Observed damage from 17 Dec 2024 M7.3 Vanuatu earthquake

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ABSTRACT

On 17 December at 12:47pm local time, Vanuatu was struck by a M7.3 earthquake 30km offshore of the main island of Efate, which is where the capital, Port Vila, is located. As part of New Zealand's commitment to our Pacific neighbours, the Ministry of Foreign Affairs and Trade offered assistance by sending a Fire and Emergency NZ (FENZ) Urban Search and Rescue (USAR) team, along with other humanitarian supplies and expertise. In this paper, engineers from this team present examples of damage encountered during their deployment, including both geotechnical and structural damage. Topics include landslides, surface ruptures, retaining wall/seawall damage, soft-storey collapses, concrete frame damage, masonry damage, and secondary/non-structural issues.

1 BACKGROUND

Vanuatu is an archipelago of volcanic origin located on the Pacific Ring of Fire. The islands were formed due to the subduction of the Indo-Australian Plate beneath the Pacific Plate along the New Hebrides Trench. Figure 1 shows the location of this earthquake in the wider south Pacific. Earthquakes are common in the area, as well as tropical cyclones.

Vanuatu was settled by Melanesian people around 3000 years ago. The first Europeans to visit the islands were Spaniards in the early 1600s. In the 1880s, both the United Kingdom and France claimed parts of the archipelago and in 1906 agreed to jointly manage the archipelago as the New Hebrides. In 1980, the Republic of Vanuatu was founded as an independent country.

The capital, Port Vila, is located on the island of Efate near the centre of the island group.

1.1 Geological setting

The island of Efate is formed from the remains of an extinct volcano and lies about 50 km east of the New Hebrides Subduction Trench. The resultant subducting plate plunges steeply eastwards beneath Efate with very high levels of seismic activity.

In broad terms the geology comprises volcanic deposits namely lava (north of the island) with pumice deposits in the centre. Raised limestone platforms (faulted blocks) surround much of the island and are of varying age.

These faulted blocks to some extent control the topography and stability of escarpments around the harbour and Port. The escarpments are also controlling features along areas of the roading system particularly the area known as Klem Hill.

1.1.1 Port Vila

Port Vila is located in the southwest of the island on a wide natural harbour, however the CBD has undergone various stages of reclamation to create the developments that now line the coast.

Whilst not investigated by the authors it is understood that the engineered filling to create development platforms is of variable quality.

1.2 Construction typology

Construction in Port Vila is primarily concrete and concrete masonry block. Many buildings appeared to be concrete frames with masonry infill walls. There are few steel frame structures or lightweight timber structures over one storey. Many structures have heavy (concrete) roofs to resist uplift forces during cyclones. Some modern structures have lightweight roofs with cyclone tie-downs. Many smaller structures have open sides to circulate air due to the hot climate.

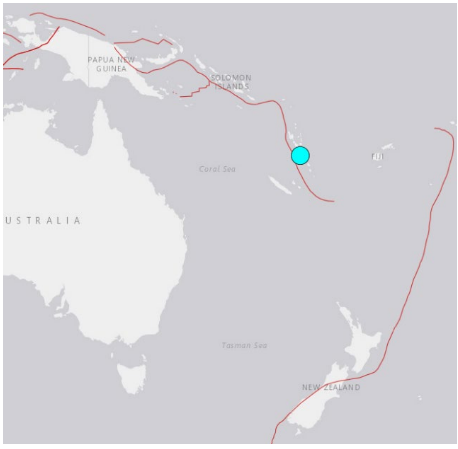

Figure 1. Location of M7.3 earthquake (USGS)

2 USAR MISSION

On 17 December at 12:47pm local time, Vanuatu was struck by a M7.3 earthquake 30km offshore of the main island of Efate, which is where the capital, Port Vila, is located. Shortly after the earthquake, the Fire and Emergency NZ (FENZ) Urban Search and Rescue (USAR) team was activated by the Ministry of Foreign Affairs and Trade (MFAT). Reports of heavily damaged or collapsed structures indicated a need for technical rescue assistance. FENZ USAR deployed a team of 34, leaving the country approximately 24 hours after the event. France and Australia also deployed USAR teams.

