smart Regulation: Designing Environmental Policy (Oxford University Press, New York, 1998) at 54.

[302] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 56. For more information on voluntarism regulation in practice see: Louise Eriksson and Camilla Sandström “Is Voluntarism and Effective and Legitimate Way of Governing Climate Adaptation? A Study of Private Forest Owners in Sweden” (2022) 140 Forest Policy and Economics 102751.

[303] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 56.

[304] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 58.

[305] Sometimes referred to as market-based alternatives

[306] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 245.

[307] Harvey Neo “Resource and Environmental Economics” (2009) International Encyclopedia of Human Geography 376 at 378; Cento Veljanovski “Economic Approaches to Regulation” in Robert Baldwin, Martin Cave and Martin Lodge (eds) *The Oxford Handbook of Regulation* (Oxford University Press, New York, 2010) 17 at 30-31; Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York,

specific behaviours in two main ways. First, the right holder is encouraged to behave, or not behave, in a specific way to avoid reducing the value of their property. Second, the public is encouraged to behave, (or not behave), in a specific way so as to avoid liability to pay compensation to the rights holder. Although property rights and the liabilities that flow from these rights can provide an incentive to act in a desired way, there are issues with this approach. For instance, the cost of enforcement, difficulties in collecting evidence, and legal uncertainties surrounding rights/liability may prevent an individual enforcing their rights, while insurance may lessen the deterrent effect created by property rights/liability.[308]

However, in Aotearoa New Zealand this model is difficult to utilise in life safety situations given the inability of individual to use the courts to claim compensation from personal injury.

Incentive-Based Regimes[309]

Under an incentive-based approach to regulation, the state induces an actor to behave in a particular way by imposing charges and/or providing grants, subsidies or tax incentives.[310] This type of regulatory approach allows the state to penalise actors for failing to reduce risk or financially reward actors for actively reducing such risks. Such incentive-based models are not particularly common in life-safety risk situations. However, seismic regulatory schemes for existing buildings are an exception. Italy utilises this model and applies minimal mandatory requirements to existing buildings. Japan also utilises an extensive incentive-based regime to address the seismic risk of existing buildings, in combination with a degree of mandatory requirements. The Japanese system is widely regarded as one of the most successful in the globe (see above). The United States and Taiwan also have similar incentive schemes.

Such schemes reflect an consensus in these states that reducing the seismic vulnerability of existing buildings community benefits from investment in private building improvements through the improved Community resilience. In the Japanese example, the government's responsibilities around the provision of accommodation in post-disaster situations also provides significant financial incentive to the government.

Public Compensation/Social Insurance Schemes

A further economic form of regulatory model applies through the use of mandatory compensation schemes. Under these schemes, a person surrenders their right to claim for certain damage, such as personal injury, against another person or business in return for being entitled to statutory compensation.[311] As the funds for this compensation are collected in the form of premiums for businesses, which are often based on past performance of the business

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1999) at 51-52; Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 70.

[308] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 51-52.

[309] Incentive-based regimes encompass fiscal instruments, financial instruments, performance bonds, and deposit refund systems. Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 75-80.

[310] Neil Gunningham, Peter Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press, New York, 1998) at 75-80; Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 42.

[311] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 53.

or industry, this approach can encourage businesses to mitigate the risk of damages occurring so as to reduce, or prevent increases in, premiums.[312]

For these schemes to work, the insurance premiums must be linked to the risks of the actions performed. In such cases the economic cost can drive reduce life safety risk. Such schemes operate in the same way as tortious liability in the Common Law (Délit in Roman systems). The financial costs of injury or death to the individual discourages poor practice on the part of the risk inducing actor.

However, when there is no incentive to reduce risk within the scheme to reduce the risk this method does not regulate the risk but rather mitigates its costs for the individual harmed. An example of this approach can be seen in the Accident Compensation Corporation scheme (ACC) used in Aotearoa New Zealand. This scheme allows a person to get state funded compensation through ACC for most personal injuries in exchange for a prohibition on personal injury claims, which is paid for through levies paid for by business owners and motorists.[313] However, the risk reduction incentives of this regime are minimal and thus the life safety elements of the model are entirely reliant upon the mandatory (command and control model) Health and Safety at Work Act and in practice the actions of WorkSafe.

Direct Action

The final types of economic approach to life safety regulation is direct state intervention. Under this approach, the state takes direct action by such as using its own resources to achieve the reduction in life safety required.[314]

Regulatory Models - Conclusion

As the above section shows, there are a variety of regulatory approaches that can be utilised to control specific activities or behaviours, particularly in relation to life safety. There is no single correct answer and different types of regulation can be used to effectively reach the same result. For instance, standards enforced by a penalty (command and control) could achieve the same results as encouraging a particular standard through an incentive based scheme. In fact in most cases a variety of regulatory models will be used to achieve the aims of the state in a particular area. This was seen in almost all the jurisdictions studied in relation to seismic vulnerability of existing buildings. However, as noted at the start of this paper, New Zealand's legal framework is globally unique in this regard. The operation of ACC means that the private law tools which act to reduce life safety risk and encourage good practice behaviour do not operate in New Zealand. There is no liability in New Zealand law for personal injury, only for property damage. Thus, although most of the world's jurisdictions operate at least two regulatory models (one private through the courts and one public through state based regulatory models), New Zealand operates only one. For this reason, the role of the state in regulating life safety is disproportionately higher. If the state system fails, there is no safety net in the form of private liability to encourage good behaviour. In addition, New Zealand is

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[312] Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 53-55.

[313] Accident Compensation Act 2001.

[314] Anthony Ogus *Regulation: Legal Form and Economic Theory* (Oxford University Press, New York, 1994) at 265-294; Robert Baldwin and Martin Cave *Understanding Regulation* (Oxford University Press, New York, 1999) at 50-51.

unique in it reliance upon mandatory command and control models to reduce the vulnerability of existing buildings to seismic events.

The consequences of such failures have been seen many times (most recently at Whaakari) where the regulatory actor (Worksafe) was unable to properly monitor and ensure correct behaviours and only acted in the wake of a serious failure to protect life. Such a post-factor intervention is evidence of failure. The job of effective regulation is to provide the barrier at the top of the cliff not the ambulance at the bottom. In the case of the seismic regulation of existing buildings (which in many overseas jurisdictions could result in financial liability if owners were shown to be negligent in addressing a known risk) without effective regulatory intervention by the state, the costs to individuals and the country will be significant and potentially catastrophic.

Conclusion

This report provides a comprehensive overview of seismic risk mitigation strategies employed by various international jurisdictions, focusing on the regulatory frameworks, financial incentives, and technical approaches to safeguarding life and property from earthquake hazards. By examining the seismic risk management practices in countries such as the United States, Japan, Italy, Taiwan, Türkiye, and Mexico, several important lessons can be drawn to improve the seismic resilience of New Zealand's built environment.

First and foremost, the diverse approaches taken by other countries reveal a strong consensus on the need for multifaceted strategies in seismic risk mitigation. These include mandatory retrofitting, the use of financial incentives, the importance of public awareness campaigns, and the application of targeted engineering standards to ensure that high-risk buildings are properly addressed. Notably, countries like Japan and Taiwan have successfully integrated financial incentives within retrofitting schemes, while the United States has utilised both command-and-control models, such as California's local ordinances, and voluntary schemes, achieving notable reductions in seismic vulnerability in older buildings.

However, New Zealand stands out in its reliance on a more singular regulatory approach, primarily based on mandatory seismic retrofitting without equivalent financial incentives or widespread enforcement mechanisms for private property owners. While mandatory retrofitting is a crucial step toward improving resilience, it is evident that a purely command-and-control model may not be sufficient to address the scale of seismic risk posed by the existing building stock. The introduction of financial incentives, tax credits, or subsidies could play a pivotal role in encouraging private owners to retrofit their properties, making such initiatives more economically viable.

