# GROUND MOTION AND SITE AMPLIFICATION CHARACTERISTICS OF THE 28 MARCH 2025 EARTHQUAKE RECORDED BY A LOW-COST SEISMIC NETWORK

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## 1. INTRODUCTION

The assessment of earthquake ground motion and site response is crucial for understanding seismic hazard and reducing earthquake risk, particularly in urban areas underlain by soft sedimentary basins. The Chiang Mai Basin in northern Thailand is a seismically active area influenced by nearby active faults such as the Mae Tha Fault, Mae Chan Fault, and the Thoen Fault Zone. Although the region experiences frequent small to moderate magnitude earthquakes, instrumental data remains limited due to sparse coverage by national seismic networks.

To address this gap, a low-cost strong motion network was developed since 2021 and deployed in 2023 as part of an ongoing structural health monitoring and earthquake engineering research program. The network's affordability and ease of deployment allow for denser coverage, providing valuable data for ground motion analysis and site characterization. The 28 March 2025 earthquake offered the first opportunity to analyze a significant event recorded by this network, enabling an integrated study of ground motion characteristics, site amplification, and the reliability of low-cost sensors.

## 2. STUDY AREA

Thailand has been perceived to be a low to moderate seismic hazard zone. Several small- and medium-sized earthquakes from active faults in the northern and western regions of the country and the neighboring countries have been frequently recorded. From PSHA study (Ornthammarath et al., 2010, Pailoplee and Charusiri, 2016), Thailand's highest seismic hazard areas are located near faults in northern and western Thailand. Chiang Mai city is situated on Chiang Mai Basin, with a maximum width of about 35 km and a north-south length of 140 km surrounded by eastern and western mountain range.

The investigated area is located within latitudes 18° 15' N to 19° 15' N and longitudes 98° 37' E to 99° 12' E, covering the central part of Chiang Mai province. The investigation point of 205 sites were observed in this study area as shown in Figure 1. The area lies on a large flood plain of Ping River, which runs southward. The subsoils of most sites are classified as Alluvium deposits (Qa) and some sites near the study boundary are located on Colluvial deposits (Qc).

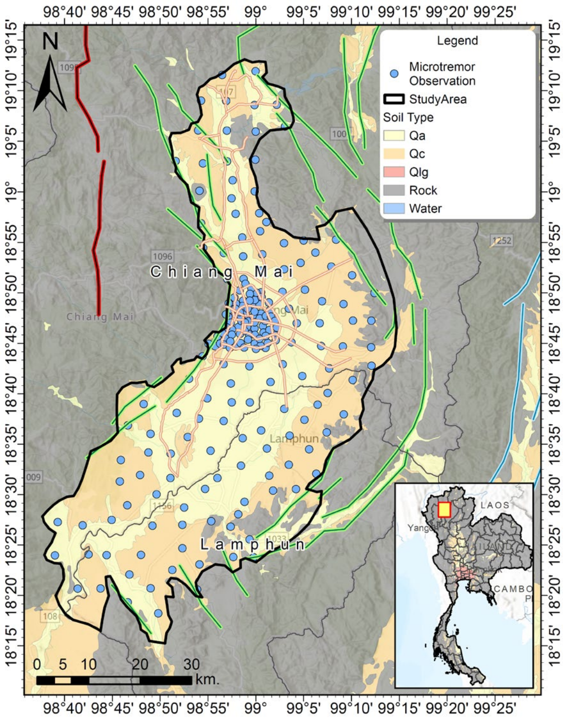


Figure 1. Study area

## 3. ARRAY MICROTREMOR AND INVERSION ANALYSIS

The Centerless Circular Array (CCA) method (Cho et al., 2006) was applied to estimate subsurface shear-wave velocity profiles. This technique uses vertical component microtremor records from sensors deployed in a circular array to derive phase velocities via spectral ratio representations. The ratio of power spectral densities, expressed using Bessel functions of the first kind, is fitted to theoretical models to obtain wavenumber and phase velocity, accounting for noise-to-signal ratio correction.

Shear-wave velocity (Vs) profiles from the surface to basement rock were obtained by inverting the observed dispersion curves against theoretical models of horizontally layered media. The inversion employed a combination of the Downhill Simplex Method with Very Fast Simulated Annealing (Yokoi, 2005) and the Neighbourhood Algorithm (Wathelet, 2008), selecting solutions with minimal misfit to reduce non-uniqueness.