The New Zealand team deployed to a few sites for technical rescue assistance during the first day in Port Vila. However, due to the elapsed time since the earthquake, the priority quickly turned to assessment of structural and geotechnical damage in Port Vila and the wider Efate area. Small teams of USAR technicians were dispatched to canvas residential, commercial, and industrial areas to assess damage extents.   USAR engineers integrated with the local government response to assess individual buildings and landslides from a more technical perspective. The main priority was to assess evacuation centres. With the assistance of Public Works Department employees, internal access to buildings was high.

3 OBSERVED DAMAGE

This section will present examples of the common types of damage seen in the Port Vila and wider Efate area. No other islands were visited during this mission so no commentary can be made on the performance of structures elsewhere; however there were no reports of major damage in outlying islands.

Note that photos have had identifying details of property and people obscured.

3.1 Landslides

The earthquake generated thousands of landslides across Efate and most likely the wider island chain.

Most of the landslides occurred in areas sparsely populated such as the high catchments of the La Colle River north of Mele; while not immediately damaging, the enormous volume of pumice, debris and resulting landslide dams (see Figure 2) within the river courses created a potentially delayed hazard in the form of debris flows and flash flooding events downstream.

This type of hazard can remain for months and is controlled to a larger extent by rainfall volume.

Figure 2. Landslide dams forming in catchment of La Colle river

The sheer volume of the pumice and debris within the La Colle catchment meant no physical removal could be undertaken during the deployment so the focus for USAR and the National Disaster Management Office (NDMO) was briefing the potentially affected villages of the hazard and providing details of potential temporary refuges.

Whilst many of the landslides were in more remote areas, damage was observed in a number of locations within Port Vila CBD and the surrounding suburbs as a result of both natural failures and cut / engineered slopes.

Figure 3 and Figure 4. Landslide behind building. Major damage to concrete columns. Ongoing risk due to further ground movement. Damage to concrete columns and infill masonry due to inertial shaking and impact of landslide.

Of particular note was the Lapetasi International Port where a series of large rock and debris avalanches occurred during the initial earthquake which blocked Wharf Road, the main road accessing the international port, and the cruise ship port beyond. At the time of the site visit on the 20th December 2024, temporary bypass had been afforded through the port processing/container storage areas.

Figure 5. Large rock avalanche at Lapetasi Port access road

Thousands of cubic meters of material including boulders up to six metres in diameter (from the limestone layer capping the slope) failed and inundated the access road and port entrance. The slope is understood to have suffered failures in the past including large rock fall however an event of this scale had not been witnessed previously.

The slope is north facing, 50m in height and around 500m long, comprised of a combination of tuff and capped with coral limestone. The slope appears to have been in the order of 60-80 degrees prior to the earthquake and is covered to varying amounts by vegetation. Multiple joint set are visible throughout the face with many boulders and loose debris still hanging above the road. Material ranges in size from silt to boulders in the order of 6m, with a large number of boulders 5m+ present.

The rockfall debris formed a slope of around 45degrees at various sections along the road totalling around 300m. Boulders have travelled up to around 20-30m from the original base of the cliff with one particularly large boulder coming to rest between the two port buildings which are located either side of the former entrance gate as seen in Figure 6.

Figure 6. 6m boulder travelled some 30m coming to rest between port buildings

The debris slope in front of the port entrance entirely covered the width road and had damaged the Port boundary fence.

At the crest of the slope above Wharf Road multiple buildings are present, both residential and commercial. Advice to residential owners was to evacuate the properties until a full assessment could be made by local authorities.

Commercial entities, which included the main telecom provider and associated mast and infrastructure, had evacuated the buildings by the time FENZ USAR had visited the site, with the exception of security guards. Advice was sought however as to whether removal of equipment from lower down the slope was feasible. As often is the case in these situations a certain amount of risk acceptance is needed to secure these key benefits/assets, and the owner decided to go ahead and remove equipment with oversight by their engineers.

