

# GEOTECHNICAL HAZARDS IN MYANMAR

## Lessons from the 2025 Mw 7.7 Mandalay Earthquake

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From observed ground failure to resilient ASEAN practice

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# Presentation Objectives

01

**Understand** Myanmar's tectonic and geomorphologic setting.

02

**Recognize** The principal geotechnical hazards observed after the 2025 earthquake.

03

**Connect** Ground failure mechanisms with foundation and infrastructure performance.

04

**Apply** Practical resilience measures for site investigation, design and response.

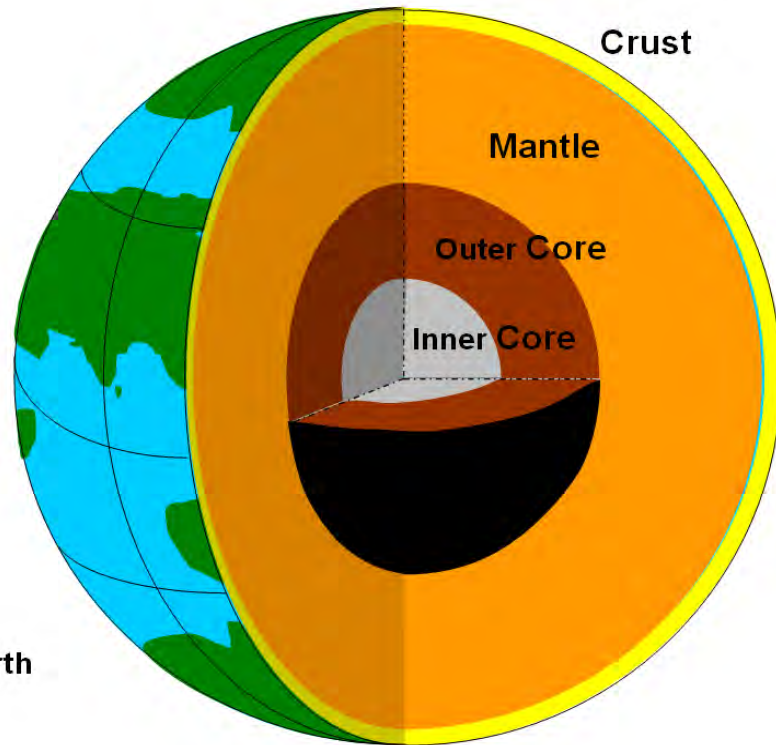
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**Collaborate** Identify ASEAN opportunities for data, standards and capacity sharing.

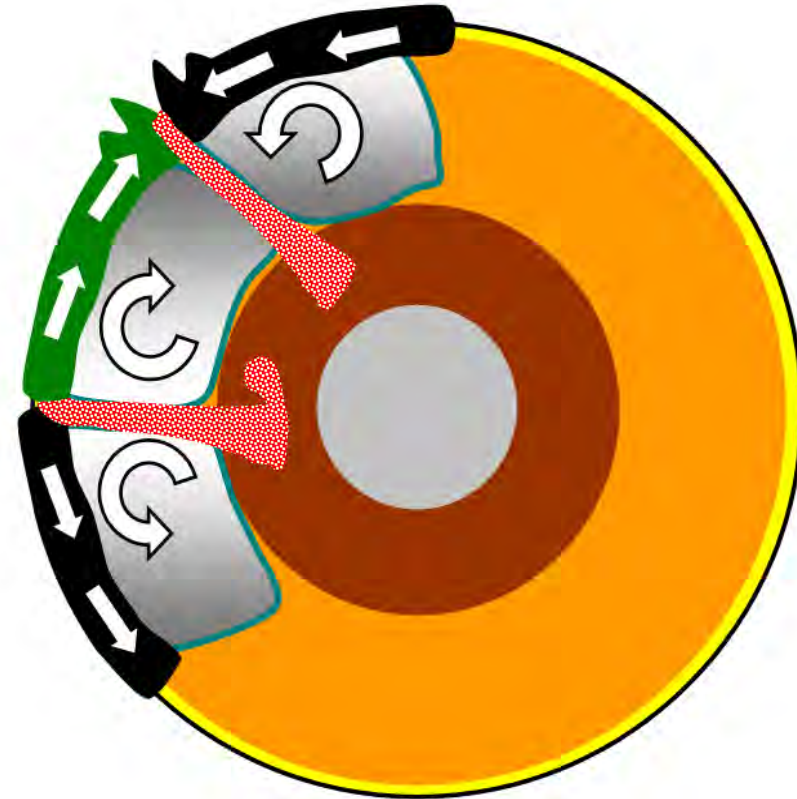
# 1. Introduction & Tectonic Context

## *The Tectonic Threat Along the Sagaing Fault System*

- **Active Strike-Slip System:** The Sagaing Fault accommodates major northward motion of the Indian Plate relative to the Eurasian Plate.
- **The 2025 Mandalay Earthquake:** Provided direct empirical ground motion data testing urban engineering infrastructure.
- **Vulnerable Geology:** Saturated alluvial deposits and highly variable shallow groundwater tables amplify local shaking amplitudes.
- **Implication for Geotechnical Design:** High susceptibility to sudden dynamic shear strength degradation during strong seismic shaking.