The absence of a civil liability framework in New Zealand, which is common in jurisdictions such as the United States, further underscores the importance of robust state intervention in managing seismic risks. Without the deterrence of personal injury claims for property owners whose buildings fail to meet seismic standards, the state's role in enforcing compliance becomes even more critical. The report also highlights the need for stronger enforcement mechanisms to prevent non-compliance, with local authorities empowered to impose penalties or even force evacuations when necessary.

An important lesson drawn from the California experience involves the implementation of seismic retrofitting ordinances for buildings with wood-frame soft-story structures. These buildings, which have weak ground floors, gained attention after the 1989 Loma Prieta and 1994 Northridge earthquakes, which caused extensive damage to soft-story buildings, particularly in San Francisco and Los Angeles. In California, large cities such as Los Angeles and San Francisco became pioneers in implementing mandatory retrofitting ordinances for soft-story buildings, setting the standard for smaller jurisdictions to follow. This highlights the role of large centres in driving policy development and providing models for other jurisdictions. The success of Los Angeles' soft-story retrofit program, for instance, depended on clear deadlines, prioritised timelines based on risk categories, and cost-effective technical solutions that allowed compliance without excessively burdening property owners. Smaller jurisdictions within California, often with fewer resources and political influence, have been able to adopt similar programs, tailoring them to their own local needs while benefiting from the framework set by the larger cities. This "top-down" model, where large jurisdictions lead and smaller ones follow, has proven to be an effective mechanism for scaling seismic risk mitigation across regions, creating a unified approach while allowing for local adjustments. New Zealand could benefit from a similar model, where larger cities like Wellington and Auckland take the lead in implementing comprehensive seismic risk mitigation programs for high-risk building types, such as URMs and concrete buildings.

California also demonstrates a unique approach to retrofitting historic buildings, which offers valuable lessons for New Zealand. The state has developed a separate code specifically for historic buildings, known as the California Historic Building Code (CHBC). This code takes into account the challenges of retrofitting historic structures while preserving their architectural integrity. The CHBC allows for a more flexible approach to seismic retrofitting, ensuring that historical value is maintained while addressing seismic vulnerabilities. Additionally, California offers tax incentives specifically designed to assist with the costs of retrofitting historic buildings. Property owners can claim 20% credit on assessed capital cost of seismic retrofit to reduce their income tax (for example, a $100,000 project would generate a $20,000 credit), which can significantly reduce the financial burden associated with upgrading these often complex and expensive properties.

Another significant challenge in seismic risk mitigation is retrofitting buildings with multiple ownerships. In many jurisdictions, this issue complicates the process, as decision-making can be slow and contentious due to the need for consensus among owners. Taiwan, Japan, and Turkey have addressed this challenge by lowering the thresholds for owner consent, requiring only a majority rather than unanimous agreement for retrofitting decisions. This approach ensures that retrofitting efforts move forward even when some owners may resist or delay action. Taiwan, for example, has implemented policies that allow for retrofitting projects to proceed with the consent of 50% of the owners, rather than waiting for full consensus, which can be difficult to achieve in multi-owner buildings.

In contrast, some jurisdictions, such as West Hollywood in California, have excluded multi-owned residential properties from mandatory retrofit ordinances, particularly when it comes to non-ductile concrete buildings. This exclusion reflects the practical challenges of addressing seismic risks in properties with complex ownership structures. While such exclusions may reduce resistance in the short term, they also highlight the need for innovative solutions that balance the interests of individual property owners with the broader goal of public safety.

Some jurisdictions, including Taiwan and Turkey, have gone a step further by enabling demolitions if retrofitting is deemed uneconomical. Notably, demolitions in these jurisdictions are often part of broader urban renewal programmes aimed at improving the residential building stock and fostering urban regeneration. In Taiwan, for example, areas with significant seismic risk are identified for urban redevelopment, where aging and structurally deficient buildings are demolished and replaced with modern, earthquake-resistant structures. Similarly, in Turkey, the government has implemented large-scale urban renewal projects that allow for the demolition of earthquake-prone buildings and their replacement with safer, more resilient housing. These demolition policies contribute not only to reducing seismic risk but also to the broader objective of regenerating urban areas, improving living conditions, and increasing the overall resilience of the housing stock.

Drawing from international best practices, several key takeaways for New Zealand’s seismic risk mitigation strategy emerge:

Expand Financial Incentives: New Zealand could benefit from the implementation of financial incentives, similar to Italy's Sismabonus or the tax exemptions for seismic upgrades in California (see Appendix 1 for a case study example). These mechanisms would make seismic retrofitting more affordable for private property owners and reduce the financial burden associated with upgrading vulnerable buildings. The implementation of financial incentives should include subsidies, low-interest loans, and tax breaks, as seen in Taiwan and Japan, to encourage property owners to retrofit their buildings, especially those in lower-income communities or those with complex ownership structures.

Incorporate Phased Retrofitting Approaches: As seen in Los Angeles and Taiwan, phased compliance programs that target the most vulnerable buildings first - such as unreinforced masonry (URM) or non-ductile concrete structures - could allow for a more manageable and strategic retrofitting process, providing flexibility to building owners while addressing the most pressing risks. Prioritising buildings with the highest occupancy and public use, such as schools, hospitals, and office buildings, would ensure that the most crucial structures are addressed first, mitigating potential loss of life in the event of a major earthquake.

Develop a Seismic Risk Disclosure System: Following the example set in California, a mandatory disclosure system for commercial and multi-unit residential buildings could increase transparency about seismic risks and encourage owners to undertake retrofitting voluntarily. This would also allow prospective buyers to make informed decisions about the seismic safety of buildings they are considering for purchase. Disclosures should include the building's seismic rating, retrofitting history, and any planned seismic upgrades, enabling market forces to support risk mitigation efforts.

Enhance Public Awareness and Stakeholder Engagement: Successful programs in Taiwan and Japan underline the importance of raising public awareness and engaging stakeholders early in the process. By fostering collaboration between local governments, property owners, and tenants, New Zealand could build broader consensus and support for seismic risk mitigation measures, improving compliance rates. Public awareness campaigns should educate property owners about the long-term financial benefits of retrofitting, including reduced insurance premiums, increased building value, and better tenant retention.

Strengthen Enforcement Mechanisms: To avoid the stagnation observed in some California programs, New Zealand should ensure that effective monitoring and enforcement systems are in place. Clear timelines, penalties for non-compliance, and regular progress reporting are crucial for ensuring that retrofitting projects stay on track. Enforcement should be coupled with support measures, such as grants or low-interest loans, to help property owners meet their obligations without facing undue financial hardship.

Foster Local Leadership and Create a Scalable Model: New Zealand's larger cities should take the lead in developing comprehensive seismic risk mitigation programs, much like California's urban centres did with retrofitting ordinances. These cities can serve as models for smaller towns, enabling a cohesive national strategy while allowing for local adaptations. A scalable model will ensure that all regions, regardless of size, are involved in enhancing seismic resilience, ensuring equitable access to safety measures.

In conclusion, seismic risk mitigation is a complex challenge that requires a coordinated approach involving robust research on the development of technical standards and retrofit alternatives cost, financial support, public engagement, and effective monitoring and enforcement. By learning from the experiences of other jurisdictions and adapting these strategies to New Zealand's unique context, we can build a more resilient and seismically safe built environment, minimising the risk to both life and property in the face of inevitable future earthquakes.

