
Post-earthquake assessment and remediation: findings from the December 2024 Port Vila earthquake

S. Gardiner, P. Cammock & J. Thompson

Egis NZ, Christchurch, New Zealand.

C. Brown

Tonkin & Taylor, Christchurch, New Zealand.

ABSTRACT

A magnitude 7.3 earthquake occurred on 17 December 2024 near Efate, Vanuatu, causing significant damage across Port Vila and neighbouring areas, and resulting in 14 fatalities and 265 injuries. In response, the New Zealand Government, through MFAT, deployed an engineering team to Vanuatu in April 2025. Under Egis coordination, working with local Vanuatu engineering firm Qualao Consulting, and with Tonkin & Taylor providing geotechnical expertise, the project supported the Ministry of Education and Training (MoET) and the Public Works Department (PWD) in assessing and developing remediation strategies for affected buildings. This paper outlines the key observations from the assessment programme, discusses prevalent construction forms and associated damage patterns, and summarises the remedial works recommended for implementation.

1 INTRODUCTION

On 17 December 2024, a magnitude 7.3 earthquake struck near the island of Efate, Vanuatu, with significant impacts across Port Vila and neighbouring communities. The earthquake caused widespread damage to buildings and infrastructure, as well as several major geotechnical failures including liquefaction-related settlement and large landslides.

Following a request from the Government of Vanuatu, the New Zealand Government agreed to provide targeted engineering assistance focused on damaged buildings. Egis was engaged to coordinate the delivery of structural and geotechnical engineering services, working alongside Tonkin & Taylor and local engineering partners Qualao Consulting. The scope of assistance focused on post-earthquake assessment, interpretation of damage mechanisms, and development of practical remediation strategies to support



Figure 1: Wharf Road Landslide

recovery. The initial assessments and remediation concepts were developed to support government decision-making and prioritisation with detailed design documentation to follow.

2 ENGINEERING ASSISTANCE PROGRAMME

2.1 Inception visits and scope

Inception visits were undertaken in April and May 2025 by structural and geotechnical engineers. Meetings were held with key government stakeholders, primarily the Ministry of Education and Training (MoET) and the Public Works Department (PWD), to identify priorities, constraints, and immediate risks. While rapid safety assessments had generally been completed soon after the earthquake, there was a clear need for further engineering input to support repair, strengthening, and reinstatement decisions.

Walkover inspections were undertaken across the Port Vila central business district, selected MoET facilities, and other government buildings. These inspections were used to identify recurring damage patterns, assess the influence of ground performance on building behaviour, and prioritise buildings for more detailed assessment.

2.2 Assessment tools and documentation

LiDAR scanning was undertaken for many buildings to support efficient assessment and remote collaboration. Point cloud scans were used by the New Zealand-based team to visualise damage, extract approximate dimensions, and develop drawings and remediation concepts. A drone was taken with the intention to assist with aerial surveys and photogrammetry to supplement ground-based observations, however, did not end up being used as no buildings were identified where the use would add value; the buildings inspected were all low-rise and easily accessible.



Figure 2: LIDAR Point Cloud Scans

3 GEOTECHNICAL OBSERVATIONS

3.1 Regional ground conditions

The earthquake-induced ground damage in Port Vila was severe but highly localised. Much of the city is underlain by competent coral limestone, which generally performed well during shaking. In contrast, significant ground damage was concentrated in areas underlain by deep marine sediments and historical reclamation, where ground performance was identified as the primary driver of the observed damage.

3.2 Liquefaction and subsidence

Ground damage associated with the failure of fill material and marine sediments was observed in two primary locations: the Port Vila CBD and the Erakor Lagoon area.