Inside the Earth



African , Eurasian, Nazca, Pacific, Indo Australian, American, Antarctic

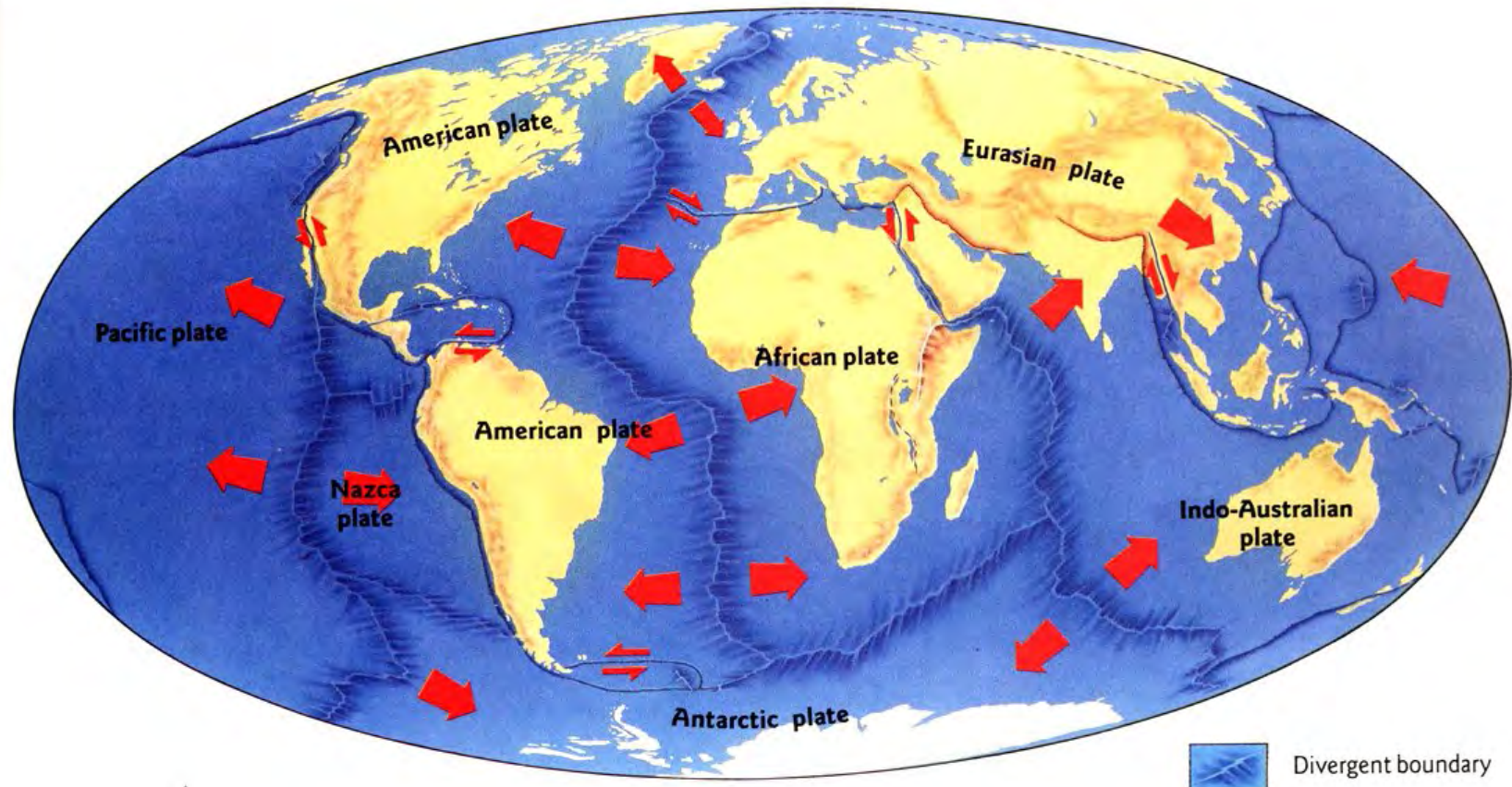
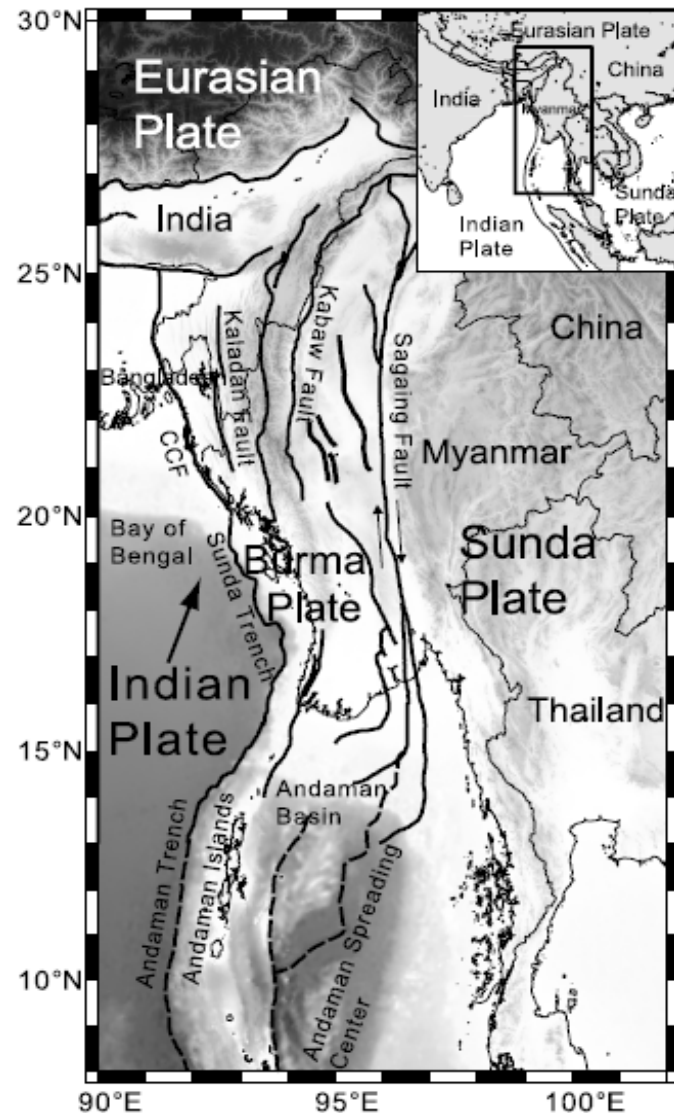


*Figure 3*  
**Major Tectonic Plates on the Earth's surface**

# Myanmar's tectonic setting



## Three interacting tectonic domains

- Indian Plate: northward convergence / underthrusting
- Burma microplate: central Myanmar lowlands
- Sunda Plate / Shan–Thai block: eastern Myanmar

## Geotechnical implication

Tectonics + young alluvial deposits + groundwater create spatially variable seismic ground response.

## The Three Tectonic Blocks

Myanmar sits directly at the high-stakes junction of three distinct tectonic plates:

- The Indian Plate:** Moving northward, underthrusting the western edge of the country.
- The Burma Microplate:** A sliver of crust sandwiched between the major plates, hosting Myanmar's central lowlands.
- The Sunda Plate:** The stable continental block forming the eastern portion of the country (Shan Plateau) and broader Southeast Asia.

## 1. The Indo-Burman Range (the Western Arc)

An accretionary wedge formed by the subduction of the Indian Plate. This region features high, rugged mountain terrain that includes the Chin and Naga Hills.

The landscape is composed of highly folded, faulted sedimentary rocks and fragments of ophiolite, which is ancient oceanic crust. It is separated from the Indian plate by the Indo-Burman subduction zone, also called the Rakhine-Bangladesh megathrust. This tectonic border forms a hyper-oblique zone that accommodates major underthrusting.

