Seismic amplification and resonance effects of the 2025 Myanmar earthquake in Bangkok's soft-soil area

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Abstract: The 7.7 Mw earthquake that struck the Sagaing region, Myanmar, on March 28, 2025, caused cross-border seismic effects felt as far as Bangkok, Thailand, about 600 km from the epicenter. Although considered a low-seismic-risk area, tremors of intensity IV–V on the Modified Mercalli (MMI) scale produced strong shaking in high-rise buildings and led to the collapse of construction projects in the Chatuchak District. This study examines the relationship between Bangkok's geotechnical conditions and the dynamic responses of buildings to the 2025 Myanmar earthquake. The qualitative-descriptive method includes literature review, field observations in Sathorn, Silom, and Chatuchak, and comparative analysis with the 2011 Tohoku and 2015 Nepal earthquakes. Results indicate that a 15–30 m thick water-saturated clay layer with a shear wave velocity (Vs30) below 150 m/s and a dominant period of 1.8–2.5 seconds amplified ground motion up to twice the theoretical value. This condition triggered ground–structure resonance, affecting buildings with 15– 25 storeys and deep-pile foundations, as well as flexible structures. The Chatuchak collapse was due to resonance combined with poor construction stability. These findings confirm that long-period waves pose significant risks to delta cities, such as Bangkok, underscoring the need to revise national seismic design standards by incorporating local amplification and long-period effects in soft soil zones.

1 Introduction

The massive 7.7 Mw earthquake that shook the Sagaing region, Myanmar, on March 28, 2025, became one of the most significant seismic events in Southeast Asia in the past two decades. According to the United States Geological Survey records [1]. The earthquake was centered approximately 50 km north of Mandalay, with a depth of 10 km, and occurred due to activity on the Sagaing Fault, one of the most active shear faults in the Indo-China region, stretching for approximately 1,200 km from central Myanmar to the Andaman Sea. This event not only caused severe damage around the epicenter but also generated transboundary seismic effects as far as Thailand, Laos, and parts of southern China, including the city of Bangkok, which is more than 600 km from the earthquake's source.

Geographically, Bangkok is located far from the active subduction zone; however, the 2025 Myanmar earthquake was felt quite strongly by the community, especially on the upper floors of high-rise buildings in the Sathorn, Silom, and Sukhumvit areas. According to a report by the Thai Meteorological Department (TMD), the intensity of the tremor in the city reached IV–V on the Modified Mercalli Intensity (MMI) scale with a vibration duration of more than one minute. This phenomenon suggests that long-range seismic waves can experience significant local amplification when passing through the soft and water-saturated soil layers that dominate delta plains such as Bangkok [2, 3].

Geotectonically, Bangkok is situated above the Chao Phraya River Delta, a vast alluvial plain composed of a 15–30 meter thick layer of soft clay atop sand and gravel. These geotechnical conditions cause the effect of soil amplification on earthquake waves, especially in long-period ground motion waves that can be amplified up to several times compared to theoretical calculations [4, 5]. Soil layers with a shear wave velocity (Vs30) of < 150 m/s play an important role in strengthening the amplitude of vibration and extending the duration of the shock, especially for high-rise buildings with a natural period of 1.5–2.5 seconds, which is comparable to the dominant period of ground waves [6].

One of the most notable events recorded after the 2025 Myanmar earthquake was the collapse of a skyscraper in Bangkok's Chatuchak District. According to a Reuters investigative report [7, 8] and AP News [9], the building was still under construction when the earthquake occurred, and some of its main structural elements (concrete beams and columns) were only cast a few days before the incident. Due to the lack of optimal concrete strength and inadequate engineering supervision in the field, long-term vibrations can trigger progressive structural failures, ultimately leading to total collapse. The incident killed dozens of workers and shook public confidence in the resilience of high-rise buildings in Bangkok. An official report from Thailand's Department

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of Public Works and Urban Planning (DPT) confirms that the dominant factor causing the failure is a combination of soil-building resonance and unstable construction conditions.

In the context of building planning and regulations, the Thailand Building Code 2023 still categorizes Bangkok as a low-seismic risk area, with a planned land acceleration value (PGA) of around 0.04–0.06 g. However, the results of field observations and numerical simulations show that the actual acceleration can reach 0.08 g in soft soil areas [10, 11] These differences suggest that structural design standards in Bangkok have not fully accounted for the effects of local amplification, particularly for tall structures with non-linear dynamic behavior. This condition renders many buildings in the city vulnerable to double resonance, a phenomenon that occurs when soft soil layers and tall building structures resonate, amplifying the dynamic response up to twice as much as in rocky areas [12].

