Disaster Reports

Damage Caused by the 2025 Myanmar Earthquake and Lessons Learned

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1. Introduction

On March 28, 2025, at 12:50 MMT, a Mw 7.7 earthquake struck near Mandalay, Myanmar, along the Sagaing Fault at a shallow depth of 10 km. This earthquake was one of the largest to hit the region in decades and caused widespread destruction across central Myanmar. Its impacts extended beyond Myanmar's borders, with shaking felt in neighboring countries as well. The scale of damage to infrastructures, buildings, and cultural heritage sites underscored the seismic vulnerability of the country.

Under the leadership of the first author, a reconnaissance mission was organized by the Japanese Geotechnical Society (JGS) immediately after the Earthquake. The mission aimed to document the extent and characteristics of ground and structural damage, as well as to collect perishable data that could support future hazard assessment and mitigation efforts. In collaboration with the Myanmar Geosciences Society (MGS), the Federation of Myanmar Engineering Societies (MES), and several international partners, the field survey was conducted from June 13 to 16, 2025. The team carried out site inspections in the earthquake-affected areas of two major cities—Naypyidaw and Mandalay—which suffered notable ground failures and structural damage (Fig. 1). Observations were supplemented by interviews with local residents and engineers, and the collection of photographic and geotechnical data for subsequent analysis. The findings provide valuable insights into seismic hazards in Myanmar and recommendations for risk reduction in the future.

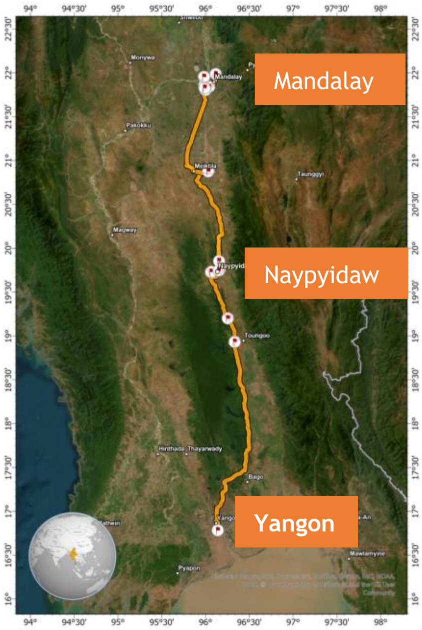

Fig. 1: Investigation route and locations

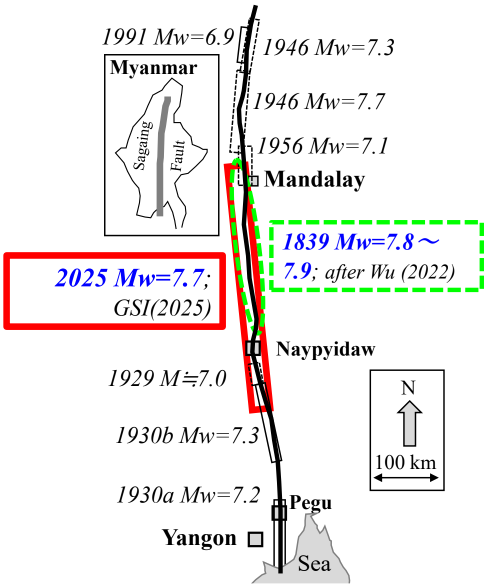

Fig. 2: Historical earthquakes caused by Sagaing fault (Modified from Soe and Watkinson, 2011 and Wang et al., 2014)

2. Earthquake characteristics

The 2025 Myanmar Earthquake originated along the Sagaing Fault, a right-lateral strike-slip fault that trends north-south across central Myanmar (Brown and Leicester, 1933; West, 1937; Dey, 1968; Socquet et al., 2006; Aung, 2009; Tsutsumi and Sato, 2009). The Sagaing Fault is recognized as one of Southeast Asia's most seismically active fault systems and has generated numerous historical earthquakes (Fig. 2, after Soe and Watkinson, 2011; Wang et al., 2014).