## 2. The Myanmar Central Belt (Central Lowlands)

A series of Cenozoic forearc and backarc sedimentary basins.

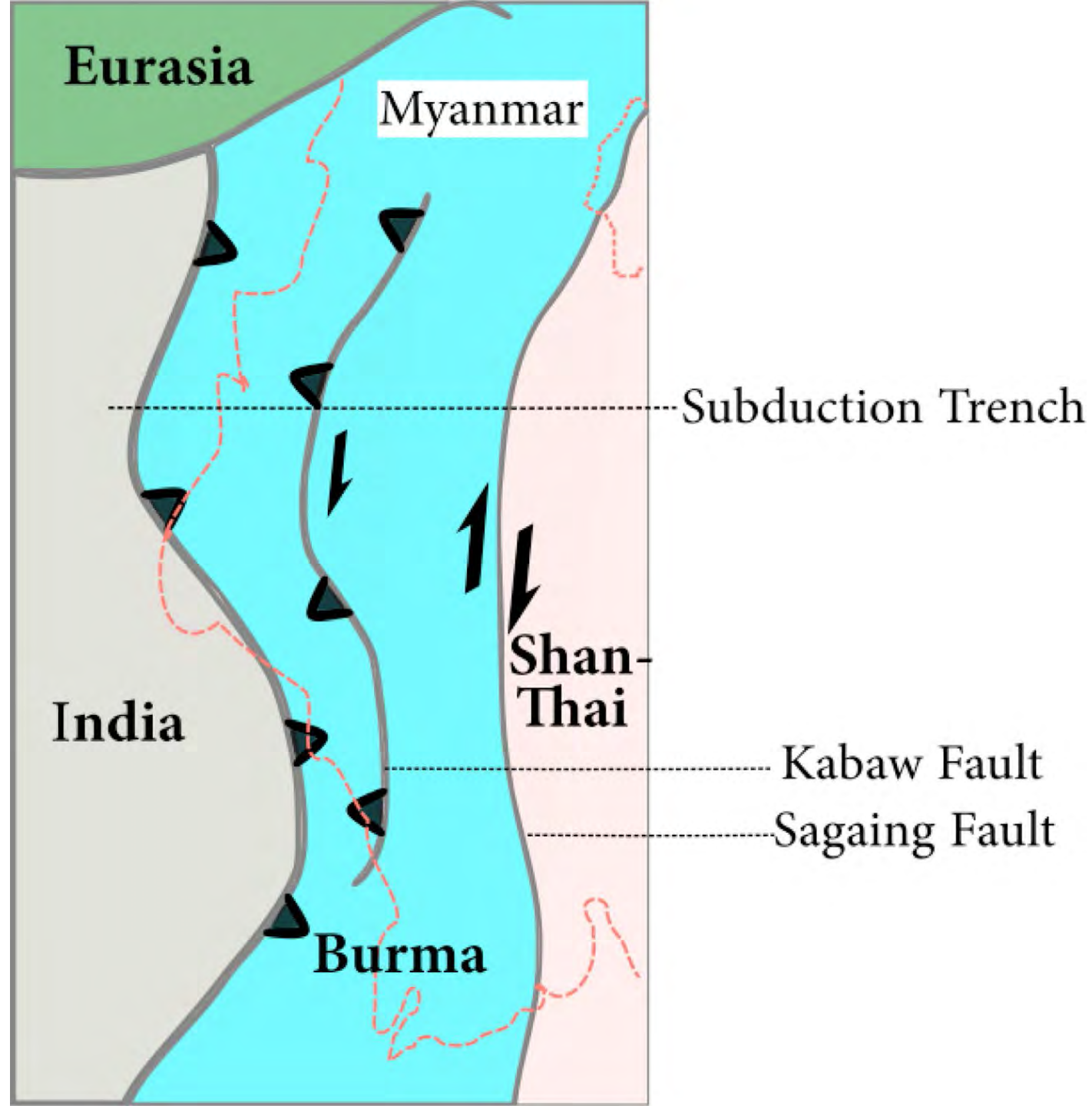
**Characteristics:** Dominated by the Irrawaddy and Chindwin river valleys. This zone contains Myanmar's vast **petroleum basins** and rich Cenozoic fossil records.

**Volcanic Arc:** Features an extinct-to-dormant volcanic line (e.g., Mount Popa, Monywa) down the center, born from historical subduction.

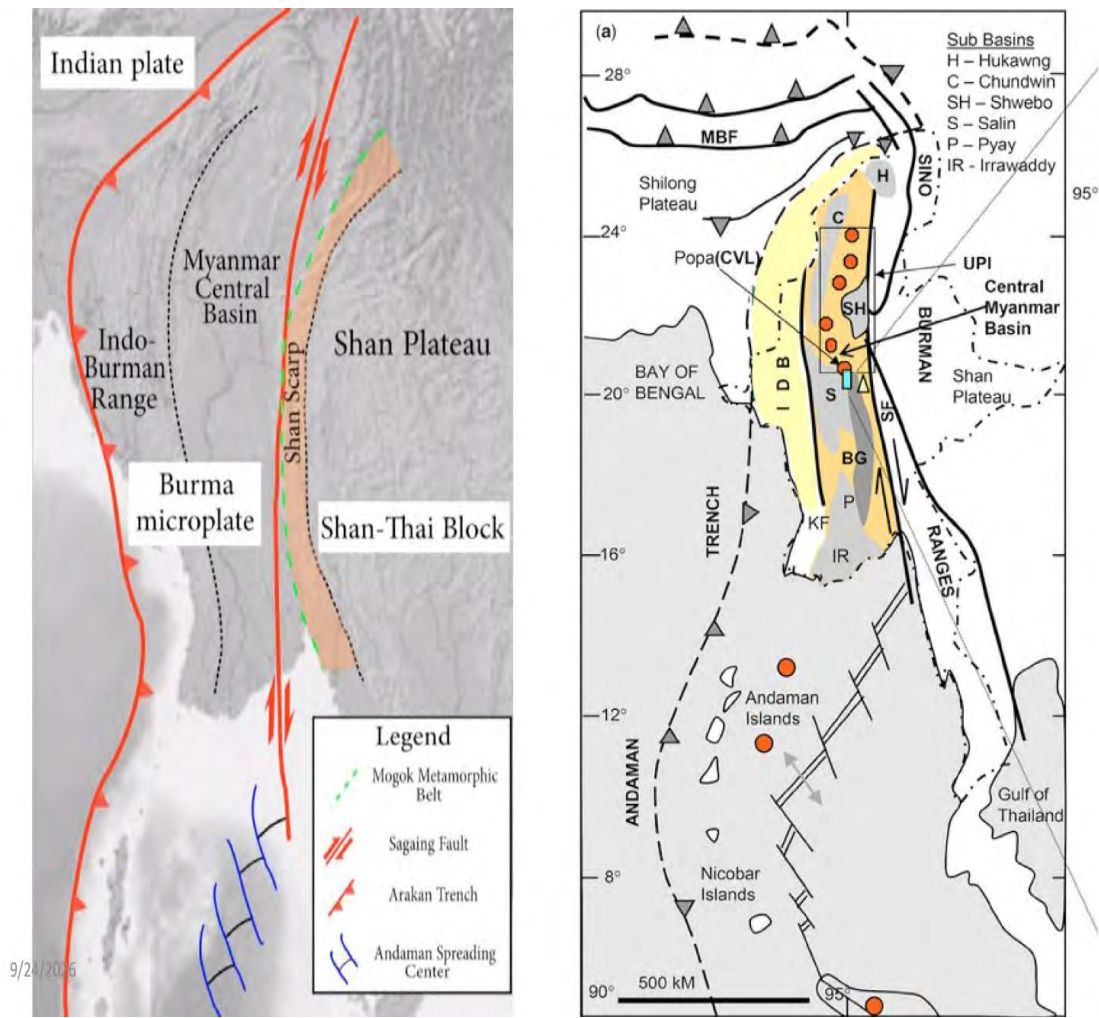
## 3. The Shan Plateau (Eastern Block)