High population density and massive vertical development magnify the potential for secondary seismic risk in Bangkok. Today, there are more than 1,200 tall buildings standing on thick layers of clay, most of them using a system of pile foundations that penetrate the hard layer at a depth of 20–30 meters [3]. Under certain conditions, these foundation systems can extend the structure's natural vibrating period and increase the resonance potential when receiving low-frequency earthquake waves from distant sources, such as those in Myanmar. Thus, the latent vulnerability of the city of Bangkok depends not only on regional seismotectonic parameters but also on the complex interactions between soil characteristics, foundation systems, and the design of high-rise buildings.

Thus, this study aims to analyze the cross-border impact of the 2025 Myanmar earthquake on the vulnerability of urban buildings in Bangkok, highlighting the role of soil amplification, soil-structure resonance, and the limitations of current seismic design standards.

2 Method

2.1 Research location

This research was conducted in the city of Bangkok, Thailand, which was deliberately chosen because this area is a densely populated urban area that will be indirectly affected by the 2025 Myanmar earthquake. Bangkok is an interesting location to study because, despite being outside the active subduction zone, the city still experiences significant tremors due to the propagation of long-range seismic waves (long-distance ground movements) from the epicenter of the earthquake in the Sagaing region, Myanmar.

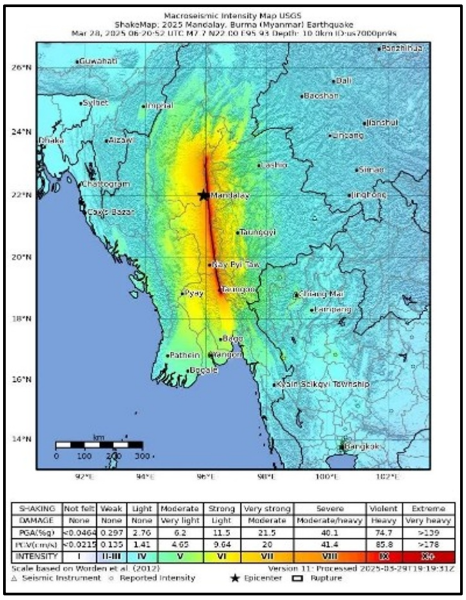

Fig. 1. Map of the macroseismic intensity of the Myanmar earthquake 2025.
Source: United States Geological Survey

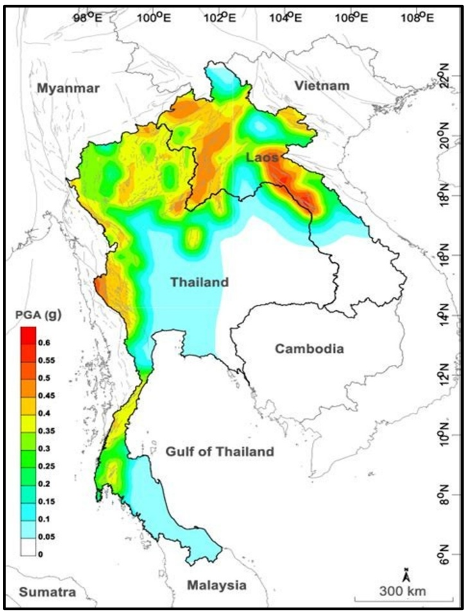

Fig. 2. Thailand and Laos deterministic seismic hazard analysis (DSHA) Map
Source: Department of Mineral Resources (DMR), Ministry of Natural Resources and Environment, Thailand

To provide a spatial overview of the study, Figure 1 shows the 2025 Myanmar Earthquake Macrorosemic Intensity Map based on USGS data [1]. Figure 2 shows the Deterministic Seismic Hazard Map (DSHA) published by the Department of Mineral Resources of Thailand (DMR). Both maps describe the range of cross-border tremors and Bangkok's position in the low-danger zone, which was significantly affected by local amplification.

2.2 Data collection and analysis methods

The data collection and analysis methods in this study were developed to gain a comprehensive understanding of the cross-border impact of the 2025 Myanmar earthquake on the seismic response of buildings in Bangkok. The approach used is qualitative-descriptive, by integrating secondary scientific data, results of field observations, and comparative analysis of regional seismic phenomena. The goal is not simply to describe physical damage, but rather to explain how the geotechnical characteristics of soil and the design of urban structures interact in amplifying long-range vibrations.