A gas main is understood to run beneath the Wharf Road; at the time of writing the condition is not known however there was a significant drop in the road due to landslide/deformation beneath Wharf Rd at the eastern end.

Instability was present along much of the Wharf Road with smaller slips/falls towards the east and the larger failure to the west at the former port entrance. Material was observed falling intermittently at the time of the inspection indicating a clearly unstable face.

Removal of the debris slope will be a difficult and dangerous exercise and requires co-ordination with all parties operating beneath the areas being excavated to be a safe as possible. It is unlikely that all risk to the operators of the excavators can be removed due to the material at the crest of the slope being unstable.

There are multiple options for slope retention and or debris fall protection however these need to be specifically designed and is beyond the scope of USAR on these types of deployment. Typical options might include rock bolting, meshing, drapes or rock fall fences/bunds or ditches, or indeed a combination of the above.

3.2 Surface ruptures

In addition to landslide related ruptures a number of areas of localised surface rupture were noted across the sites visited ranging from potential localised block movements (e.g. above the Port), through to potential fault rupture within the CBD.

Figure 7. Surface rupture through building. Uplift approximate 300mm.
Figure 8. Concrete frame and masonry infill damage as a result of uplift

Figure 9. Possible fault rupture through Port Vila CBD. This building was not inspected by the FENZ USAR team.

3.3 Retaining walls and seawalls

Damage was observed to many retaining structures mainly due to the unreinforced or informal construction methods; however a notable departure from this was the sea front in Port Vila.

In places the sea wall had moved forward most likely due to a combination of lateral spreading and translation due to excessive loading during the M7.3 event.

As mentioned above, significant areas of the coastline have been reclaimed in the past to generate building platforms in the area and the variable control or nature of the engineered filling could have contributed to this lateral spreading.

Figure 10. Seawall damage leading to cracking and subsidence next to concrete spread footings.

Figure 11. Damage to masonry retaining wall. In addition to the hazard posed by falling blocks, this retaining wall supports a road beyond, which is at risk.

3.4 Concrete frames

Figure 12. Partial soft-storey collapse of concrete frame building. The building appears to be three seismically separated structures. The left most has suffered a soft-storey collapse at ground level. The other two are also heavily damaged at ground level and above but remain standing with a pronounced lean at ground level.
Figure 13. Right side of same building, showing heavy damage to columns and infill masonry walls at ground and first levels.

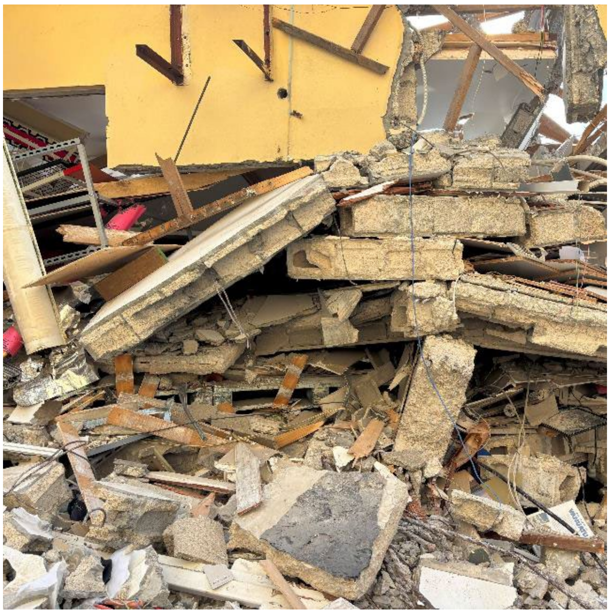

Figure 14. Complete pancake collapse of concrete frame building. Non-ductile concrete frame with masonry infill walls and brittle flooring system with post-tensioned ribs.