The western highland margin of the **Sunda Plate**.

**Characteristics:** Elevated limestone plateau featuring heavily deformed Paleozoic and Mesozoic rocks. It is rich in metallic mineral resources, including the world-famous Mogok metamorphic zone (rubies, sapphires, and jadeite).



# Sagaing Fault: a long-lived seismic source



## Selected damaging earthquakes in the source record

|      |                    |        |
|------|--------------------|--------|
| 1930 | Bago               | M 7.3  |
| 1956 | Sagaing            | M 7.0  |
| 1975 | Bagan              | M 6.8  |
| 1991 | Tagaung            | M 7.1  |
| 2012 | Thabeikkyin        | M 7.0  |
| 2025 | Sagaing / Mandalay | Mw 7.7 |

The 2025 event renewed the need to treat seismic ground failure as a design-level geotechnical issue.

Significant earthquakes in Myanmar (1988–2025), including magnitude, depth, and reported casualties.

| Date       | Location   | Mag.   | Depth (km) | Deaths | Injuries | Refs.                        |
|------------|------------|--------|------------|--------|----------|------------------------------|
| 3/28/2025  | Sagaing    | 7.7 Mw | 10         | 4390+  | 5450+    | (Le Monde, 2025)             |
| 6/7/2023   | Ayeyarwady | 4.8 mb | 10         | 3      | –        | (People's Spring, 2023)      |
| 5/31/2023  | Mohnyin    | 5.9 Mw | 10         | –      | –        | (Center, N.E.I., 2023)       |
| 7/21/2022  | Kengtung   | 5.9 Mw | 5          | –      | –        | (USGS, 2025)                 |
| 11/26/2021 | Hakha      | 6.2 Mw | 42.5       | –      | –        | (USGS, 2021)                 |
| 1/11/2018  | Bago       | 6.0 Mw | 9          | –      | –        | (USGS, 2018)                 |
| 3/13/2017  | Yangon     | 5.1 mb | 10         | 2      | 36       | (USGS (M 5.1 –34 km) 2025)   |
| 11/11/2012 | Sagaing    | 6.8 Mw | 9.8        | 26     | –        | (USGS (M6.8 Burma) 2012)     |
| 2/4/2011   | Monywa     | 6.4 Mw | 85         | 1      | –        | (WorldData, 2025)            |
| 12/25/2007 | Kachin     | 4.8 Mw | 35         | –      | 19       | (USGS (M 4.8 –46 km) 2025)   |
| 7/11/1995  | Shan       | 6.8 Mw | 12.5       | 11     | –        | (USGS (M 6.8 – Myanmar))     |
| 1/5/1991   | Sagaing    | 7.0 Mw | 19.7       | 2      | –        | (USGS (M7.0 - Myanmar) 2025) |
| 11/6/1988  | Shan       | 7.7 Mw | 17.8       | 470    | 7289     | (USGS (M7.7 - Myanmar) 2025) |
| 8/6/1988   | Sagaing    | 7.3 Mw | 98.1       | 3      | 30       | (USGS (M7.3 - Myanmar) 2025) |

Source : Journal of Dynamic Disasters 1 (2025) 100017

## 2. Observed Geotechnical Hazards

### *Widespread Ground Failures Across Mandalay Region*

- Soil Liquefaction: Saturated alluvial soils experienced complete loss of effective stress, leading to widespread sand boils.
- Lateral Spreading: Massive lateral soil displacement observed along the banks of the Ayeyarwady River, ripping apart quay structures.
- Ground Fissures & Cracks: Linear ruptures sliced through secondary road networks and agricultural plains.
- Localized Slope Failures: Significant instability triggered along highly weathered natural ridges and engineered fill slopes.

# Why this case matters to ASEAN

**The 2025 Mandalay earthquake was not only a seismic event.  
It was a large-scale field experiment in ground–structure interaction.**



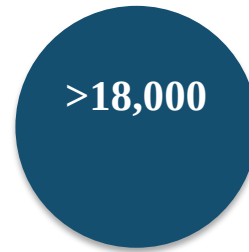
**Mainshock**

28 March 2025



**Surface rupture**

Sagaing Fault



**Mapped  
liquefaction sites**

Regional inventory



**Regional lesson**

Ground hazards  
cross borders

**The engineering lesson: understand the ground before designing the structure.**

# The 28 March 2025 earthquake — in numbers

**Mw 7.7**

Magnitude

**10 km**

Hypocentral depth

**~475 km**

Mapped rupture

**>80 s**

Rupture duration

**5.6 m**

Maximum surface slip

## The Catastrophic 2025 Mandalay/Sagaing Earthquake

On **March 28, 2025**, central Myanmar was struck by a massive **M<sub>w</sub> 7.7 earthquake** centered just 16 kilometers northwest of Sagaing (near Mandalay).

•**The Mechanism:** The earthquake originated at a shallow depth of 10 km. It was a highly unusual **supershear rupture**, where the crack ripped along the fault line faster than the speed of seismic shear waves.