The research began with a comprehensive literature review that combined scientific sources, technical reports, and official data from seismological institutions. Key data on the 2025 Myanmar earthquake was obtained from the United States Geological Survey [1] which recorded a magnitude of 7.7 Mw with a depth of 10 km in the Sagaing region, Myanmar. This information is complemented by records from the Thai Meteorological Department (TMD), which recorded a maximum ground acceleration of about 0.08 g and an IV–V shock intensity on the Modified Mercalli (MMI) scale in the Bangkok area. The data was used to verify that, despite the city of Bangkok being more than 600 km from the epicenter, its vibrations still have sufficient energy to cause resonance in tall buildings.

The literature review also focused on the geotechnical conditions of the Bangkok area, which was identified as having a water-saturated soft clay layer with a thickness of 15–30 meters and a shear wave velocity (Vs30) of less than 150 m/s. This condition has a significant influence on the local amplification of seismic waves and prolongs the duration of the shock. Research by Subedi et al. [3] and Ornthammarath et al. [2] confirming that soil layers with these characteristics can strengthen the amplitude up to twice the theoretical value. Meanwhile, the results of the Poovarodom and Jirasakjamroonsri studies [4] and Soralump et al. [10] suggests that soils in Bangkok tend to magnify long-term waves, which is a high risk for high-rise buildings with flexible structures.

Direct field observations were conducted in three main areas of Bangkok: Sathorn, Silom, and Chatuchak. These three areas were chosen because they represent the center of high density and the region that reported the strongest tremors after the 2025 Myanmar earthquake. Observations were conducted in June 2025 using a visual-descriptive approach to identify both structural and non-structural damage, including wall cracks, façade shifts, column deformation, and temporary element failures. The results of the observations showed that most of the damage was light to moderate, while total collapse occurred only in buildings that were still under construction, as was the case with the collapsed building in the Chatuchak District.

Field inspections were also conducted to assess the soil conditions in the affected area. Based on observations of foundation excavations, the soils in the Chatuchak and Silom regions exhibit very soft, plastic, and water-saturated properties, characterized by poor natural drainage. This condition is in accordance with the soil profile identified in the results of the microtremor survey and HVSR (Horizontal-to-Vertical Spectral Ratio) reported by Ornthammarath et al. [2]. These field findings support the hypothesis that soil amplification is the primary cause of the increase in local vibration intensity in Bangkok, rather than the unusually large influence of earthquake energy at the source.

Furthermore, it is carried out through a comparative approach between regional seismic events. This comparison involves data from the 2011 Tohoku Earthquake in Japan and the 2015 Nepal Earthquake, both of which elicit similar resonance phenomena in tall buildings in areas with soft soils [12, 13]. Analysis of the response spectrum revealed that the long-range waves from Myanmar had medium to long dominant periods, characterized by high energy content at low frequencies. This pattern is comparable to the Tohoku and Nepal earthquake spectrums, allowing it to be used as a basis for comparison to understand the mechanism of cross-boundary resonance in the Southeast Asian region.

3 Results

Observations show that most of the damage in Bangkok was light to moderate, affecting only non-structural elements, while total collapse occurred only in buildings that were still under construction (Figure 3).

During field observations, no severe damage was found to the high-rise buildings operating in Bangkok City (Figure 4). These field findings corroborate the TMD and USGS data, which indicate that the earthquake's intensity in Bangkok was moderate (Figure 1). However, soft soil resonance and temporary structural instability lead to increased local risks.

Fig. 3. The rest of the building ruins are still in the construction work stage.

In addition to observing building conditions, field observations were also conducted on the geotechnical environment surrounding the affected location. The Chatuchak and Silom regions exhibit characteristics of wet and plastic soils with poor drainage systems, thus strengthening the hypothesis of soil amplification due to

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seismic vibrations. This condition aligns with the findings of Subedi et al. [3] and Poovarodom et al. [4] which states that the water-saturated clay layer in the Chao Phraya Delta has a low shear wave velocity value (Vs30 < 150 m/s) and is therefore potentially capable of amplifying long-period waves. These results are also in line with seismic simulations by Ornthammarath et al. [5], which show an increase in local acceleration of up to 30–40% compared to the theoretical values listed in the 2023 Thailand Building Code, especially in areas with poor drainage and clay layer thicknesses exceeding 25 meters.

Bare clay soils with little sand or gravel content generally dominate the soil in the Bangkok City area. Based on the results of observations and sampling from excavations at a depth of tens of meters, the soil condition in the area is characterized by very wet conditions. The soil found is soft, deformable, and plastic when subjected to pressure or load (Fig. 5). This characteristic is characteristic of fine-grained soils with a fine consistency, such as water-saturated clay. These conditions show that the soil in Bangkok has a high potential for deformation and a decreased carrying capacity when loaded. In addition, high levels of softness and water saturation can strengthen the suspicion that there is an increase in site amplification in locations with soft soils, because seismic waves tend to be magnified when passing through weak and plastic soil layers.

a. Before Earthquake

b. After Earthquake

Fig. 4. Building damage in Bangkok City before (a) and after (b) the 2025 earthquake

Fig. 5. Soil from deep excavation in Bangkok City.