Within the Port Vila CBD, significant ground settlement, in the order of several hundred millimetres, was observed along a linear zone within the CBD. While initially attributed to surface fault rupture, preliminary investigations identified a buried sea cliff beneath the site. This feature marks a distinct boundary between competent limestone to the north and deep marine soils overlain by reclamation fill to the south. An area-



Figure 3: Ground damage effects at Port Vila CBD (Left), Erakor Lagoon (right)



Figure 4: Wharf road landslide behind crest slope failure

the natural shoreline was extensively modified. These modifications involved the placement of hydraulically pumped lagoon sediments to extend the shoreline outwards and form Erongo Island.

wide investigation is currently underway to isolate the specific drivers of damage, including potential liquefaction of marine sediments or fault movement along the buried escarpment. Similar, though less severe, ground damage was recorded during the January 2002 earthquake.

For Erakor Lagoon, widespread liquefaction-induced settlement and lateral spreading were observed along the Erakor Lagoon coastline and across Erongo Island. A review of historic aerial imagery from 1971 indicates that the ground damage caused by the 17

December 2024 earthquake aligns with areas where

3.3 Landsliding

Slope instability was primarily observed as shallow, translational failures within the weathered horizons of steep terrain, alongside localised rockfall events within jointed coral reef limestone.

However, the landslide at Wharf Road, displacing tens of thousands of cubic metres of material, involved a combination of complex failure mechanisms due to the local stratigraphy. The initial failure was primarily translational failure along the weathered horizon of weathered volcanic Tuff. However, this failure undermined large, jointed limestone blocks at the crest of the slope, which subsequently toppled downslope. Cracking and displacement were also observed behind the slope crest, revealing cavities associated with karstic features and uncontrolled fill.

4 STRUCTURAL OBSERVATIONS

4.1 Building typologies

Buildings assessed in Port Vila comprised a mix of locally designed structures and donor-funded buildings, with varying levels of engineering input and construction quality. Common construction forms included reinforced concrete frames with masonry infill, reinforced concrete shear wall buildings, and low-rise



Figure 5: Concrete frame with masonry infill typology (Left), Observed URM infill failures (Right)

masonry structures. Durability issues, cyclone damage, and construction detailing deficiencies were frequently observed and were assessed to have influenced earthquake performance.

4.2 Damage patterns

Common damage included cracking and crushing of unreinforced, or lightly reinforced, masonry infill panels (particularly at the interface with the surrounding concrete frame), flexural and shear cracking in reinforced concrete elements, pounding between adjacent buildings, and damage associated with differential settlement. In areas affected by liquefaction and ground settlement, otherwise well-performing structures experienced significant damage driven primarily by foundation movement rather than inertial seismic demand.

In several cases, damage was exacerbated by limited confinement reinforcement, corrosion of reinforcement, and construction practices that differed from original design intent. These issues were observed to reduce deformation capacity and increase damage at relatively modest levels of structural demand.

Whilst cleared before our arrival, the worst structural damage causing collapse and loss of life, occurred to a two-storey, corner, CBD commercial building (Billabong) with little bracing structure to the street faces, resulting in significant torsional response and pancaking.

The four-storey, concrete, La Casa D'Andrea E Luciano building in Port Vila, housing the New Zealand High Commission on the top floor, suffered catastrophic damage, separating vertically near the middle of the building and completely collapsing the ground floor level at one end.

“Regular” structures, particularly those constructed with an in-situ concrete frame over the masonry infill, generally performed well. Less well-confined infills, such as those installed after the frame was constructed, generally suffered more damage, include complete failure out-of-plane, in some instances.



Figure 6: Billabong building before and after (Left) (Witnol Benkor Tor, Ni Vanuatu News, <https://www.facebook.com/groups/649624838544277/posts/2805904292916310/>)

La Casa D'Andrea E Luciano (Right) (Maia Ingoe, Vanuatu quake: 'You could hear people absolutely screaming their heads off', <https://www.rnz.co.nz/news/world/536977/vanuatu-quake-you-could-hear-people-absolutely-screaming-their-heads-off>)

- (iii) NZS 1170.5:2004 Structural design actions - Part 5: Earthquake actions - New Zealand. The maps and tables for New Zealand shown in the Standard are to be disregarded. Use Hazard factor, Z for Vanuatu as follows:

(b) Dead, Live and earthquake loads:

NZS4203 Part 1,2 and 3 General structural design and design loadings for buildings.