The results of bedrock depth estimated from inversion analysis and average shear-wave velocity for the first 30 meters (Vs30) are shown in Figure 2 and Figure 3, respectively. The maximum depth of the Chiang Mai Basin is approximately 600 m at its center. The Vs30 values for most areas range between 200–350 m/s, which corresponds to soil class D according to standard site classification.

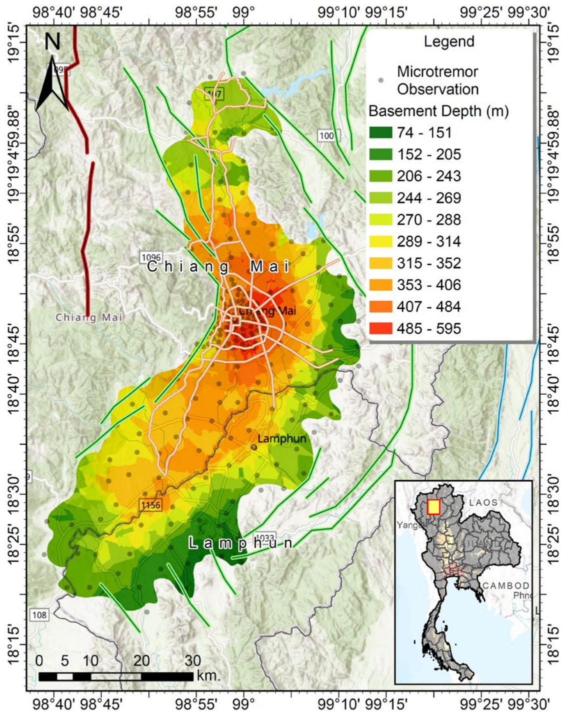


Figure 2. Map of bedrock depth

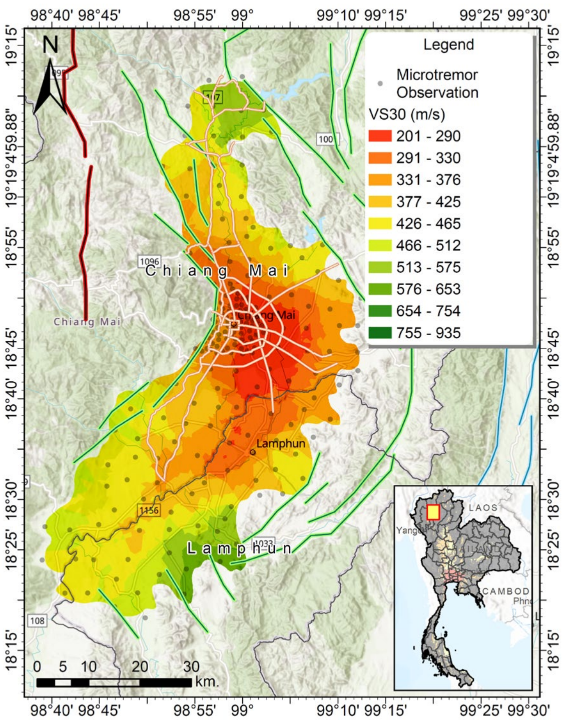


Figure 3. Map of Vs30

## 4. LOW-COST SEISMIC NETWORK

The low-cost seismic network, named as "TUSHM" comprises triaxial MEMS accelerometers (ADXL355), connected to Raspberry Pi data loggers with Network Time Protocol (NTP) for time synchronization and continuous recording capability. The sampling rate is 125 Hz, and data are stored locally while also being uploaded to a central server via Ethernet or Wi-Fi.

Calibration tests, conducted using a high-performance reference sensor, confirmed that the low-cost units can accurately capture earthquake motions up to at least ±2 g with low self-noise, making them suitable for both strong and moderate events.

During the 28 March 2025 earthquake, 10 stations successfully recorded the entire event, providing high-quality acceleration time histories for subsequent analysis. However, a few stations failed to capture the earthquake due to electricity outages and temporary internet disruptions, highlighting the need for enhanced backup power capacity and redundant communication systems in future deployments.

## 5. RECORDED GROUND MOTION

The 28 March 2025 earthquake (Mw 7.7, depth 10 km) occurred at Sagaing, Sagain, Burma (Myanmar), approximately 480 km from Chiang Mai city. The distribution of the low-cost seismic network within the Chiang Mai Basin is shown in Figure 4. In this network, station ST1 is located on a mountain site, stations ST2 and ST3 are situated near rock sites, while the remaining stations are located within the basin on soft alluvial deposits.