Appendix 1. Example of Application of California's Proposition 13 in New Zealand

Proposition 13: Limits on Property Tax Assessment for Seismic Retrofitting of Existing Buildings

Proposition 13 was originally enacted in 1978 and amended in 2010 to ensure that construction undertaken to seismically retrofit existing buildings does not trigger reassessment of property tax value, regardless of building type. The exclusion remains in place indefinitely, lasting until the property is sold. The 2010 amendment removed the previous 15-year limit on the exclusion for safety upgrades of unreinforced masonry buildings. Legislative impact assessments indicated that this change would result in only a minor reduction in local property tax revenues related to earthquake-related upgrades.

Case Study: Kennedy Building, 33 Cuba Street, Wellington

The case study[315] examines a commercial property located at 33 Cuba Street, Te Aro, Wellington, also known as the Kennedy Building. Built in 1905, this Category 2 Historic Place has an earthquake rating of 25% NBS, with a strengthening deadline set for 2028 according to the Earthquake-Prone Buildings (EPB) Register[316].

Property Details

Address	33 Cuba Street, Te Aro, Wellington
Capital Value	$3,040,000
Land Value	$2,910,000
Improvements Value	$130,000
WCC Rates (Billing Cat K1)	1.250514
GWRC Rates (Regional - CBD)	0.392752

Rates Assessment for 2024/2025

WCC Rates	($3,040,000 × 1.250514) ÷ 100	$38,016
GWRC Rates	($3,040,000 × 0.392759) ÷ 100	$11,940
Total Combined Rates		**$49,956**

Financial Performance Assumptions Post-Seismic Retrofit

To estimate the financial impact of seismic retrofitting, conservative office market figures from CBRE's Q3 Wellington Market Overview were used. The value of the

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[315] Assumptions for the calculations were sourced from: Wellington City Council (WCC) - wellington.govt.nz/-/media/property-rates-and-building/rates-and-property/rates/files/wellington-city-council-rates-2024-2025.pdf?la=en&hash=C7C1B16A6C8003A2301D6D8DB20A75660AC7B312#page=1.00; https://services.wellington.govt.nz/property-search/account/1124290/, Greater Wellington Regional Council (GWRC) - https://rates.gw.govt.nz/, and CBRE Market Overview (Wellington, Q3 2024) - https://www.cbre.com/insights/figures/wellington-figures-q3-2024

[316] EPB Register details for 33 Cuba Street - https://epbr.building.govt.nz/register/view/0842f0c2-bf3e-465f-a9af-83e369a568c8

property was calculated using the income capitalisation approach (Market Rent ÷ Rental Yield).

Annual Effective Rent	$250 per m^2
Rental Yield	9%
Building Footprint	410 m^2
Number of Stories	4
Total Floor Area	1,640 m^2

Property Valuation Calculation

Total Effective Rental Income: ($250 × 1,640) = $410,000

Property Value (Capitalization Method): ($410,000 ÷ 9%) = $4,555,556

Revised Rates Assessment Post-Retrofit

WCC Rates	($4,555,556 × 1.250514) ÷ 100	$56,968
GWRC Rates	($4,555,556 × 0.392759) ÷ 100	$17,892
Total Combined Rates		**$74,860**

Impact of Proposition 13-Style Policy in New Zealand

If an equivalent of Proposition 13 were implemented in New Zealand, the property owner would be able to save annually the difference between the pre- and post-retrofit rates assessments:

Difference in Annual Rates ($74,860 - $49,956) =	**$24,905**

This means that up to $1,515,556 (the difference between the current value and value post remediation) will not be taxed until the property is sold.

By freezing property rates at the pre-retrofit level, the **present value of savings over 15 years** (assuming a 5% discount rate) can be calculated as follows:

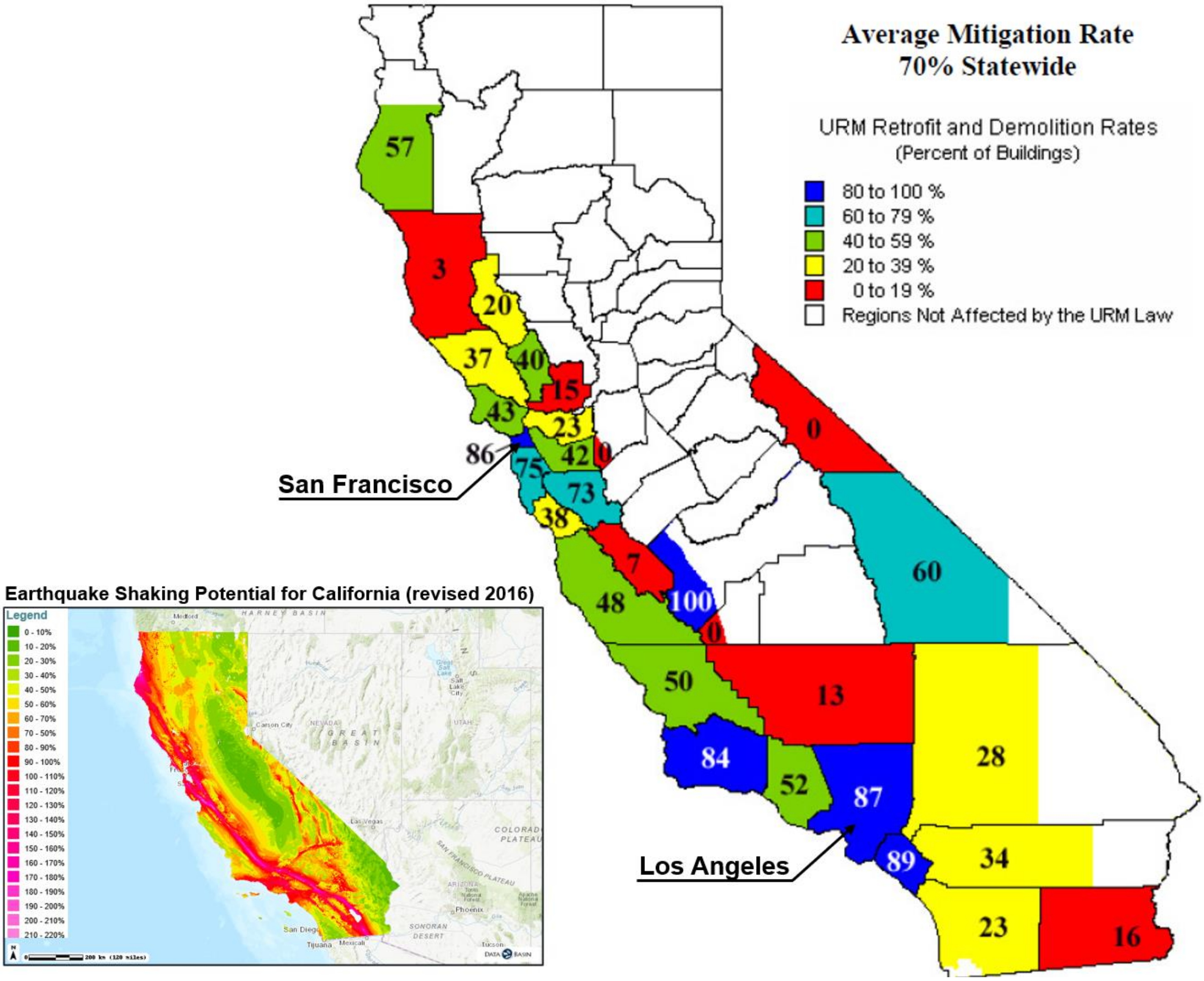
N (Years)	15
Discount Rate	5%
Annuity Payment (Annual Savings)	$24,905
Present Value of 15-year Rates Freeze Benefit	**$258,500**

Conclusion

This example demonstrates that implementing property rates freeze for seismically retrofitted buildings could significantly improve financial incentives for property owners to undertake earthquake strengthening. By locking in pre-retrofit rates, property owners can capture long-term savings, making seismic retrofitting a more financially viable investment.