The maps of New Zealand shown in the Standard are to be disregarded. The earthquake zones for Vanuatu are marked in Figure B1.2. For use with NZS 4203 the zone factors corresponding to the zone numbers given in the figure are:-

Zone No.	Zone Factor
7	0.7

Province	Hazard factor, Z
Malampa Province	1.4
Penama Province	1.0
Sanma Province (including Luganville City)	1.4
Shefa Province (including Port Vila City)	1.3
Tafea Province (including Lenakel Town)	1.1

Figure 7: Vanuatu National Building Code Demands (2000 vs 2025 Official Gazette 37)

4.3 Regulatory context

At the time of the earthquake, the Vanuatu National Building Code was in the process of being updated, with proposed changes significantly increasing seismic design loads. These changes were rapidly enacted following the earthquake with official Gazette 37 published in April 2025, although subsequent discussions considered revisiting aspects of the update pending further seismic hazard studies. This evolving regulatory context influenced both assessment criteria and discussions around appropriate remediation and rebuild strategies.

To understand the level of shaking experienced, and to help inform the subsequent development of remediation and rebuild strategies, it was desirable to review local accelerometer data from the December earthquake. Unfortunately, local recorded data from PWD was not easily recovered and, when reviewed, was found to be truncated and unusable. USGS estimates have the PGA around Port Vila around 0.5g, (USGS. *M* 7.3 - 24 km WNW of Port-Vila, Vanuatu. <https://earthquake.usgs.gov/earthquakes/eventpage/us7000nzf3>).

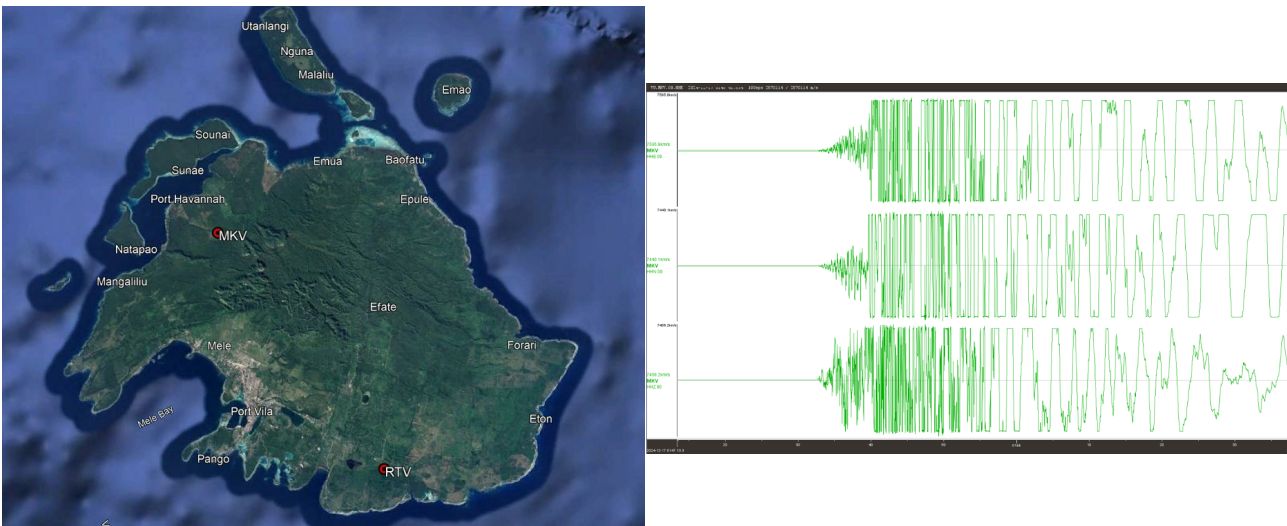


Figure 8: Recording stations and truncated ground shaking records

4.4 Remediation approaches

Remediation strategies were developed and prioritised based on constructability, availability of materials, local contractor capability, and the need for timely implementation. Solutions were developed in close collaboration with government stakeholders and local engineers, recognising constraints related to procurement processes, funding arrangements, and regulatory uncertainty.