The network recorded ground motions at 10 stations, with peak ground accelerations (PGA) ranging from 0.02 g at rock sites to 0.05 g at soft-soil sites within the basin. Acceleration time histories show notable amplification and waveform elongation at stations within the basin compared to rock sites, as illustrated in Figure 5. Acceleration response spectra indicate that soft-soil stations experienced significant amplifications in the 1–5 second period range, while rock-site stations amplified primarily in the less than 1 second period range, as shown in Figure 6.

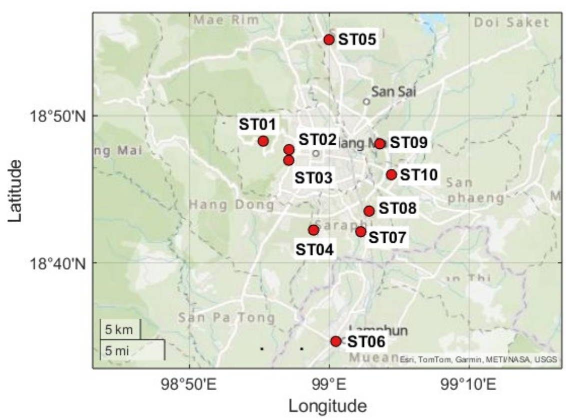


Figure 4. Location of Low-Cost Seismic Network

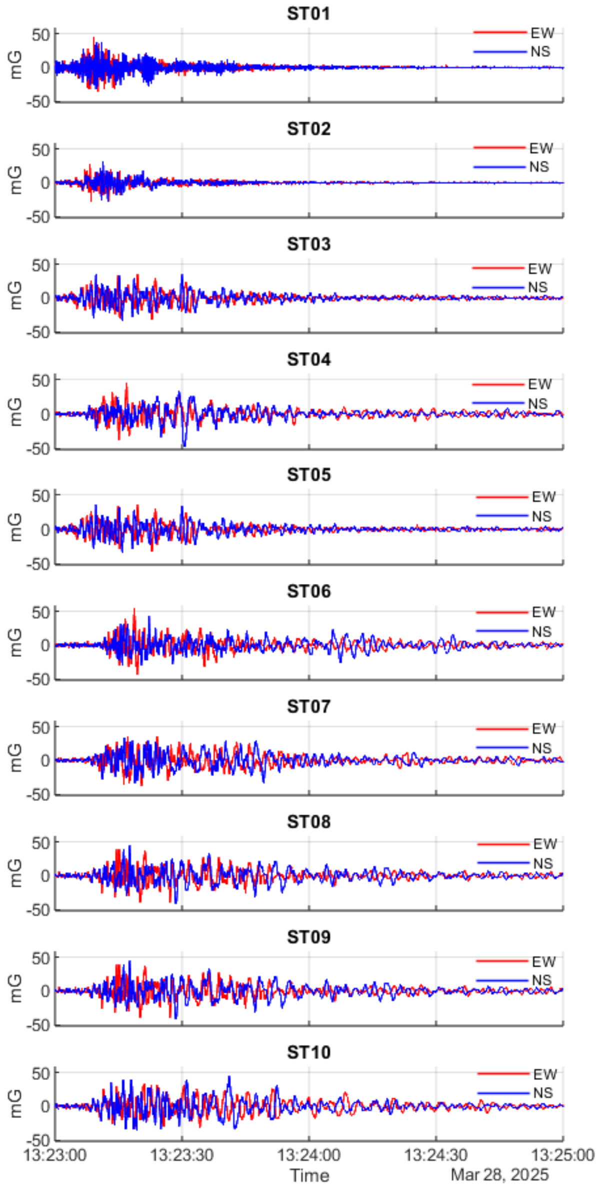


Figure 5. Acceleration Time History in N-S direction

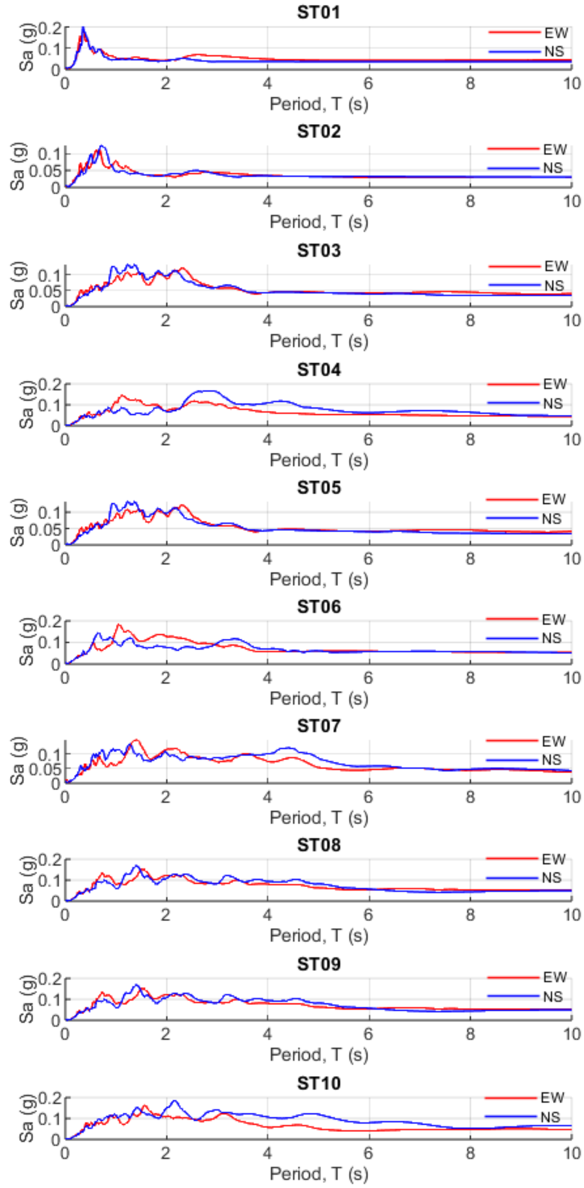


Figure 6. Acceleration Response Spectra

## 6. 1D EQUIVALENT LINEAR (EQL) SITE RESPONSE ANALYSIS

In order to evaluate seismic site effects, ground response analysis at each site was performed by propagating ground motions recorded at a station located near a rock site in Chiang Mai through soil models defined by the measured shear-wave velocity (Vs) profiles. Since the dynamic soil properties in this study area are limited to the equivalent linear approach, therefore the equivalent linear analysis is only applied in this study. In the equivalent linear analysis procedures, the 1-dimensional soil columns were modeled as a series of homogeneous, viscoelastic, infinite horizontal layers using the observed Vs profiles. The subsoil layers were subjected to vertically incident shear waves.