•**The Impact:** The rupture extended over a massive ~470 km stretch, tearing through the "Meiktila seismic gap"—a segment that hadn't seen a major event since 1839.

•**The Damage:** It stands as one of the deadliest earthquakes in modern Southeast Asian history. The disaster resulted in over **3,400 to 3,800 fatalities**, displaced more than 200,000 people, and caused widespread collapse of infrastructure across Mandalay, Sagaing, and Naypyitaw. Tremors were violent enough to cause a high-rise building under construction to collapse in **Bangkok, Thailand**, nearly 800 km.

9/24/2026

## What changed our geotechnical understanding?

- Very long rupture increased the spatial footprint of strong shaking.
- Supershear rupture was documented in the event.
- Ground failure occurred in both fault-proximal and fluvial settings.

# From earthquake to geotechnical disaster



**Engineering principle: seismic resilience starts with the soil profile, groundwater condition and failure mechanism — not only the superstructure.**

# Hazard 1 — Liquefaction and sand boils

## Mechanism

Unsaturated / surficial soil

Loose saturated sand  
 $\Delta u \uparrow \rightarrow \sigma' \downarrow \rightarrow \text{shear strength} \downarrow$   
↑ ↑ ↑

Shallow groundwater / aquifer

Sand + water ejected as sand boils

## What we observed / need to check

- Loose, saturated alluvial or fluvial deposits are susceptible.
- Cyclic shaking raises pore-water pressure and reduces effective stress.
- Manifestations include sand boils, ejecta, fissures, settlement and tilting.
- Groundwater level and geomorphology are critical site variables.

# Liquefaction was regional — not isolated

**>18,000**

liquefaction sites mapped

**>80,000 km<sup>2</sup>**

mapped study area

**>95%**

of sites within 20 km of rupture

## Key spatial controls

1

### Holocene fluvial deposits

Floodplains, meanders and paleochannels can host susceptible loose sediments.

2

### Rivers & groundwater

Irrawaddy and Sittang valleys showed high concentrations.

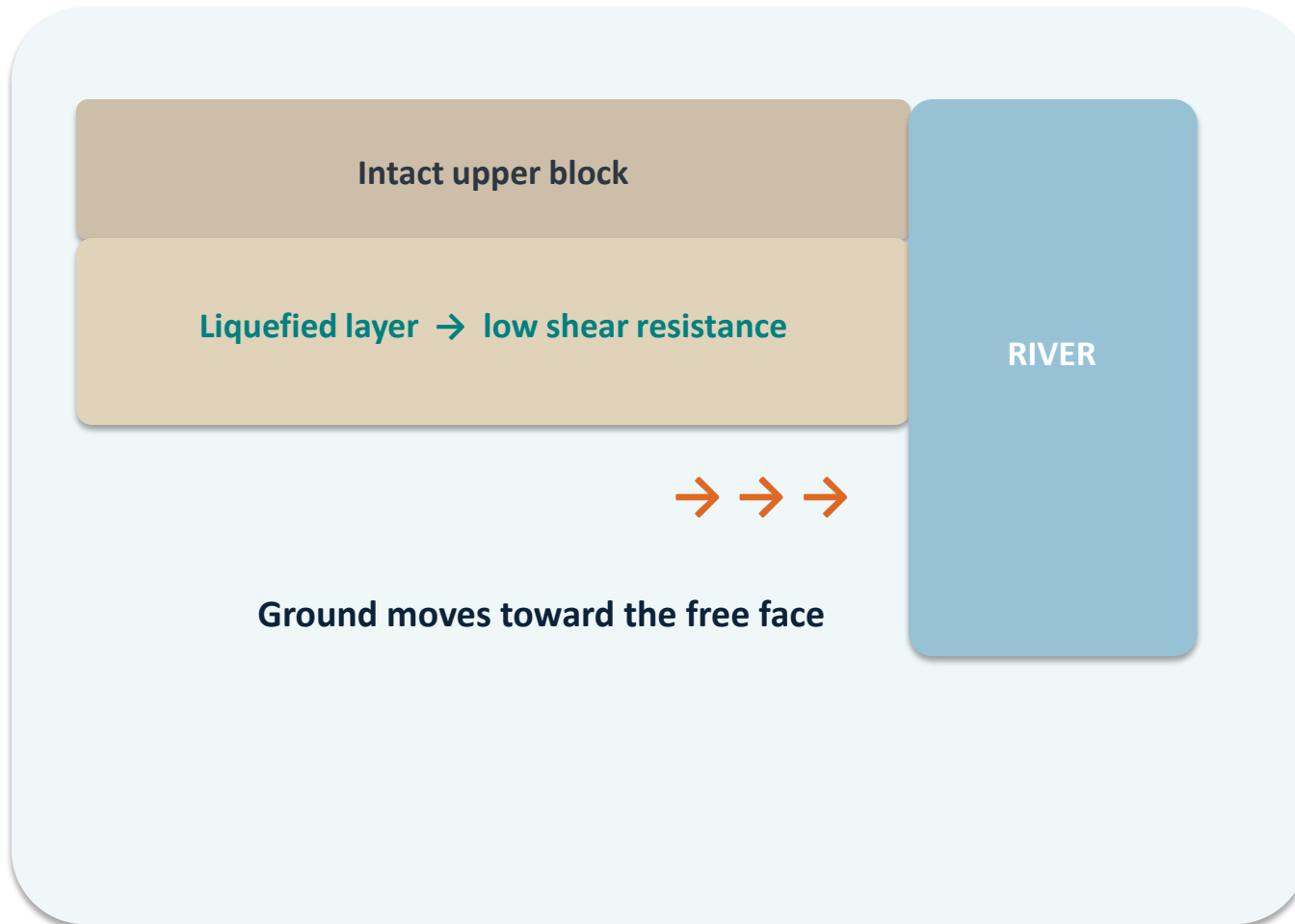
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### Rupture proximity

The study found proximity to the rupture more informative than epicentral distance alone.

**This is a site-investigation and land-use planning message as much as an earthquake message.**

## Hazard 2 — Liquefaction-induced lateral spreading



### Typical consequences

- Riverbank and waterfront deformation.
- Lateral displacement of roads, embankments and quay structures.
- Tensile cracking and differential movement across foundations.
- High relevance to ports, bridges and riverside infrastructure.