Appendix 2. 2006 Survey of City and County Seismic Risk Mitigation Rates

URM Retrofit and Demolition Rates[317]



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[317] Seismic risk mitigation rates map from the *Status of the Unreinforced Masonry Building Law*, California Seismic Safety Commission 2006 Progress Report to the Legislature (SSC 2006-04); Earthquake shaking potential map from California Geological Survey, California Department of Conservation, https://databasin.org/datasets/d228ac585b1f4588bea78fcb720b6f05

Appendix 3. Examples of financial and policy incentives used in overseas jurisdictions

Financial incentives directly reduce project costs (e.g., through grants) and improve access to financing:

Financing Instrument	Examples
Grant Funding	
Local- and national-level subsidies	Overseas: FEMA grants, City of Berkeley Retrofit Grants; Taiwan's "Private Building Seismic Weak Story Retrofit Program" grants fund up to 45% of project costs; Japan's "Act for the Promotion of Seismic Retrofit of Buildings" grants fund up to 50% of project costs. NZ: Wellington City Council Heritage Resilience and Regeneration Fund; HeritageEQUIP
Local Government Budget	
Consent fee waivers and discounts	Overseas: common practice in jurisdictions with mandatory retrofit programmes in California
Seismic rehabilitation rebate scheme	Overseas: City of Upland reimbursed owners for engineering and architectural design, council fees and a portion of retrofit costs up to a certain percentage and an upper cap (URM Ordinance)
Development Controls	
Transfer Development Rights	Overseas: Seattle NZ: Heritage Floor Space Bonus (Auckland City District Plan, Central Area, Part 6); Auckland Unitary Plan encourages policies that provide TDRs in areas with heritage overlays.
Property Rates Relief	
Limits on property rates assessment	Overseas: Proposition 13 (Appendix 1)
Personal Tax Credits	
Historic Tax Credit	Overseas: USA - 20% Federal Historic Tax Credit which promotes private investment into the rehabilitation of historic buildings (inc. seismic retrofit) used to offset federal tax liability.
Financing	
Property-assessed financing loans	Overseas: PACE (Property Assessed Clean Energy) financing in California is upfront funding provided by private lenders, repayment is made as an assessment on the property rates notice and is based on financing terms and costs comparable to a standard residential or commercial loan; Assessment district – Long Beach
Private lending consortium	Overseas: Cities of San Francisco and Upland negotiated discounted loans for seismic retrofits from private lenders; Japanese Housing Financing Agency. NZ: Several banks already offer low-cost financing for certain energy efficient upgrades, and this can be extended to seismic retrofits.

Policy incentives simplify seismic retrofit projects by offering indirect benefits to property owners:

Scope	Policy incentive
National	Time limited exemption from future retrofit requirements
	Exemption from triggering other code requirements (e.g. electrical, fire, accessibility)
Local	Expedited consent applications, inspections and reviews
	Technical assistance on retrofit project
	Development incentives such as increased density, transfer of development rights

Appendix 4. Summary of the seismic mitigation risk programmes

Jurisdiction	Date started	Programme type	Building type and scope limitations	Number of buildings	Prioritisation	Timeframe for compliance	Standard / criteria used to show compliance	Incremental or phased retrofit encouraged	Financial incentives	Compliance	Comments
Long Beach, CA	1971 with revisions in 1976 and 1990	Mandatory strengthening	URM Pre-1934	936	Grade I – Excessive Hazard (most dangerous - top 10% of the buildings); in addition, buildings with dangerous parapets and appendages were classed as Immediate Hazard; Grade II – High Hazard (more dangerous - the next 30% of the buildings); Grade III – Intermediate Hazard (least dangerous - the remaining 60% of the buildings).	Grade I – repaired immediately or demolished from notice; Grade II – until 1985; Grade III – until 1991	1970 edition of Uniform Building Code (UBC)	In cases of partial retrofit to Grade I and II, the city had discretion to grant a compliance extension until 1991	Special Assessment Bond Loans; The city formed an assessment district composed of URM properties which allowed the city to issue bonds for seismic retrofit financing. The bonds were repaid by the rating assessments that were placed on the owners. Financing was at the prevalent market rate. 137 URM buildings were included in the assessment district	100% by 2007; by 1989 Grade I and II buildings complied with the ordinance (approx. 376 buildings).	After the 1933 Long Beach earthquake, the construction of the URM was prohibited (Riley Act), therefore all URM's in the city are pre-1934. In 1959, the city adopted regulations requiring mitigation of parapets and falling hazards; Highest demolition rate (40% - 372 URMs) attributed to strong enforcement of demolition orders for non-complying owners.

Los Angeles, CA	1981 (Division 88 ordinance)	Mandatory strengthening	URM, Pre-1934 (detached residential buildings with < 5 dwelling units excluded from the ordinance)	9,211	I - Essential; II – High risk (>100 occupants); III – Medium risk (>20 occupants); IV - Low risk (<20 occupants)	Notification: Class I – 0 - 3 months; Class II – 3 – 12 months; Class III – 1 – 3 ¼ years; Class IV – 3 ¼ - 4 years; Compliance: (without anchors) – 3 years from notification; (with anchors) – 1 year to install anchors, full compliance 4-10 years after installation of anchors (depending on class)	Alesch and Petak (1986, p. 79) note that the ordinance imposed 50-70% of the 1980 Los Angeles Building Code requirements for new construction	The city ordinance promoted dual-time phased retrofit. Owners could either strengthen their buildings within 3 years to conform with the ordinance or anchor URM walls within 1 year and depending on building classification were permitted additional 4-10 years for full compliance.	No comprehensive financial incentives; National Development Council (2019) notes that from approx. US$1.7B spent on URM retrofits, less than 10% came from government funding. Building owners were permitted to pass through 50% of retrofit costs amortised over 120 moths and a cap of $38 per month to residential tenants. CA state law exempts seismic retrofits from revaluation (Proposition 13) and owner of historic buildings could claim 20% tax credit.	As of 2006 (CSSC report): 88% mitigation rate: Retrofitted – 6,146; Demolished – 1942; No progress – 1,123	LA was the first major city to adopt a seismic retrofit ordinance for URMs (the URM Law passed in 1986). Mandatory programmes within the URM law were based on the Division 88 ordinance; the ordinance is also the basis for UCBC Appendix Chapter 1.
The URM Law, CA	1986; Seismic Zone 4	Required 365 local governments to: Inventory URM buildings within each jurisdiction; Establish loss reduction programmes for URM buildings by 1990; Report progress to the CSSC.	URM	25,536	Types of loss reduction programmes implemented locally included: Mandatory strengthening; voluntary strengthening; notification only; other types (variations of other programmes with unique requirements)	Within mandatory programmes, time for compliance were scheduled around the number of occupants. Average timeframe for compliance was 10 years	CA required all jurisdictions to adopt 1997 UCBC Appendix Chapter 1. UCBC standards are intended to significantly reduce but not eliminate the risk to life from collapse. Some retrofitting was performed under local ordinances that preceded the UCBC.	Some ordinances permitted phased retrofits	Range of incentives are presented in case studies in FEMA-254 (1994) Seismic Retrofit Incentive Programs	By 2006, 70% of URMS were retrofitted or demolished – 18,144. Majority of these are in jurisdictions with mandatory programmes – 16,563 (this represents 87% mitigation rate of buildings within mandatory programmes)	Mandatory programmes typically results in higher retrofit rates than other programme types. However, demolition rates are also higher in mandatory programmes (17% vs 8% in voluntary).