Structural remediation approaches ranged from targeted repair and strengthening to partial demolition where repair was not considered viable. In liquefaction-affected areas, remediation strategies considered both foundation solutions and acceptance of residual settlement risk. For landslide-affected areas, stabilisation measures, exclusion zones, and longer-term planning controls were identified as key components of risk management. While addressing and repairing or rebuilding critical structural elements and systems, consideration and implementation of local practices was incorporated, including required allowances and integration of architectural works, ongoing maintenance, accessibility upgrades, and provisions for continued or improved durability of structural elements and systems.

A key objective of the programme was to provide clear, implementable guidance that could be acted upon promptly, rather than complex solutions requiring specialist construction techniques

4.5 Seismic repair and reinstatement

Structural retrofit or repair solutions were designed for reinstatement to at least the pre-earthquake building/system capacity or to a minimum level of seismic demand corresponding to the 2000 Vanuatu National Building Code, which for Port Vila, when converted from NZS4203, was approximately equivalent to a seismic hazard factor of $Z = 0.2$ from NZS1170.5. Primarily, this was implemented as a result of the

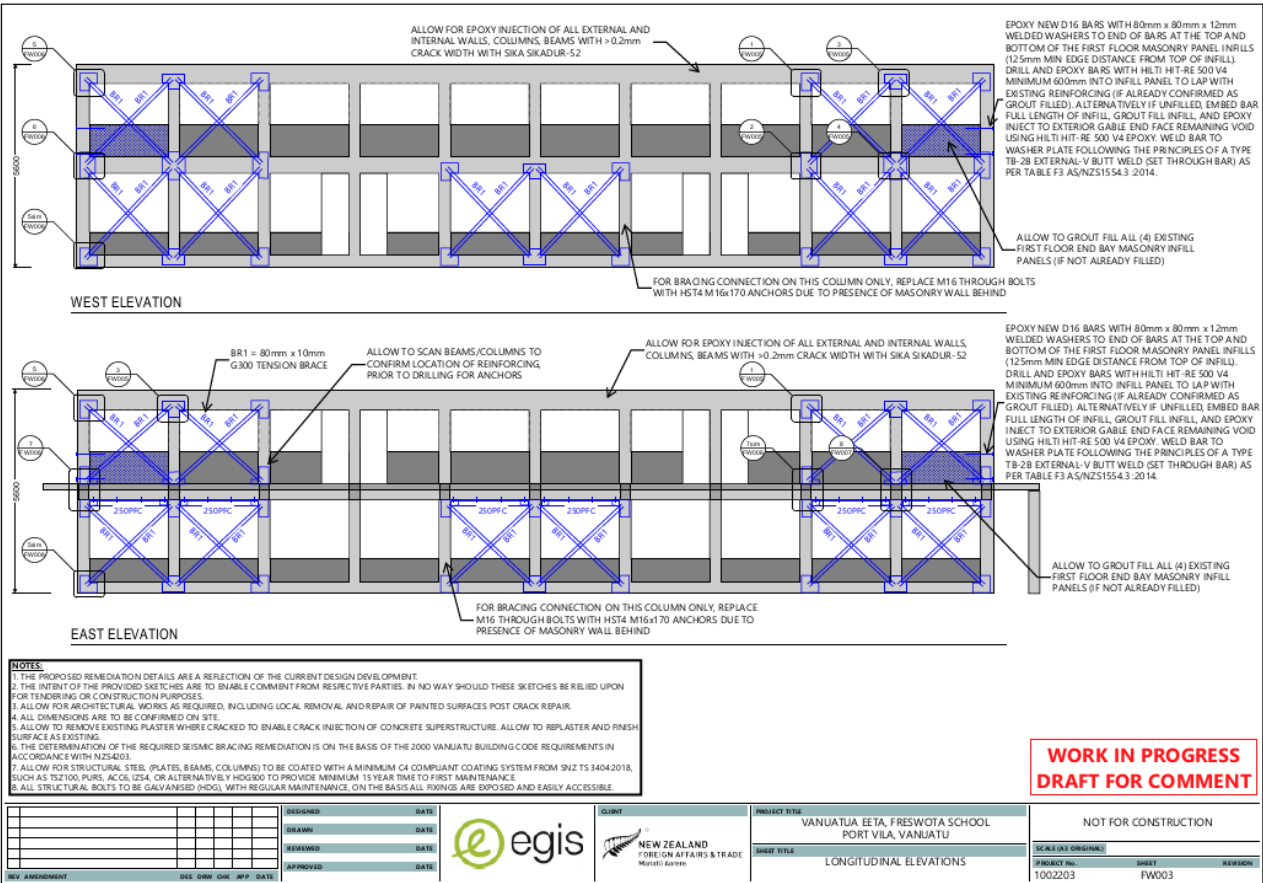


Figure 9: Typical Concrete Frame Conceptual Strengthening Solution

Official Gazette 37 released in April 2025 inducing seismic demands on existing building structures well in excess of their capacity (up to seven times that of the earlier 2000 Vanuatu National Building Code requirements) with the proposed hazard factor $Z = 1.3$ for Port Vila, which was deemed impractical and uneconomic to design, detail, and construct retrofit solutions for.

With consideration to the evolving regulatory context, observed damage, and local capability, structural intervention involving repair or reinstatement considered general good practice principles, such as ensuring a ductile building response where possible and adopting overstrength design principles such as those for connections, with introduced lateral load resisting systems detailed to be capable of withstanding higher seismic demands, if imposed.