It is noteworthy that the 2025 event occurred within a previously identified seismic gap along the fault (Hurukawa and Maung, 2011), as indicated by the red and green boxes in Fig. 2. The rupture extended over a distance of approximately 400–460 km, producing strong ground motions across a wide region. Recent seismological investigations (Melgar et al., 2025; Diao et al., 2025; Ye et al., 2025) further suggest the occurrence of a supershear rupture, wherein the rupture front propagated at a velocity exceeding the shear-wave speed of the crust.

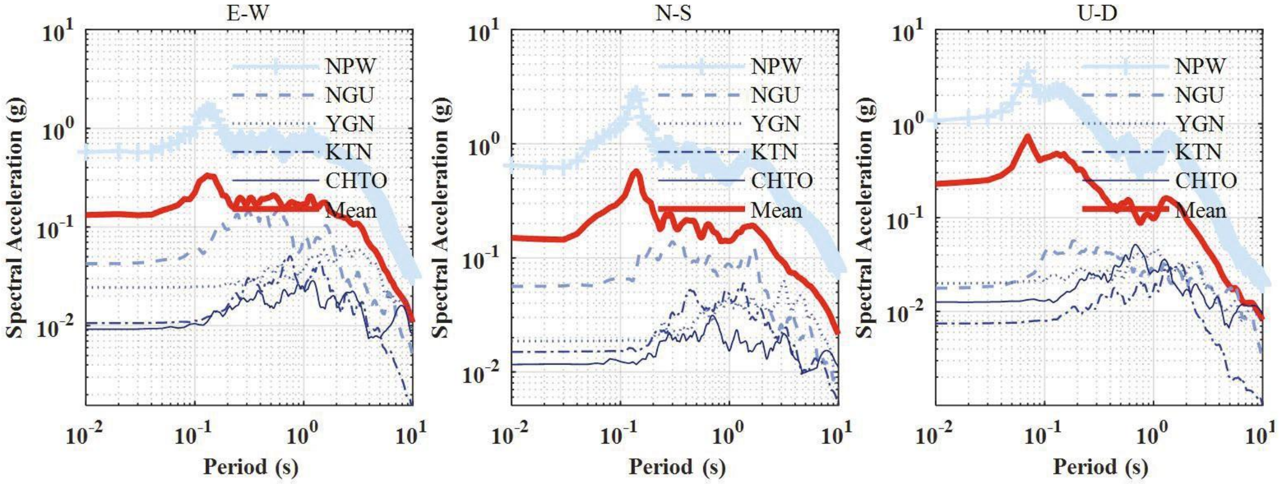

Fig. 3: Spectral acceleration based on seismograph data (Wang et al., 2025)

Recorded seismograph data and subsequent analyses carried out by Wang et al. (2025) revealed varied characteristics depending on location. In Naypyidaw, the records were dominated by short-period motions, while in Yangon long-period components were more prominent. In Mandalay, close to the epicenter, the peak ground acceleration was recorded at around 0.18 g, though the data reliability was uncertain. These results indicate a complex distribution of seismic energy across the affected region (Fig. 3).

3. Observed geotechnical and infrastructural damage

The earthquake severely impacted Myanmar's transportation network, especially the Yangon–Mandalay Highway (Asian Highway No 1: AH1). Extensive liquefaction-induced settlement was observed in a location near Pegu along the Yangon–Mandalay Highway, leading to uneven road surfaces and distorted alignment (Photo 1). Bridge abutments were damaged due to lateral spreading of soils, resulting in severe structural failure (Photo 2). In adjacent farmland, utility poles had toppled, further illustrating the extent of lateral ground displacement.

Photo 1: Liquefaction induced damage to road

Photo 2: Abutment damage

In Mandalay City, the construction site of a new shopping mall in Amarapura township exhibited traces of liquefaction despite reported countermeasures such as groundwater lowering (Photo 3). This suggests that the countermeasures were insufficient under strong shaking conditions. Nearby road also suffered extensive damage (such as lateral spreads, cracks and voids beneath roads) due to liquefaction and slope failures, with kerb displacement measured up to 2.5 meters. Such large-scale soil movements indicate that the road embankment possible was constructed using loose river sands, which are highly vulnerable to liquefaction (Photo 4).