San Francisco, CA	1992	Mandatory strengthening	URM Pre-1934	1,976	Level 1 - Assemblies (>= 300 occupants), >3 stories on poor soil (areas of poor soil mapped); Level 2 - Non-level 1 on poor soil in certain mapped locations Level 3 - Buildings in Level 2 mapped areas not on poor soils Level 4 - All other URMs	Ranged from 3.5 to 13 years	1991 UCBC Appendix Chapter 1 with modifications; allowance of seismic upgrade to Bolts Plus level for certain types of buildings	Bolts Plus was allowed for certain buildings : <6 stories, w/out significant vertical irregularities or weak stories at the ground level, had qualifying cross walls and a specified min areas of solid URM wall)	Low interest loans: 2.5% for retrofits on affordable housing units; other URMs could access loans at 8.5% (interest rate at the time) through SF voter authorised issuance of US$350M in bonds (US$150M for low-interest and US$200 for market-rate loans	As of 2019, around 15-20 buildings remained non-compliant. By 2006, the latest date for compliance (level 4 buildings), mitigation rate was at 86% (1,555 retrofits and 158 demolitions). As of March 2000, only 17 market-rate loans were issued (US$10.4M) because private banks started to offer loans at competitive rates	The 1992 ordinance followed the previous Parapet Safety Program of 1975. It is estimated that ~1/4 of URMs were retrofitted to Bolts Plus standard. Comerio (1994) notes that "structural engineers were not very happy with the outcome of this code [Bolts Plus provisions], but they did not formally oppose it".

Palo Alto, CA	1986	Mandatory evaluation	URM except for those smaller than 1,900 square feet or with six (6) or fewer occupants	47	All hazardous URM buildings	Notification within 6 months of ordinance; 18 months from notification submit engineering report identifying structural measures to bring to at least up to the seismic standards of the 1973 UBC; following that notify occupants in writing and submit a letter to the city indicating intentions regarding mitigation of seismic deficiencies 12 months are engineering study Historic structures were given an additional 18 months to comply	1973 UBC for voluntary retrofits	n/a	Development incentives (bonus floor areas, exemption from onsite parking requirements); capping the floor area of new developments to the size of the site area (floor area ratio 1:1)	As of 2014, 77% mitigation rate: 22 retrofitted; 14 demolished	The 47 URMs were in the downtown area and primarily commercial use. In addition to URMs, the ordinance classified two other types of hazardous buildings: pre-1935 structures with 100+ occupants (19 buildings); pre-1976 structures with 300+ occupants (23 buildings); 25 buildings in these two categories were retrofitted or demolished (60% mitigation rate)

Berkeley, CA	1991	Mandatory strengthening	URM, pre-1956	587	Risk cat I: Hospitals, fire and police offices/stations, emergency operation centres, buildings housing medical supplies, government administration offices, or any building with an occupancy load of one thousand (1,000) or more. Risk cat II: Commercial buildings - Businesses, assembly buildings, educational and institutional occupancies with an occupancy load of three hundred (300) or more; Residential buildings - Hotels, motels, apartments or condominiums containing more than one hundred (100) living units/bedrooms; Mixed use occupancies - Any building with a combined occupancy load greater than three hundred (300). Risk cat III: Commercial and mixed use – load >100;	Risk category I buildings - by March 1, 1997; Risk category II buildings - by March 1, 1997; Risk category III buildings - by June 30, 1997; Risk category IV buildings - by December 31, 1997; Risk category V buildings - by December 31, 1998; Risk category VI buildings - by December 31, 2001.	Current edition of UCBC at the time of the ordinance adoption; in 2001 the ordinance was updated to adopt 1997 UCBC Appendix Chapter 1	Bolts Plus was allowed for certain buildings: regular (square or rectangular) simple buildings which were 1 or 2 storeys	Limited financial incentives; tax break on the city's real estate transfer tax – commercial buildings excluded; Since 2018 the city offers retrofit grants: design grants (up to 75% of design costs, max USD 5,000) and construction grants (up to 40% of construction costs, max USD 25,000 – 150,000)	By 2004 compliance was at 85%; 2006 compliance rate – 92%; as of January, 2025, three buildings remain on the current list of URMs	The programme's demolition rate was only 1%. It has been noted that Berkeley's approach has been one of the strictest in California from creating six compliance categories and compliance schedules to close monitoring of compliance where the city enforced regulatory laws and penalties for non-complying property owners. The city has been credited for investing in community resilience and leading by example by rebuilding or retrofitting every public school, fire station and numerous administrative buildings.

					Residential - >50 units. Risk cat IV: Commercial and mixed use – load >50; Residential <50 units. Risk cat V: Commercial and mixed use – load <50; Residential - <20 units. Risk cat VI: Any non-residential building that is used less than twenty (20) hours per week, or any building with a masonry veneer of at least ten (10) feet in height or with a masonry parapet exceeding a one and one-half (1-1/2) ratio or masonry in-fill that is located in a high pedestrian traffic corridor.						

Oakland, CA	1990	Other	URM, pre-1948	1,612	Three priority levels based on the type of soil on which the building is located, number of stories, pedestrian and vehicle traffic adjacent to the building, use of building, number of occupants and complexity of retrofit work	Priority 1 – submit building permit for mandatory standard – 1 year; complete construction – 2 years. Priority 2 – permit 2 years; complete construction 3 years. Priority 3 – permit 3 years; complete construction 4 years.	1973 UCBC Appendix Chapter 1	Mandatory standard - Bolts Plus tie roof and floors to exterior walls, brace parapets, remove or fix other exterior falling hazards; Voluntary standard - UCBC Appendix Chapter 1	Permit fee discount, rent pass through (70% of costs amortised over 5 years); URMs retrofitted to voluntary standard were exempt from future retrofits.	As of 2006 compliance rate was 89%: Mandatory – 1,107; Voluntary – 222; Demolition – 106. Media reports indicated that in 2014 around 80-90 URMs remained unretrofitted (NDC, 2019).	URMs upgraded to mandatory standard issued a "Certificate of Compliance of the Mandatory Requirements," but remain on the city's list of potentially hazardous URM buildings. After the building has been upgraded or demonstrated to be in compliance with the applicable voluntary standards the building is removed from the inventory list of potentially hazardous URM buildings.

Los Angeles, CA	2015	Mandatory strengthening	Soft story (Wood frame buildings with soft, weak or open front walls – SWOF), pre-1978	~12,500	Priority I - buildings containing 16 or more dwelling units. Priority II - buildings with three stories or more, containing fewer than 16 dwelling units. Priority III - buildings not falling within the definition of Priority I or II.	Priority I – order to comply issued May-July 2016; Priority II - order to comply issued October 2016; Priority III - order to comply issued July-November 2017. From the receipt of the Order to Comply, building owners had: 2 years to submit plans to retrofit or demolish, or proof of previous retrofit; 3.5 years to obtain permit to start construction or demolition; 7 years to complete construction or demolition	The design force in a given direction shall be 75% of the design base shear specified in the seismic provision of ASCE 7.	n/a (targeted retrofit to ground floor)	Due to the large number of buildings in the inventory, implementing financial incentives and subsidies was deemed less feasible, leaving building owners responsible for covering retrofit costs. To alleviate some financial pressures, the city enacted a cost-sharing ordinance, allowing property owners to pass through 50% of seismic retrofit costs to tenants, amortised over 120 months, with a monthly cap of US$ 38.	As of February, 2024 76% of the buildings had either completed construction or been demolished (9,377 – complied, 2,970 – pending compliance).	Ordinance was adopted following recommendations in the *Resilience by Design* report prepared by the Mayoral Seismic Safety Task Force and presented to the city in January 2015.