Comparative analysis is used to place the phenomenon of the impact of the Myanmar earthquake in Bangkok in a regional and global context. This analysis compares seismic parameters, geotechnical conditions, and structural characteristics between the Bangkok case and the events of the 2015 Nepal Earthquake and the 2011 Tohoku Earthquake [12]. The results of the comparison revealed a pattern of similarities, where long-range seismic waves exert significant resonance in high-rise buildings in large cities located in soft soil layers, despite being hundreds of kilometers away from the epicenter.

Meanwhile, based on discussions with several researchers at the Asian Institute of Technology (AIT),

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the earthquake that occurred in Myanmar is suspected to have the characteristics of seismic waves with a relatively long dominant period. This characteristic suggests that the vibrational energy of earthquakes is more concentrated at low frequencies, causing ground movement to occur more slowly but with greater amplitudes. These types of waves have significant implications for the dynamic response of modern buildings, especially those designed with flexible structural systems to mitigate seismic forces through deformation and lateral displacement mechanisms.

In the context of seismic engineering, modern buildings, such as tall buildings, bridges, and towers, are generally designed to have relatively long periods of natural tremors (Fig. 6). When there is a similarity between the natural period of the structure and the dominant period of the earthquake wave (resonance phenomenon), seismic energy will accumulate in the structural system, so that the amplitude of the oscillation increases significantly. As a result, while the inertial force may not be as large as that of a high-frequency earthquake, its lateral displacement can be enormous and potentially cause severe damage to both structural and non-structural elements.

This phenomenon suggests that the characteristics of Myanmar's earthquake response spectrum tend to have high energy content in the medium to long-term time frames, which is detrimental to buildings with modern multi-storey designs.

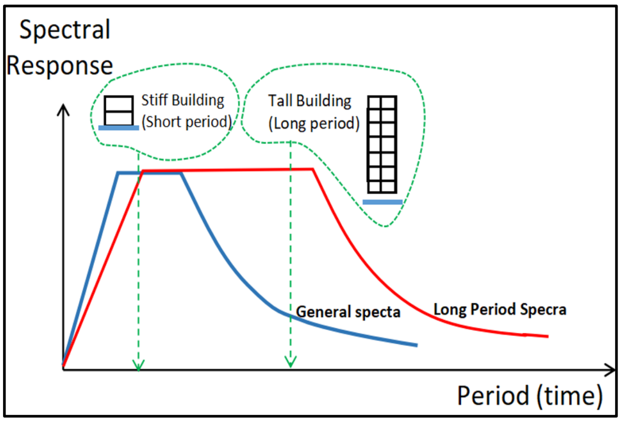

Fig. 6. Long and short response spectrum

Thus, the analysis of the structural response to earthquakes over the long term is an important aspect that needs to be evaluated in the context of building resilience in the Southeast Asian region, including areas with soft soil conditions, such as Bangkok, where vibration amplification can further exacerbate the resonance effects that occur.

Validation is carried out by cross-checking the results of field observations and official literature data. Soil acceleration values recorded by the Thai Meteorological Department (TMD) compared to data from the United States Geological Survey [1] to ensure the suitability of earthquake parameters and characteristics of seismic sources. In addition, the chronology of the collapse of the buildings in Chatuchak was verified through official reports of the Thai Ministry of Public Works and Transport (DPT) as well as international media documentation [7-9], which provides visual evidence and witness statements related to the collapse of the multi-storey structure. This validation process ensures that the analysis does not rely solely on a single source but has been confirmed by various independent parties.

4 Conclusion

Based on this study, it is evident that the geotechnical conditions of the city of Bangkok, which are characterized by soft clay layers 15–30 meters thick, significantly affect the amplitude of seismic vibrations. The water-saturated and plastic nature of the soil causes a local amplification effect on long-range earthquake waves, so even though Bangkok is about 600 km away from the epicenter of Myanmar's 2025 earthquake, the vibrations are still quite strong on the surface.

The results of the observations showed that most of the damage was minor and occurred in non-structural elements. In contrast, the collapse of buildings in the Chatuchak District was caused by unstable structural conditions during the construction phase, rather than by the force of a major earthquake. The spectra of earthquakes that are suspected to have long periods reinforce this.