# Hazard 3 — Surface rupture, fissures and ground deformation



## Interpretation framework

|                                |                                                                           |
|--------------------------------|---------------------------------------------------------------------------|
| <b>Tectonic</b>                | Direct fault displacement or distributed deformation.                     |
| <b>Liquefaction</b>            | Ejecta, settlement, fissures and lateral spreading.                       |
| <b>Differential settlement</b> | Post-liquefaction reconsolidation or variable ground response.            |
| <b>Structural</b>              | Cracking caused by building deformation — a different diagnostic pathway. |
| <b>Field lesson</b>            | <b>Map geometry + location + soil context before assigning cause.</b>     |





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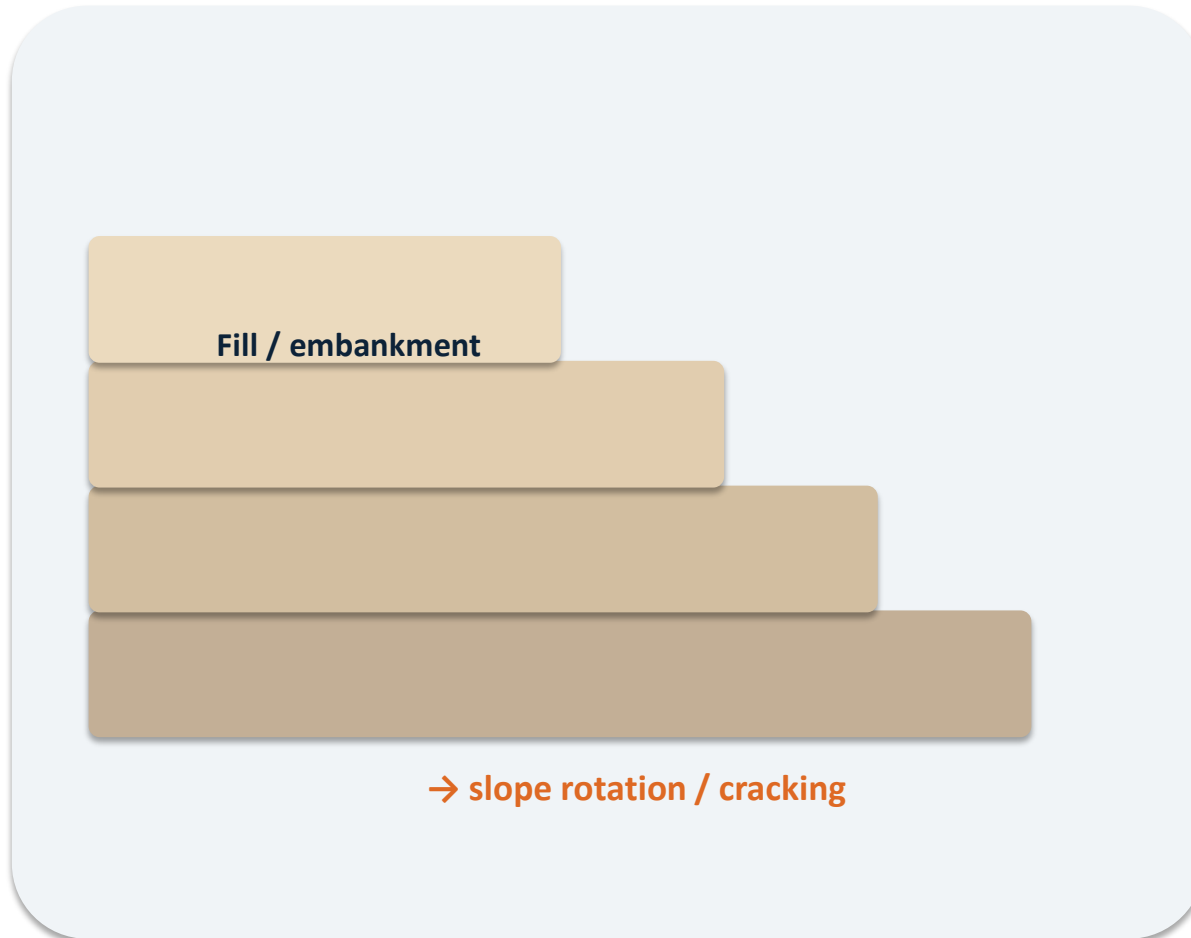
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## Hazard 4 — Slopes, embankments and localized failures



### Failure triggers

- Poorly compacted or heterogeneous fill.
- Loss of strength or support in saturated layers.
- Cracking and slope rotation under strong cyclic loading.
- Road and bridge approaches require explicit geotechnical checks.

**Design the earth structure for movement — not only for static capacity.**

# Geotechnical Hazards Summary

| Hazard            | Primary Driver                    | Primary Infrastructure Risk            |
|-------------------|-----------------------------------|----------------------------------------|
| Liquefaction      | High pore-water pressure          | Foundation sinking & tilting           |
| Lateral Spreading | Gravity + underlying liquefaction | Destruction of quays, docks, & bridges |
| Ground Fissures   | Tensile ground pulling            | Rupture of secondary roads & utilities |
| Slope Failures    | Dynamic seismic acceleration      | Landslides on ridges & road fills      |

Mitigation Strategies: Soil compaction (vibrocompaction), installing deep stone columns for drainage, and building reinforced retaining structures to safeguard riverfront infrastructure

# Why Mandalay requires a ground-focused approach



**The same earthquake produces different consequences because ground conditions vary over short distances.**

**Therefore: regional hazard maps → local microzonation → project-level site investigation → foundation design.**

# 3. Engineering Failure Mechanisms

## *Why Foundations and Earth Structures Failed*

- Inadequate Site Characterization: Standard Penetration Tests (SPT) and shear wave velocity profiling were missing in legacy designs.
- Differential Settlement: Unequal foundation sinking in low-to-mid rise residential buildings due to uneven liquefiable layers.
- Embankment Slumping: Poorly compacted, unreinforced approach embankments suffered severe slope rotation and cracking.
- Neglected Soil-Structure Interaction (SSI): Structural designs lacked proper consideration of altered flexible foundation dynamics.



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**GROUND → FOUNDATION → STRUCTURE → SEISMIC RESPONSE → COLLAPSE**

with three investigation layers:

➤ **GEOTECHNICAL**

**Soil profile → Site amplification → Foundation response → Liquefaction assessment**

➤ **STRUCTURAL**

**RC frame → Infill distribution → Soft Storey → Drift concentration → Column/joint demand**

➤ **PERFORMANCE**

**Local damage → Loss of support → Progressive collapse → Life safety failure**



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# Engineering failure mechanisms

## Site characterization

Missing or insufficient SPT / Vs / groundwater information.