San Francisco, CA	2013	Mandatory strengthening	Soft-story; wood-frame SWOF buildings of three or more stories and containing five or more residential dwelling units where the permit to construct was applied for prior to January 1, 1978	4,941	Tier I -Any building containing educational, assembly, or residential care facility uses Tier II - Any building containing 15 or more dwelling units Tier III - Any building not falling within another tier Tier IV - Any building containing ground floor commercial uses, or any building in a mapped liquefaction zone	All tiers submit screening form 1 year from notification; Submittal of permit application (from notice): Tier I – 2 years; Tier II – 3 years; Tier III – 4 years; Tier IV – 5 years; Completion of work (from notice): Tier I – 4 years; Tier II – 5 years; Tier III – 6 years; Tier IV – 7 years;	*Engineering Criteria:* A proposed seismic evaluation and/or retrofit plan shall demonstrate that the building satisfies one of the following: **1.** FEMA P-807, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings With Weak First Stories with the performance objective of 50 percent maximum probability of exceedance of Onset of Strength Loss drift limits with a spectral demand equal to 0.50 SMS, or **2.** ASCE 41-13, Seismic Evaluation and Rehabilitation of Existing Buildings, with the performance objective of Structural Life Safety in the BSE-1E earthquake, or **3.** ASCE 41-06, Seismic Rehabilitation of Existing Buildings, with the performance objective of Structural Life Safety in the BSE-1 earthquake with earthquake	n/a		As of January 2025, 94% of buildings in compliance with the ordinance (4,651 buildings); 6% (288 buildings) remain non-compliant, most of these are in Tier IV which include buildings with commercial uses on the ground floor. This is likely due to the complexities of retrofitting these buildings that involve temporary relocation of tenants and requirement to comply with the Americans with Disabilities Act (ADA) for buildings with commercial uses. It was reported that finding qualified ADA specialists willing to work on smaller projects has been a significant challenge.	The Community Action Plan for Seismic Safety (CAPSS), started in the City and County of San Francisco's Department of Building Inspection beginning in 1998, was a nine-year, US$1M study to understand, describe, and mitigate the risk San Francisco faces to earthquakes. The report produced an extensive analysis of potential earthquake impacts as well as community-supported recommendations to mitigate those impacts. In Dec 2010 Mayor Gavin Newsom formed the Earthquake Safety Implementation Committee (ESIC) under the City Administrator's Office, which created the Earthquake Safety Implementation Program (ESIP) in late 2011. ESIP is a thirty-year work plan and timeline implementing the

							loads multiplied by 75 percent, or **4.** for evaluation only, ASCE 31-03, Seismic Evaluation of Existing Buildings. with the performance level of Life Safety, or **5.** for retrofit only, 2012 International Existing Building Code (IEBC) Appendix A-4, or **6.** any other rational design basis deemed acceptable by the Department that meets or exceeds the intent of this Chapter.				CAPSS. The CAPSS 17 recommendations. The 1st recommendation was to: Require the evaluation of all wood-frame residential builds of three or more stores and five or more units, and retrofit those that are vulnerable to earthquake damage. The soft story ordinance followed in 2013.

Berkeley, CA	2005; 2014	2005 – Phase 1: Mandatory evaluation and voluntary retrofits; 2014 – Phase 2: Mandatory strengthening	Soft story; All existing wood frame multi-unit residential buildings that contain five or more dwelling units, as defined in BMC Title 23, and that were designed under a building permit applied for before January 1, 1978	369	No priority tiers	**Phase 1:** notices sent to 321 buildings; within two years of receiving the notice, the owners were required to submit engineering analysis of their building, notify tenants in writing of the building listing on the inventory and submit a copy of the letter to the city, and post a clearly visible earthquake warning sign until the building is removed from the inventory (voluntary retrofit). **Phase 2:** Mandatory strengthening complete within four years from 2014: apply for a building permit by December 31, 2016, and complete the seismic retrofit work within two years after submitting permit application by December 31, 2018.	Potentially hazardous SWOF buildings shall be retrofitted in conformance with one of the following engineering criteria: **1.** 2012 edition of the International Existing Building Code (IEBC) Appendix Chapter A-4; or **2.** ASCE 41-06, Seismic Rehabilitation of Existing Buildings, using a performance objective of S-5 (Collapse Prevention) in the BSE-C earthquake; or **3.** ASCE 41-13, Seismic Evaluation and Rehabilitation of Existing Buildings, using a performance objective of S-5 (Collapse Prevention) in the BSE-2E Earthquake; or **4.** FEMA P-807, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings With Weak First Stories, as a pre-approved "substantially equivalent standard" under procedures of	To evaluate the feasibility of Phase 2, the city conducted an economic analysis of building owners to determine their financial capacity to fund retrofits without incentives or subsidies. The estimated retrofit cost was approximately US$50,000 per building. The study found that most owners would be able to afford retrofits	For owners of soft story buildings with 5 or more residential units, owners can receive up to US$5,000 in design grant (capped at 75% of design costs) and US$25,000-150,000 in construction grant (capped at 40% of construction costs).	As of December 2024, the only remaining non-compliant buildings were not on the original inventory and were newly added (6 buildings). The ordinance resulted in only one demolished building.	While experience of voluntary programmes in jurisdictions within the URM law resulted in low retrofit rates, as the result of the Phase 1 2005 mandatory screening and evaluation ordinance, 40% of buildings were retrofitted.

							CBC Section 104.11 for Alternative Materials, Design and Methods of Construction, and with a retrofit objective as established by the Building Official; or **5.** Subject to the project specific approval by the Building Official, the 2003 edition of the International Existing Building Code (IEBC) Appendix Chapter A-4, for buildings with Seismic Engineering Evaluation Reports submitted prior to January 1, 2014, that (i) include structural design calculations and construction documents demonstrating conformance to Chapter A4 of the 2003 IEBC; and (ii) are suitable for building permit submittal.				

California	2007-2025	Mandatory strengthening	Soft story (wood frame SWOF), pre-1978	28-12,500	Most existing ordinances prioritise buildings into tiers based on the number of residential units	Completion of construction ranges between 3-7 years	Most common criteria found in ordinances: **Structural seismic evaluation.** Where performed, seismic evaluation of each wood-frame target story shall comply with the latest edition of Seismic Evaluation and Retrofit of Existing Buildings [ASCE/SEI 41] with a performance objective of Structural Life Safety with the BSE-1E hazard or Structural Collapse Prevention with the BSE-2E hazard, as interpreted by the Building Official. **Structural seismic retrofit.** Seismic retrofit of each wood-frame target story shall comply with one of the following criteria. **1.** Chapter A4 of the California Existing Building Code, as interpreted by the Building Official. **2.** The latest edition of Seismic Evaluation and Retrofit of Existing Buildings	Not observed, limited extensions are available (typically 6-12 months) in case of significant financial hardship, to prevent or minimise tenant displacement, a temporary shortage of price increase for construction materials or labour.	Retrofit grants available in some jurisdictions. Common incentives are rent pass-through, reduction in permitting application fees, property rates freeze, development incentives (e.g. SF planning rules allow unlimited number of Accessory Dwelling Units (ADUs) on projects undergoing Mandatory or Voluntary seismic upgrades generate additional rental income stream by converting some of the ground floor areas)	While first example of a mandatory ordinance was in 2007 in Fremont, the major cities began implementing mandatory programmes in mid-2010's (SF 2013, LA 2015). Currently there are 14 active mandatory programmes. Several jurisdictions are considering soft story mandates.	Assembly Bill 304, Chapter 525 (2005) amended Section 19160 of the California's Health and Safety Code authorises "cities and counties to address the seismic safety of soft story residential buildings and encourage local governments to initiate efforts to reduce the seismic risk in vulnerable soft story residential buildings." In other words, while the state legislature recognises the risks of soft story buildings, local mitigation efforts are encouraged but no affirmative action is required on the part of the municipalities (this is in contrast to the 1986 URM law). California's approach to soft-story retrofitting has evolved through regional influences, with jurisdictions often adapting and refining ordinances based on neighbouring cities' policies. A

							[ASCE/SEI 41] with a performance objective of Structural Life Safety with he BSE-1E hazard or Structural Collapse Prevention with the BSE-2E hazard, as interpreted by the Building Official. **3.** For subject buildings qualified as historic, alternate building regulations of the California Historical Building Code.				distinct pattern emerges between Northern and Southern California, where larger cities (LA, SF) lead in implementing seismic resilience measures, prompting smaller jurisdictions to follow suit.