Figure 15. Concrete frame building with major damage to ground floor columns. Likely soft-storey effect due to "tuck-under" parking in the rear and open shopfront in the front.
Figure 16. Buckled longitudinal reinforcing at ground floor column. Top joint and other columns sustained similar damage.

Figure 17. Major damage to ground floor concrete frame and infill masonry wall. Large vertical irregularity with discontinuous frame above entry and potential soft-storey effect.

3.5 Infill masonry

Many concrete frame buildings in Vanuatu are built with infill masonry as partition and façade walls. These walls typically did not appear to have detailing to accommodate the interstorey drift of the frames and consequently acted as a stiff load path until major cracking occurred. While the concrete frames in many cases appeared undamaged or only minorly so, the infill wall can pose a major life-safety falling hazard with enough disconnection from the frame.

3.5.1 Major damage

Figure 18 and Figure 19. Major damage to masonry walls on side of building, minor-to-major damage at front. Concrete frame appeared to be generally intact. Close up of damage.

Figure 20. Major damage to infill masonry walls in concrete frame building. No major damage to concrete frame noted, however serious fall hazard from heavily damaged walls and ceilings remains.

3.5.2 Minor damage

Figure 21. Infill wall damaged at interface with concrete frame. Wall on left verging on major damage due to increasing disconnection from frame and supporting utilities.

Figure 22. Minor damage to masonry walls at interface with concrete frame. Like many other similar buildings in Port Vila, this building had a thick plaster render applied to the surface of the wall and frame, which failed in a brittle manner before any significant cracking developed in the structure behind.

Figure 23. Minor cracks to plaster finish on infill walls. Most common type of damage observed.

3.6 Steel frames

Steel frame buildings were not observed to have any significant damage. There are very few of these type of structures in Port Vila, and those that were observed were known to be modern.

3.7 Secondary and non-structural issues

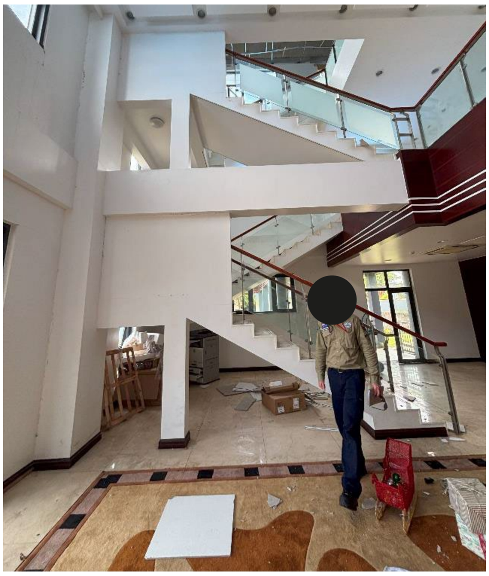

Figure 24. Heavy cement plaster ceiling tile which has fallen from two storeys above (metal ceiling supports can be seen above stairs at top of photo). Many similar buildings featured these heavy ceiling tiles which pose a major falling hazard in an earthquake if not sufficiently restrained.
Figure 25. Dislocated water tank. Many buildings were otherwise usable but lacked water supply due to water tank damage, including to pipe work, connection to foundation, or damage to the tank itself.

4 CONCLUSIONS

Like many other developing nations, Vanuatu has mixed building stock with varying degrees of compliance with relevant standards. However, many structures sustained little to no structural damage in the M7.3 earthquake or subsequent aftershocks, which may have been due to a relatively short duration of shaking (approximately 30 seconds). The structures shown here were the exception to that. These structures show damage in recognisable patterns, familiar to many engineers, and serve as a reminder of the importance of careful design and adherence to the latest professional knowledge. This includes the consideration of ground hazards (especially slopes), avoidance of soft storeys, use of structurally regular designs, the importance of confinement of column hinge locations, careful detailing of stiff infill walls to avoid interaction with the main lateral system, and restraint of non-structural items.

5 REFERENCES

USGS. *Latest Earthquakes*. https://earthquake.usgs.gov/earthquakes/map (Accessed 2 February 2024)