Mandalay City is surrounded by two major rivers: the Ayeyarwady River to the west and the Myitnge River to the south (Fig. 4). The Myitnge River embankments experienced large-scale failures, leading to toppling of bridge piers and completely blocking the AH-1 (Photo 5). In some locations of the river embankment, fluidized flow exceeding 10 meters destroyed as many as 30 houses and resulted in human casualties (Photo 6).

In another location of Mandalay city, the damage of bridge piers was observed, with one pier settling by about 1.5 meters (Photo 7). Insufficient embedment of foundations could have contributed to the scale of the damage. These failures highlight the combined effects of liquefaction, weak foundation soils, and hydraulic influences, which pose serious risks to riverine infrastructure in Myanmar.

Photo 3: Sand boils at shopping mall site

Photo 4: Liquefaction-induced damage to the nearby road surface

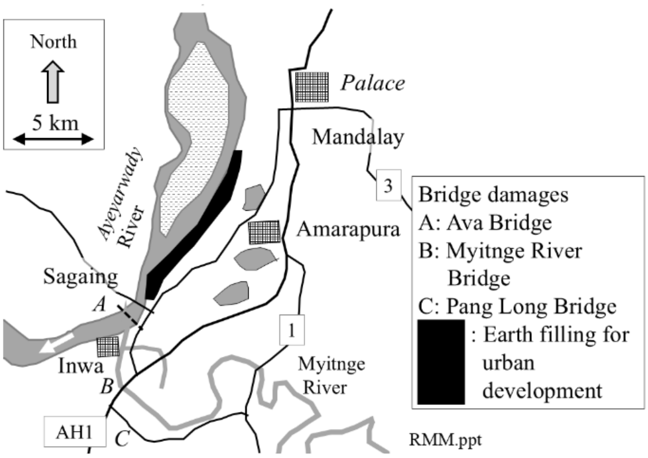

Fig. 4: Location of Amarapura township (From Towhata and Hazarika, 2025)

(a)View from the north

(b)View from the south

Photo 5: Riverbank landslides and bridge pier collapse

Photo 6: Landslides and collapse of houses

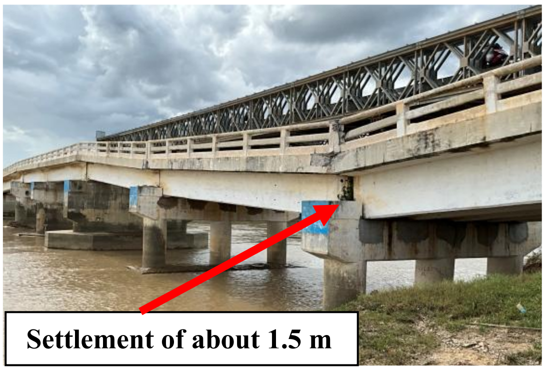

Photo 7: Bridge pier settlement

4. Building damage

In Nyaung Pin Gyi Su Village, near Naypyidaw, an elementary school experienced significant differential settlement due to liquefaction. Cracks developed in the walls, and misalignment of rain gutters was observed (Photo 8). Widespread sand boiling occurred throughout the village (Photo 9). Dynamic Cone Penetration Tests (DCPT) performed by the authors revealed that the soil at the investigated site was very loose, with a converted N-value of less than 5, and a shallow groundwater table approximately 1.2 meters below the ground surface. These findings confirm the high susceptibility of the site to liquefaction and associated ground deformations.

Photo 8: Damage to school buildings

Photo 9: Traces of sand boils in the village

Photo 10: Sky Villa condominium in Mandalay

Photo 11: Structural damages in lower storeys of buildings (Nepyidaw)

In Mandalay city, the 12-storey Sky Villa Condominium, constructed in 2017, collapsed completely, with its lower stories (up to the 4th floor) crushed (Photo 10), resulting in 207 fatalities. The building featured a pilotis-style design, where the ground floor consisted primarily of columns with very few shear walls. This configuration is known to exhibit poor seismic performance, as observed during the 1995 Kobe Earthquake in Japan. Similar patterns of soft-storey failure (Photo 11) were observed in several other apartment and hotel buildings, where severe cracking and crushing were concentrated in the lower floors, while the upper floors remained relatively intact. The repeated occurrence of such soft-storey collapses highlights a fundamental design deficiency that must be urgently addressed in future seismic design codes and retrofitting programs, particularly for reinforced concrete buildings in high-risk areas.