## Differential settlement

Variable liquefiable layers produce uneven foundation response.

## Embankment slumping

Poor compaction and weak zones amplify deformation.

## Soil–structure interaction

Foundation flexibility and altered ground conditions change system response.

**Key lesson: “structural safety” and “geotechnical safety” are inseparable.**

# 4. Response & Stabilization Challenges

## *Post-Disaster Engineering Actions & Remediation*

- Rapid Structural Tagging: Collaborative rapid hazard assessments conducted by structural and geotechnical engineering teams.
- Infrastructure Stabilization: Emergency underpinning, heavy shoring, and debris clearing to prevent progressive building collapse.
- Temporary Ground Improvements: Utilizing rapid jet grouting and stone column installations to secure undermined foundation zones.
- Strategic Data Collection: Capturing perishable field data to accurately model failure modes before site reconstruction.

# Stone Column in Mandalay









To make this actionable, how would you like to build on this framework?

Standard Operating Procedure (SOP): Expand these points into a step-by-step field protocol for rapid response teams.

Executive Briefing: Format this into a high-level situation report for stakeholders or incident commanders.

Technical Expansion: Flesh out the specific methodologies (e.g., LiDAR and drone photogrammetry for perishable data, or specific jet grouting and shoring parameters).

## Field evidence: damage, assessment and strengthening

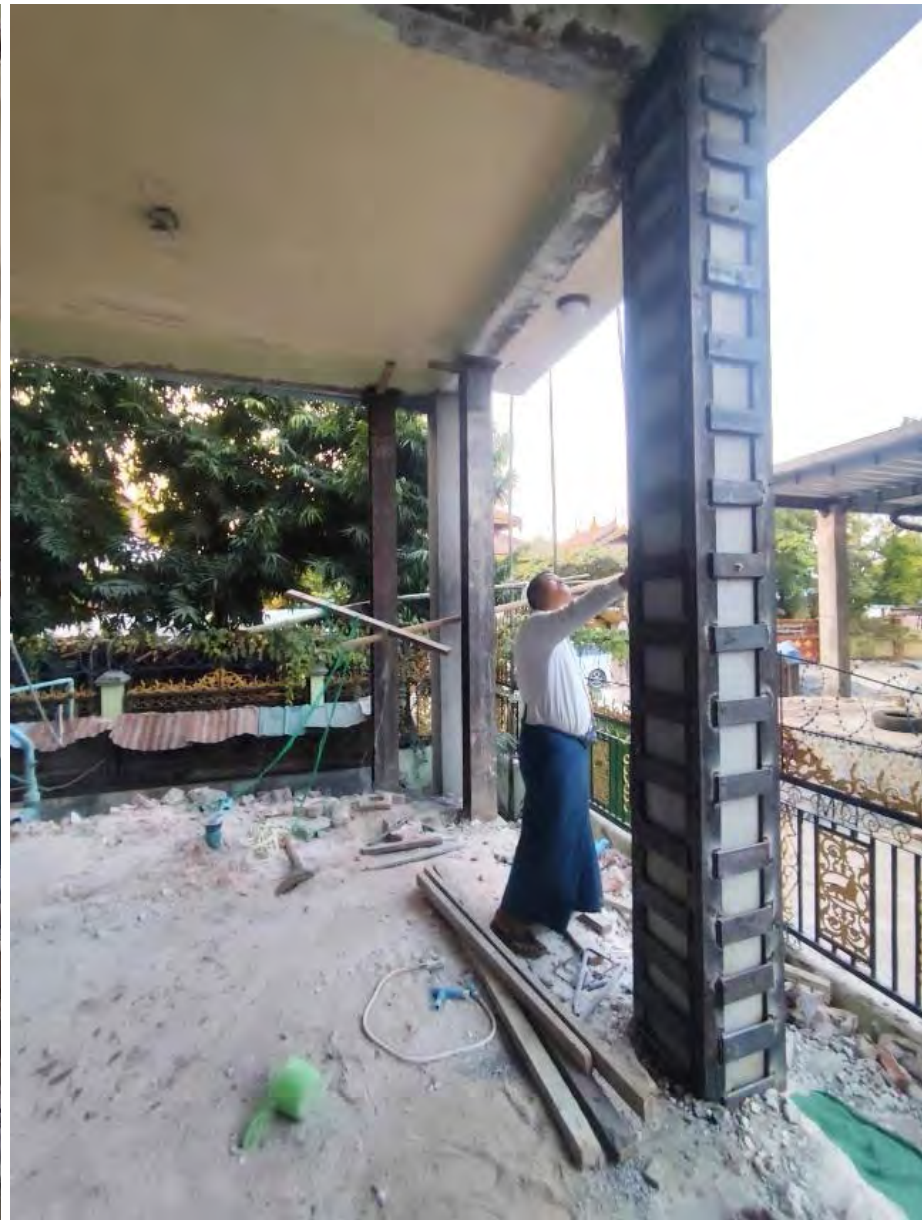


## Field evidence: damage, assessment and strengthening



# Field evidence: damage, assessment and strengthening







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# 5. Framework for Seismic Resilience

## *Strategic Key Recommendations for Myanmar*

- Updating the MNBC: Enforcing modern, mandatory seismic and soil-structure interaction design parameters in the National Building Code.
- Mandatory Microzonation Mapping: Scaling up high-resolution seismic microzonation maps to govern urban land-use zoning laws.
- Enforced Site Investigations: Requiring certified geotechnical reports for all multi-story and high-occupancy structures.
- Advanced Remediation: Adopting deep soil mixing, stone columns, and vibro-flotation techniques as standard practice.

#### 4.2.4.2 Number and location of borings

Site investigation shall be carried out to sufficient extent to establish adequate information for the significant soil/rock strata and ground variation. Location of borings shall be determined by registered geotechnical professional and/or design professional. Number of borings shall be as follows:

1. Minimum of 2 borings for every project.
2. One boring for every 2500 sq-ft (or 250 sq-m) for built-over area  $\leq$  10,000 sq-ft (or 1,000 sq-m).
3. One additional boring for every extra 5,000 sq-ft (or 500 sq-m) for large area projects  $>$ 10,000 sq-ft (or 1,000 sq-m).
4. Additional borings for irregular soil conditions as required by design professional and/or concerning building authority.



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**PART 3 - STRUCTURAL DESIGN**  
**PART 4 - SOIL AND FOUNDATION**

#### **4.2.4.3 Depth of boring**

Site investigation shall be carried out to sufficient depth to establish adequate information for the significant soil/ rock strata and ground variation.