Los Angeles, CA	2015	Mandatory strengthening	Any existing concrete building built pursuant to a permit application for a new building that was submitted before January 13, 1976	1,194	n/a	From the service of order: Within 3 years submit a checklist; within 10 years submit a detailed evaluation; within 25 years complete construction	Retrofit design criteria: 1. Strength of the lateral-force resisting system shall meet or exceed 75% of the seismic base shear specified in "The Equivalent Lateral Force Procedure" of the current Los Angeles Building Code. Elements not designated to be part of the lateral-force resisting system shall be adequate for gravity load effects and seismic displacement due to the full (100%) of the design story drift specified in the current Los Angeles Building Code seismic provisions, or 2. Meet or exceed the requirements specified for "Basic Performance Objective for Existing Buildings" of ASCE 41, using a Tier 3 procedure and the two level performance objective for existing buildings (BPOE) in Table 2-1 of ASCE 41 for the applicable risk category, and	Not specified in the ordinance, however compliance timeframes apply from the receipt of the order which maybe sent out in stages.	No incentives other than commonly available in the retrofits of other building types (URM and soft story)	Compliance is at 6% (72 buildings)	Retrofit cost remains a significant impediment to retrofits. With evidence from a small sample of completed retrofits under the ordinance, it was found that retrofit costs alone range between US$ 30-50 per sqf, however when combined with peripheral works such as partial demolitions, building systems upgrade, tenant relocation, interior fitouts, accessibility etc, the cost of comprehensive seismic retrofit is pushed to US$50-100 per sqf. For an average 7-story, 68,000 sqf (~6,300 sqm) building in the programme, total retrofit work can range from US$2.1m to US$6.8m. It was also observed that it was difficult for property owners or developers to secure bank lending to fund retrofits because presently the retrofitted buildings do not

							using ground motions and procedures established by the Department.				generate increased rents.
West Hollywood, CA	2018	Mandatory strengthening	Any existing concrete building determined by the Building Official to have been built under Building Code standards enacted before the 1979 Uniform Building Code with local amendments	~55	Prioritisation: I – 8 or more stories; II – 3 – 7 stories; III – 2 or less stories	Phase 1: 10 year from notice evaluation and major deficiency retrofit; Phase 2 – 20 years from notice complete full retrofit.	Building Structural Analysis, Design and Evaluation. The building shall meet or exceed the structural performance level for the associate earthquake hazard levels as indicated in Table C based on the Risk Category as defined in ASCE 41	Two phase approach: **Phase 1:** Engineering report and major deficiency mitigation – within 10 years from notice (major deficiencies include: load path, weak or soft story, vertical irregularity, torsion, captive column); **Phase 2:** complete retrofit – 20 years from notice (10 additional years from Phase 1)	No specific incentives provided by the city	No compliance data available yet	Residential common interest developments are excluded from the ordinance.
Torrance, CA	2023	Mandatory strengthening	Any existing concrete building determined by the Building Official to have been built under Building Code standards enacted before the 1979 Uniform Building Code with local amendments adopted on April 28, 1981	~50	Prioritisation: Priority I: Buildings with 3 or more stories. Priority II: Buildings with 2 stories and 7 or more units. Priority III: Buildings not included in Priority I & II.	Same as in West Hollywood	Same as in West Hollywood	Same as in West Hollywood	Incentives are being explored	No compliance data available yet	The latest jurisdiction to enact a mandatory retrofit ordinance for older concrete buildings.

Santa Monica, CA	2017	Mandatory strengthening	Any concrete building built under building code standards enacted before January 11, 1977.	~70		Structural evaluation report due in 3 years; Application for building permit within 4 ½ years; Retrofit must be completed within 10 years (2027)	*Building structural analysis, design and evaluation*. The building shall meet one of the following criteria: 1. Strength of the lateral-force resisting system shall meet or exceed seventy-five percent (75%) of the base shear specified in the California Building Code seismic provisions. Elements not designated to be part of the lateral-force resisting system shall be adequate for gravity load effects and seismic displacement due to the full (100%) of the design story drift specified in the California Building Code seismic provisions. 2. Meet or exceed the requirements specified for "Basic Safety Objectives" from ASCE 41-13 using ground motions and procedures established by the City based on ASCE 41-13.	None specified		Current list of properties contains 49 buildings (~30% compliance rate)	Building use of listed properties: Church 1 (2 stories) Commercial 27 (number of stories – 1-21, mode 8) Hotel 5 (number of stories 5-15) Parking Garage 6 (number of stories 3-7) Residential 10 (number of stories 2-17. mode 6). SM enacted the most extensive retrofit ordinance which identifies and orders retrofits for URM (100 buildings), concrete tilt-up (30), soft story (1,700), non-ductile concrete (70) and steel moment frame buildings (80). Nearly 2,000 commercial and multi-family residential buildings made a list of sites that need to be assessed for possible structural improvement.

Japan	1995; Revised in 2006 and 2013	Act for the Promotion of Seismic Retrofitting of Buildings; Mandatory evaluation and strengthening; Mandatory evaluation and strengthening: Public and critical facilities (government offices, schools and universities, hospitals and medical centres, fire stations and police stations, emergency shelters, public transportation hubs; Large private buildings with public use (>5,000 sqm)(shopping centres, supermarkets, hotels, office buildings etc); Buildings along high priority routes – local authorities have the power to mandate seismic retrofits; Mandatory evaluation and voluntary strengthening:	Pre-1981	Public buildings (government-owned) ~93,000; Private buildings (commercial and industrial with public use) ~80,000; Residential buildings (detached and apartments) ~18.5 million	Public buildings; Large private buildings with public use (commercial and industrial); Residential buildings (detached dwellings and apartments)	The government sets targets for retrofitting: 75% by 2003; 90% by 2015	*Required Seismic Resistance Level* Retrofitted buildings in Japan must meet at least 80% of the current building code. Public buildings, evacuation route structures, and high-risk zones require 100% of code. Under the 1981 seismic code structures should not collapse under a JMA seismic intensity scale 6 upper earthquake (approximately Magnitude 7.0–7.5). The standard requires that buildings withstand both: Moderate earthquakes without structural damage, and Large earthquakes (seismic intensity 6 or higher) without collapse, ensuring occupant safety	Not identified	To encourage building owners to carry out needed retrofit measures, Japan has implemented a system of financial incentives that divides the cost of works between the central government, the local government, and the building owners. This has been delivered through tax breaks, loans, and subsidies: Regular subsidy: Seismic evaluation – 33.3% each central government, local government, building owner; Retrofitting – 11.5% central govt, 11.5% local govt; 77% building owner; Limited-time promotional offer (to 2018): Evaluation – 50% central govt, 33-50% local govt, 0-17% building owner; Retrofitting – 33.3% central govt, 11.5-33.3% local govt, 33.3-55% building owner' for buildings on evacuation	Public schools – 99% (as of 2021); Other public buildings – 75-95% (as of 2014); Earthquake resistance of pre-1981 residential buildings: Detached dwellings – 3.4m earthquake resistant, 5.6m insufficient earthquake resistance; apartment buildings – 2.7m earthquake resistant, 1.4m insufficient earthquake resistance	Japan has made significant progress in retrofitting public buildings but private and residential buildings still face challenges due to high costs and slow adoption. Local authorities can publish the names of non-compliant buildings, thus pressuring owners to retrofit. Rural areas lag behind urban areas in terms of earthquake-resistant residential buildings; in rural areas with high proportion of aging population retrofit rates were below 50% while in many urban areas the rate exceeds 90%.