The Myanmar earthquake has a long dominant period with energy at low frequencies. This characteristic is especially hazardous for tall, flexible buildings, as it can generate resonance when the natural period of the structure aligns with the period of earthquake waves, thereby increasing lateral displacement and the risk of damage.

The combination of soft soil, which magnifies vibrations, and buildings with long periods of vibration in Bangkok created dual resonance conditions, amplifying the seismic response of the structure. This phenomenon explains why cities with delta land, such as Bangkok, can experience significant impacts despite being far from the epicenter.

A comparative analysis with the case of the Asian Earthquake reveals that similar cross-border impacts also occur in the Asian region, characterized by comparable geological and vertical development features. This suggests that resonance due to long-period waves is a common challenge in the Southeast Asian region.

Overall, the study confirms the need for an evaluation of seismic designs to consider the impact of long-period waves, especially in regions with soft soils. Improving structural design standards and dynamic response analysis is a crucial step in enhancing the resilience of buildings to future long-range earthquakes.

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Reference

1. United States Geological Survey (USGS), M 7.7 – 2025 Mandalay, Burma (Myanmar) Earthquake, Mar. (2025). [Online]. Available: https://earthquake.usgs.gov/earthquakes/eventpage/us7000pn9s/executive
2. T. Ornthammarath et al., Preliminary analysis of amplified ground motion in Bangkok Basin using HVSR curves from recent moderate-to-large earthquakes, Geoenvironmental Disasters, **10**(28), (2023). https://doi.org/10.1186/s40677-023-00259-0
3. B. Subedi, J. Kiyono, A. Furukawa, and P. Latcharote, Estimation of ground profiles based on microtremor survey in the Bangkok Basin. Earthquake Science. **34**(4), 403–417 (2021). https://doi.org/10.3389/fbuil.2021.651902
4. N. Poovarodom and A. Jirasakjamroonsri, Seismic site effects of soil amplifications in Bangkok. Science & Technology Asia. **21**(3), 59–69 (2016). [Online]. Available: https://ph02.tci-thaijo.org/index.php/SciTechAsia/article/download/67196/54822/157250
5. T. Ornthammarath, P. Warnitchai, Y. Maruyama, and others, Far-field ground-motion characteristics of the Bangkok Basin, Thailand, in the 2025 Mw 7.7 Mandalay earthquake: Initial insights. Bulletin of Earthquake Engineering, (2025). https://doi.org/10.1007/s10518-025-02295-7
6. A. S. M. F. Hossain and P. Anbazhagan, A review of parameters and methods for seismic site response analysis. Geosciences (Basel). **15**(4), 128 (2025). https://doi.org/10.3390/geosciences15040128
7. Reuters, Thai watchdog had flagged concerns over building that collapsed in earthquake, Mar. 2025. [Online]. Available: https://www.reuters.com/world/asia-pacific/thai-watchdog-had-flagged-concerns-building-that-collapsed-earthquake-2025-03-31/
8. Reuters, Thai construction tycoon and 14 others surrender to police over fatal Bangkok tower collapse, May 2025. [Online]. Available: https://www.reuters.com/world/asia-pacific/thai-construction-tycoon-14-others-surrender-police-over-fatal-bangkok-tower-2025-05-16/
9. AP News, Bangkok officials end search operation at the skyscraper that collapsed following an earthquake, Jun. 2025. [Online]. Available: https://apnews.com/article/f697b0d506f6a531f2ff5d83f9362438
10. S. Soralump, K. Panthi, P. Nuannin, and T. Ornthammarath, Seismic damage of high-rise buildings in Bangkok caused by soft-soil amplification from Mw 6.4 Laos earthquake. Earthquake and Structures. **28**(6), 469–477 (2024). https://www.technopress.org/content/?journal=eas&num=6&ordernum=3&page=article&volume=28&utm_source
11. T. Ornthammarath et al., Probabilistic seismic hazard assessments for Northern Southeast Asia (Indochina): Smooth seismicity approach. Earthquake Spectra. **36**(1), 69–90 (2020). https://doi.org/10.1177/8755293020931866
12. D. M. Boore and J. Boatwright, Ground motion from distant earthquakes. Bulletin of the Seismological Society of America. **110**(3), 1154–1169 (2020). https://doi.org/10.1785/0120190215
13. T. Furumura, Y. Yamanaka, and T. Maeda, An early forecast of long-period ground motions of large earthquakes. Geophys Res Lett. **50**(4), e2022GL101774 (2023). https://doi.org/10.1029/2022GL101774