5. Obsreved fault and associated damage

Fault-induced dislocations were observed at numerous locations during the field survey. Photo 12 illustrates one such example in Sagaing, near Mandalay, where the displacement was purely horizontal with no vertical component.

An important observation on fault rupture was obtained approximately 140 km south of Mandalay (Photo 13), where a surveillance motion camera captured both the ongoing ground shaking and the onset of fault rupture. This video footage was made available on the web shortly after the event. Interestingly, there was a time lapse of about five seconds between the beginning of strong shaking and the initiation of fault displacement. This delay appears to contradict the previously mentioned supershear hypothesis, in which rupture propagation exceeds the shear-wave velocity. It is possible, however, that the supershear behavior was a localized phenomenon, as suggested by Ye et al. (2025), who reported that the rupture became supershear only after it had propagated approximately 200 km south of the epicenter, near Mandalay.

Photo 12: Right-lateral fault dislocation in Sagaing (Left bank of the Ayeyarwady River, near Mandalay)

Photo 13: Fault dislocation in a solar power station

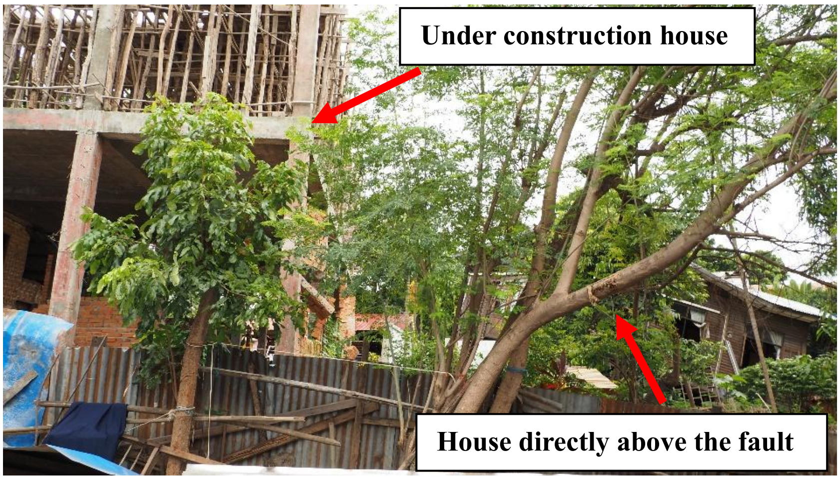

Photo 14: Contrast of damage of two adjacent houses on the opposite side of fault dislocation in Photo 12

Notably, in Sagain area, building damage was concentrated within approximately 50 meters of the fault trace (Photo 14). An under-construction building (left to the damaged house) remains unaffected. This observation implies that the damage was primarily caused by surface soil deformation rather than strong ground shaking.

Photos 15(a)-(e) show the fault dislocation and its impact on surface structures in Naypyidaw, where the observed ground motion intensity was high (Fig. 3). Photo 15(a) shows a right-lateral displacement consistent with that observed in Sagaing (Photo 12), accompanied by significant shear deformation of the ground surface. Photo 15(b) displays a building situated directly atop the fault rupture that sustained severe damage, as further evident from the interior shown in Photo 15(c). In contrast, a room located about ten meters away from the rupture (Photo 15(d)) suffered much less damage. This again confirms that the primary cause of fault-induced damage was surface deformation rather than ground shaking.

A noteworthy finding during the survey was the absence of landslides on natural slopes. Photo 15(e) depicts the continuation of the fault rupture toward the north of the site. Despite extensive damage to buildings and numerous failures in man-made slopes and fills, the small natural cliff in this photograph remained intact. This lack of failure in natural hill slopes was consistently observed at many other sites as well.