		Residential buildings.							routes or designated as emergency management hubs – 40% central govt, 33.3-40% local govt, 26.6-33.3% building owner; Supplementary financial incentives: Tax exemptions, low-interest loans		

Taiwan	2000	Building Seismic Assessment and Strengthening Programme (public buildings)	Pre-1997	31,146 Including government offices, hospitals, schools and other essential service buildings; This count includes 27,741 school buildings	All pre-1997 public buildings	3-stage approach: Preliminary assessment; Detailed assessment; Retrofit (or demolition). Retrofits were prioritised based on risk assessments and building age.	Structural analysis of school buildings: The screening evaluation consists of a simple “capacity to demand” comparison based on the ratio of ground floor column and wall areas to building total floor area. If the screening evaluation result in a Capacity/ Demand ratio (Is) that exceeds 0.8, the school building is subjected to a more detailed analysis: The detailed analysis procedure - referred to as Taiwan Earthquake Assessment for Structures by Pushover Analysis (TEASPA) is a non-linear static pushover analysis like those used in ATC-40 and ASCE-41. TEASPA calculates the ultimate seismic base shear capacity of the structure and then uses the results to compute the building capacity in terms of peak	Not identified	From 2009 to 2022, the government funded NTD 128.4 billion (NZ$6.8b) for seismic assessments and retrofitting of schools. 9,550 school buildings were upgraded.	Public buildings: 10,143 buildings required retrofitting and 2,445 buildings required demolition; 10,143 buildings required retrofitting and 2,445 buildings required demolition. As a result, 9,369 buildings completed retrofitting (92%) and 2,179 buildings demolished (89%). From these statistics,	The retrofitting of public schools has been a significant priority of the central government. National Centre for Research on Earthquake Engineering (NCREE) was engaged to develop technologies (more accurate assessments and cost-effective retrofits) for the seismic evaluation and retrofit of schools between 1999-2009.

							ground acceleration (Ap) for comparison to the code derived peak ground acceleration. The analysed school buildings with insufficient strength are tagged for retrofit. A solution is developed to strengthen the building to meet the required demand under the peak ground acceleration. Typical reinforcing schemes include the introduction of new moment frames, shear walls, jacketing of columns or introducing shear panels adjacent to existing columns (Gilsanz et al. 2016)				

Taiwan	2019	Private Building Seismic Weak Story Retrofit Programme; Voluntary evaluation and retrofit	Pre-1997;	~36,000	Privately-owned multi-story buildings with weak story			The program offers three distinct plans, each tailored to address different levels of structural vulnerabilities. **Plan A** - Targets buildings with soft-story weaknesses, usually caused by open ground floors used for parking or commercial spaces; **Plan B** - Comprehensive retrofitting to ensure buildings meet at least 80% of modern seismic code standards; **Plan C** - Designed for single-ownership buildings requiring localised structural repairs from earthquake damage	Plan A - Subsidies cover up to 45% of retrofit costs, capped at NTD 4.5 (~NZ$240k) million; Plan B - Subsidies cover up to 45% of retrofit costs, capped at NTD 4.5 million; Plan C - Subsidies are capped at NTD 500,000 (~NZ$27k) focusing on localised repairs	As of January 2025, 120 projects have been approved through the programme including 20 buildings where retrofit has been completed or under construction, 51 projects where subsidies have been approved and remaining projects in the various stages of design and construction.	NCREE plays an important role in the oversight and implementation of retrofit programmes in Taiwan. The centre takes an active role in technology development, public outreach and monitoring of the programme. Currently, the Ministry of the Interior and NCREE are actively evaluating the feasibility of introducing mandatory retrofit requirements for private buildings. The central government (Legislative Yuan) received a draft proposal titled "Seismic Assessment and Retrofit of Existing Buildings Promotion Act". The act proposes a systematic approach that mandates completion of: Preliminary seismic assessment; Detailed seismic assessment, if preliminary assessment raised concerns;

											Seismic retrofit design and strengthening, if detailed assessment indicated the need for retrofit.
Istanbul, Turkey	2006	Istanbul Seismic Risk Mitigation and Emergency Preparedness Project	Pre-2000		Public buildings				Initial project secured US$563m from the World Bank. The funding was available until 2015. The project remains active after securing additional financing from international financial institutions including European Investment Bank, Council of European Development Bank, Islamic Development Bank and German Development Bank (KfW). By 2018, the total amount of committed financing was in excess of EUR€ 2b	1,624 public buildings (majority schools [1,454] and hospitals [54]) have been retrofitted or demolished; 64 projects are ongoing. 88% of public schools in Istanbul have been retrofitted.	Retrofitting private commercial and residential buildings remains a significant challenge. The government implemented the Law on the Regeneration of Areas Under the Risk of Disaster, no. 6306 in 2012. Known as the Urban Transformation Law, the law introduced the framework for earthquake-focused urban transformation through the rehabilitation, demolition and renewal of areas at risk. Limited financial assistance is available to owners of private buildings including low interest loans, tax exemptions and temporary relocation costs.

Mexico	No active retrofit programs								In post-disaster response, rehabilitation and reconstruction of housing is typically covered with public funds and support from private foundations.	Following 2017 Mexico City earthquake, by 2020, out of 11,880 damaged single-family masonry houses, 9,050 were under rehabilitation and 2,830 were rebuilt or being relocated . In addition, 525 multi-story residential buildings (containing more than 11,000 apartment units) were rehabilitated. The government was able to recover part of the reconstruction costs through densification by increasing the floor area of new builds by 35%.	Most commonly structural retrofits are because of earthquake damage. Instances of proactive retrofit are rare and likely triggered by change of use or major remodelling.

Italy	2013	Sismabonus	All residential and productive properties located in seismic zones 1, 2 and 3 (zone 4 – lowest risk – is excluded)				The Sismabonus programme categorises buildings into eight seismic risk classes from A+ (lowest risk) to G (highest risk)		The incentive is capped at EUR€ 96k. The deduction rate can range from 50% to 85%: 50% deduction for interventions that do not bring any improvement in the seismic class of the building subject to the work; 70% deduction for interventions that improve one seismic class of the building; 80% deduction for interventions that improve two seismic classes of the building; 85% deduction only for condominiums if the interventions improve two seismic classes.	From 2020 Sismabonus is a sub-scheme within a Superbonus scheme. The other part of Superbonus is a scheme called Ecobonus aimed at energy efficient building improvements. Combined, Ecobonus and Sismabonus cover up to 110% of energy and seismic retrofit costs. No separate statistics are reported for each sub-scheme. As of 2021, 70,000 superbonus application have been received at a cost of EUR 11.9b	The Sismabonus is repaid over 5 years in annual instalments as a credit on their tax return.