Depth of boring shall meet the most critical condition of following criteria.

1. For shallow foundations, minimum depth of boring shall be larger value of 1.5 times lesser dimension of the shallow foundation or 30ft (10 m).
2. For deep foundations, minimum depth of boring shall be as follows:
  - a)  $20 S^{0.7}$  (ft.) or  $6 S^{0.7}$  (m) where  $S$  = number of storeys including basements.
  - b) The boring shall not be terminated until soil layer in which SPT refusal condition (ASTM D 1586) is encountered.
3. For any type of foundation in seismic design purposes (Seismic Design Categories A to F), minimum depth of boring shall be 100 ft. (or 30 m) to enable proper determination of Site Class in the proposed project.
4. Boreholes should penetrate more than 5 meters into hard stratum in which SPT refusal condition (ASTM D 1586) is observed or at least 5 times pile diameter beyond the intended founding level for deep foundations.
5. In all cases, depth of boring shall be decided by the requirements of design professional and/or building authority to provide adequate information for design purposes.

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**PART 3 - STRUCTURAL DESIGN**

**PART 4 - SOIL AND FOUNDATION**

# 6. ASEAN Technical Collaboration

## *The Role of AFEO in Driving Regional Resilience*

- Cross-Border Knowledge Exchange: Sharing technical data and engineering strategies through the ASEAN Federation of Engineering Organisations.
- Standardizing Professional Standards: Unifying geotechnical testing protocols and disaster response frameworks across ASEAN borders.
- Capacity Building Programs: Joint training initiatives between regional engineering institutions to elevate professional competencies.
- Shared Vision for Safety: Building a robust, disaster-resilient ASEAN community via proactive engineering excellence.

## Soil–structure interaction: the missing link



**Resilient design treats the three domains as one coupled system.**



A total of 206 people died in the collapse of the 11-story **Sky Villa condominium** during the devastating **7.7-magnitude Mandalay earthquake**.

The Myanmar Fire Services Department concluded a grueling months-long search-and-rescue operation at the site on September 15, 2025, ultimately pulling **52 survivors** from the rubble alongside the 206 recovered bodies.

Legal court documents and state media later adjusted the final count to **207 bodies** recovered from the complex, which housed over 400 residents.



The maximum slip recorded was 4.3334 m, occurring southeast of the hypocenter between Sagaing and Amarapura. The entire rupture process spanned just over 80 seconds, with the highest seismic moment release occurring approximately 30 seconds after initiation. The rupture velocity is believed to have exceeded the shear wave velocity, classifying the event as a supershear earthquake.

# A regional signal: the earthquake was felt beyond Myanmar



## Bangkok case

The 28 March 2025 earthquake caused the collapse of a high-rise building under construction in Bangkok. Later investigations reported design and construction deficiencies; the earthquake and local ground conditions were part of the wider context.

## ASEAN message

- Hazard footprints can cross national borders.
- Engineering standards and site investigation quality remain local responsibilities.

# Post-earthquake response: stabilize first, learn while data are fresh

1

## Rapid assessment

Joint structural +  
geotechnical  
reconnaissance

2

## Stabilization

Shoring, underpinning,  
debris control

3

## Temporary ground improvement

Jet grouting / stone  
columns where  
appropriate

4

## Perishable data capture

Photographs,  
coordinates, crack maps,  
groundwater and soil  
evidence

**Before reconstruction: preserve evidence of how the ground failed.**

# Rapid geotechnical reconnaissance workflow

01

## Locate

Fault trace, rivers, slopes,  
damaged assets

02

## Observe

Cracks, ejecta, settlement, tilt,  
lateral displacement

03

## Measure

Coordinates, crack width,  
displacement, groundwater

04

## Test

SPT / CPT / Vs / laboratory  
testing as appropriate

05

## Classify

Liquefaction, rupture,  
spreading, slope or settlement  
mechanism

06

## Act

Stabilize, monitor, redesign or  
restrict access

**Record uncertainty explicitly — not every observed crack has the same cause.**

# Ground improvement toolbox

## Stone columns

Densification / drainage / reinforcement

Liquefaction-prone granular soils

## Jet grouting

Localized strengthening / cutoff

Foundation zones and restricted access

## Deep soil mixing

In-situ soil improvement

Weak / variable soils

## Vibro-flotation

Densification of loose granular deposits

Large areas of susceptible sand

**No single technique is universally appropriate: treatment selection follows soil type, groundwater, geometry, access and performance target.**

# A practical resilience framework for Myanmar



**Resilience is a system: hazard knowledge → investigation → design → construction → response.**

# ASEAN technical collaboration

## Data

Post-earthquake ground-failure inventories, GIS layers, photos and case histories.

## Methods

Common minimum protocols for SPT/CPT/Vs, liquefaction screening and rapid reconnaissance.

## Capacity

Joint training, university–professional exchange and specialist field teams.

## Standards

Compare national codes and develop interoperable guidance for lifelines and critical facilities.

## Communication

Translate complex geotechnical evidence into decision-ready information.

**The objective is not identical practice — it is compatible knowledge, evidence and professional cooperation.**

# Five messages to take home

01

## The earthquake

The 2025 Mw 7.7 event demonstrated that long, fast rupture can produce a very wide engineering footprint.

02

## The ground

Liquefaction and lateral spreading can be as consequential as structural shaking damage.

03

## The site

Geomorphology, soil stratigraphy and groundwater strongly influence local performance.

04

## The design

Geotechnical investigation and soil–structure interaction must be integral to seismic design.

05

## The region

ASEAN can accelerate resilience through shared data, methods, training and standards.



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# Selected references

- USGS (2026). Surface rupture and slip distribution of the 2025 Mw 7.7 Mandalay earthquake. Seismological Research Letters.
- USGS (2026). Remote Surface Rupture Observations for the M7.7 2025 Mandalay, Burma (Myanmar) Earthquake.
- USGS (2025). M7.7 Mandalay earthquake event page and ground-failure information.
- Valkaniotis, S. et al. (2026). Regional-scale inventory and initial analysis of liquefaction triggered by the 2025 Mw 7.7 Mandalay earthquake. Engineering Geology, 363, 108543.
- CAFE044 source document supplied by Prof. Dr. Hla Myo Aung: Geotechnical Hazards in Myanmar — Lessons from the 2025 Mandalay Earthquake.
- AFEO official website: CAFE044, Bandung, Indonesia, 20–22 October 2026.