5 CONCLUSIONS

The December 2024 Port Vila earthquake caused significant but highly variable damage, strongly influenced by local ground conditions, building typologies, and construction quality. While much of the Port Vila infrastructure performed well, where bearing on competent limestone geology, development on reclaimed ground resulted in disproportionate damage, driven primarily by below ground geotechnical effects, indicating the need for clear planning guidance to avoid unnecessary land exclusion, promote ground-appropriate foundation solutions, and enable a consistent, resilient rebuild.

The New Zealand-supported engineering assistance programme provided integrated structural and geotechnical assessment and developed practical remediation strategies to support recovery.

The development of remediation and rebuild strategies was largely informed by a critical review of post-event observations. While recorded ground motion data proved limited due to instrumentation sensitivity and insufficient capture range, corroborating geological evidence and the observed pattern and extent of damage provided valuable insight into the likely seismic demand experienced by structures. This informed a proportionate, evidence-based engineering response, ensuring that strengthening and reinstatement strategies were appropriately targeted, resilient, and aligned with the actual seismic performance demands observed.

The adopted repair and strengthening strategy balanced regulatory change, observed damage, and local constructability by applying good-practice ductile and overstrength principles, while designing to the 2000 Vanuatu National Building Code (or pre-earthquake capacity), as the significantly increased seismic demands introduced by Official Gazette 37 were considered impractical and uneconomic to implement for existing buildings.

The project demonstrated that timely, integrated geotechnical and structural input, aligned with local capability, can materially improve post-earthquake recovery outcomes in resource-constrained environments. The findings and lessons from this work are applicable to Port Vila and to other Pacific Islands/territories exposed to similar seismic and geotechnical risks, where repair and rebuild strategies require consideration of local practices, capability, regulatory and economic constraints.