The nonlinearity of shear modulus and damping ratio was incorporated using equivalent-linear soil properties compatible with the effective strain in each layer. Average relationships between dynamic shear modulus and damping ratio as functions of shear strain and soil type were applied based on established laboratory data.

The study is limited by available dynamic soil property data, with surveys reaching depths of approximately 30 meters. Plasticity Index (PI) values for local soils are generally in the range of 15–20. Based on these parameters, it is assumed that soil stiffness increases with depth, consistent with the measured Vs ranges summarized in Table 1.

Table 1. Dynamic soil properties used in this study

| Shear Wave Velocity, Vs (m/s) | Dynamic soil properties | Reference |
|---|---|---|
| Less than 500 | Soil PI = 15 | Vucetic and Dobry (1991) |
| 500 < Vs < 1500 | Soil PI = 0 | Vucetic and Dobry (1991) |
| Vs > 1500 | Sand | Seed and Idriss (1970) |
| Basement | Rock | Schnabel (1973) |

The analysis used the recorded ground motion at the rock site as the input motion at the base of each soil model. The calculated surface response spectra from the EQL analysis were then compared with the corresponding recordings from the low-cost seismic stations. The results show good agreement for sites located near stiff-soil or rock conditions as shown in Figure 7, indicating that the simplified 1D EQL model adequately represents their site response. However, noticeable differences were observed for stations located on soft alluvial deposits, particularly in the long-period range as shown in Figure 8, suggesting the influence of basin geometry and 2D/3D wave propagation effects.