(a) Right-lateral dislocation (looking eastward)

(b) Main building resting directly on the fault dislocation

(c)Damage inside the main building

(d) The same building ten meters away from the fault (leftward in (b))

(e) Continuation of fault rupture on the northern side of the site

Photo 15: Fault dislocation in the Children's Specialized Hospital in Nepyidaw

6. Cultural heritage damage

The earthquake caused devastating losses to Myanmar's rich cultural heritage. Temples, pagodas, and historic buildings collapsed or were severely damaged. Photo 16 shows one such damage of a pagoda constructed during 19th century. The reconstruction of these heritage sites raises a fundamental question: whether to prioritize authentic restoration using original materials or to focus on rapid recovery using modern methods. Authentic restoration is time-consuming and technically demanding, but it preserves cultural and spiritual values. Rapid reconstruction ensures continuity of cultural practices but risks diminishing historical authenticity. This dilemma was also faced in Japan after major earthquakes, where ancient temples were restored using modified designs. The Myanmar case underscores the need for policies that balance heritage preservation with seismic safety.

Photo 16: Destroyed Me Nu Brick Monastery in Inwa.

7. Regional and long-distance effect

The earthquake's effects extended beyond Myanmar, with noticeable damage in Bangkok, Thailand, nearly 1,000 km from the epicenter. A few of the city's high-rise buildings suffered from long-period ground motions, which induced resonance and amplified shaking. Although supershear mechanism is sometimes claimed to be responsible for this long-distance impact, there is so far no evidence that supershear ground motion is not affected by attenuation or decay and can maintain its energy over a long distance. It is more reasonable that the thick soil deposit in Bangkok amplified the motion and made the long predominant period of shaking. There are historical evidences that previous strong earthquakes in the Sagaing Fault were associated with sloshing of canal water in Bangkok; Mw = 7.8-7.9 in 1839 (Prinya and Sodsri, 1983) and Mw = 7.3 in December 1930 (Brown and Leicester, 1933). Water sloshing in canal suggests the dominance of long-period earthquake motion in Bangkok

8. Key lessons learned

The reconnaissance revealed several urgent lessons:

1. Seismic Monitoring: Myanmar currently has very few seismic observation stations. Expanding a dense, low-cost but reliable seismic network is critical for early warning and hazard assessment.
2. Microzonation: Urban areas such as Mandalay and Yangon need detailed microzonation studies to map liquefaction susceptibility and site amplification zones.
3. Design Weaknesses: The collapse of pilotis-style buildings and the ineffectiveness of groundwater lowering measures show that structural and geotechnical design standards must be revised.
4. River Embankments: The failures along the Myitnge River demonstrated the extreme vulnerability of embankments constructed of loose fill. Strengthening and monitoring of riverbanks are necessary to prevent similar disasters.
5. Cultural Heritage: Preservation strategies must strike a balance between authenticity and resilience, ensuring heritage sites can withstand future earthquakes while maintaining cultural value.
6. Regional Preparedness: Countries neighboring Myanmar, particularly Thailand, must recognize that long-period ground motions from large earthquakes can affect them significantly. Cross-border collaboration in seismic hazard studies is also vital.

9. Conclusions

The 2025 Myanmar Earthquake has reinforced the seismic risk posed by the Sagaing Fault system. The event caused a wide spectrum of damage, including liquefaction-induced failures, slope failures, building collapse, and cultural heritage destruction. The reconnaissance survey confirmed that Myanmar's infrastructure and building stock remain highly vulnerable to strong earthquakes.

Moving forward, Myanmar must prioritize:

- Strengthening foundations and embankments against liquefaction.
- Retrofitting vulnerable soft-storey structures.
- Expanding seismic monitoring networks.
- Developing regional hazard assessments that incorporate long-period seismic impacts.

The findings of this reconnaissance are not only important for Myanmar but also provide critical lessons for seismic risk management throughout Southeast Asia. By acting on these lessons, academia, governments and industries can reduce future losses and build greater resilience against major earthquakes.

Acknowledgements

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