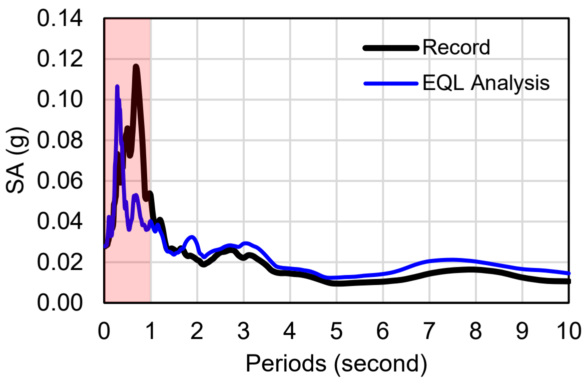


Figure 7. Comparison of SA for stiff soil site

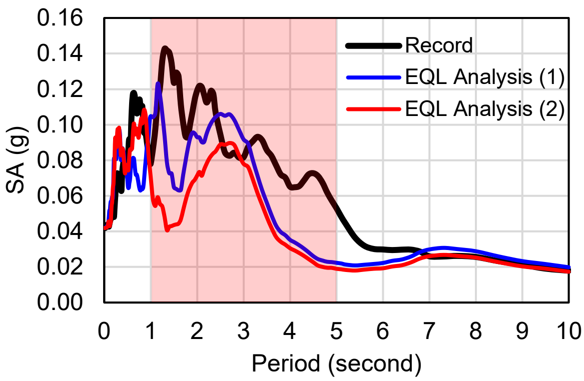


Figure 8. Comparison of SA for soft soil site

## 7. ONGOING WORKS

The current research is continuing in two main directions:

- Expansion of the Low-Cost Seismic Network

The network is being expanded to cover more seismically active areas, with particular emphasis on the northern part of Thailand where earthquake hazards are highest. Additional stations are being deployed to improve spatial coverage, enabling more accurate mapping of ground motion patterns and enhancing regional earthquake monitoring capabilities.

- Advanced Site Response Analysis Considering Basin Geometry

Site response studies are underway to incorporate basin shape effects using 2D and 3D soil models. Numerical simulations are being performed to better capture complex wave propagation, focusing on edge-generated surface waves and three-dimensional resonance effects. This approach aims to provide a more realistic assessment of seismic amplification within the Chiang Mai Basin and other similar geological settings.

## 8. CONCLUSIONS

The 28 March 2025 earthquake provided valuable data for assessing the performance of a low-cost seismic network and for characterizing site amplification in the Chiang Mai Basin. The combined use of microtremor array inversion, strong motion records, and equivalent-linear site response analysis confirms the significant role of basin effects in amplifying seismic waves. In particular, the observed differences between simulated and recorded responses at soft alluvial sites suggest that the three-dimensional geometry of the Chiang Mai Basin influences long-period ground motions, likely through edge-generated surface waves and basin resonance.

The results highlight the potential of low-cost seismic networks for improving earthquake resilience in regions with limited instrumentation, while also emphasizing the need to incorporate basin shape effects in advanced site response modeling to achieve more accurate seismic hazard assessments.

## 9. REFERENCE


[1] Cho I., Tada T., and Shinozaki Y. (2006). Centerless circular array method: Inferring phase velocities of Rayleigh wave in broad wavelength range using microtremor records. Journal of Geophysical Research, 111: B09315.

[2] Ornthammarath T., Warnitchai P. (2014). Action plan for earthquake disaster prevention and mitigation in Bangkok. Report submitted to Bangkok Metropolitan Administration.

[3] Pailoplee S. and Charusiri P. (2016). Seismic hazards in Thailand: a compilation and updated probabilistic analysis. Planets and Space, 68(98), DOI 10.1186/s40623-016-0465-6.

[4] Seed H.B., Romo M.P., Sun J.I., Jaime A., and Lysmer J. (1987). Relationships Between Soil Conditions and Earthquake Ground Motions in Mexico City in the Earthquake of September 19, 1985. Earthquake Engineering Research Center, Report No. UCB/EERC-87/15

[5] Vucetic M., and Dobry R. (1991). Effect of Soil Plasticity on Cyclic Response. Journal of Geotechnical Engineering, 117: 89-107.

[6] Wathelet M. (2008). An improved neighborhood algorithm: parameter conditions and dynamic scaling. Geophysical Research Letters, 35, L09301, DOI 10.1029/2008GL033256.

[7] Yokoi T. (2005). Combination of down hill simplex algorithm with very fast simulated annealing method-an effective cooling schedule for inversion of surface wave's dispersion curve. Proc. of the Fall Meeting of Seismological Society of Japan, B049.