Damage due to 24 March 2011 M6.8 Tarlay Earthquake in Northern Thailand

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SUMMARY:
On 24 March 2011, the M6.8 earthquake having an epicenter in Tarlay, Myanmar shook the eastern part of Myanmar and the northern provinces of Thailand. Several buildings and roads in northern provinces of Thailand suffered damage and there was one casualty in Thailand. Most of buildings in Maesai District are not designed for seismic resistance. The survey was of an interest to understand how moderate earthquakes affect buildings and geotechnical structures not designed for seismic resistance. Most of buildings in the area are of reinforced concrete. The damage to columns was found to be attributed to 1) limited flexural capacity of columns with small sections, 2) shear failure of short columns, 3) shear failure of columns due to forces transferred from masonry walls, and 4) low construction quality. Beside damage to structures, it was the first time in Thailand that liquefaction was observed in a seismic event.

Keywords: building damage, seismic hazard, post-earthquake reconnaissance

1. INTRODUCTION

At 13:55 (UTC) on 24 March 2011, the M6.8 earthquake having an epicenter at 20.705 degrees N and 99.949 degrees E in Tarlay, Myanmar shook the northern provinces of Thailand. Several buildings and roads in northern provinces of Thailand suffered damage and there was one casualty in the event. Shaking was also felt in Bangkok in some high-rise buildings which were taller than 10 stories. Maesai District in Chiang-rai Province was the hardest hit area where failures in structural members and liquefaction were observed. The authors together with a group of engineers and scientists from Thai Meteorological Department, Department of Mineral Resources, Department of Public Works and Town & Country Planning, Department of Rural Roads, Asian Disaster Preparedness Center, and Electricity Generating Authority of Thailand investigated damage in Chiang-rai Province. This paper presents damage observed in this seismic event and lessons learned.

2. REGIONAL SEISMOTECTONIC SETTING AND OBSERVED SEISMICITY

One common pattern of active faults in Indochina region is left-lateral NE-SW to ENE-SWS striking faults to accommodate two major right lateral strike-slip Red River fault in Vietnam and Sagaing fault in Myanmar. This pattern is characterized by bookshelf types of tectonic, which means that the Indochina area is described as a stack of rotated blocks creating numbers of secondary faults between these two major faults.

The Nam Ma fault, a NE-SW trending strike-slip fault, is believed to generate the 24 March 2011 event (Fig. 1). This fault originates in southern China, extends into northwestern Laos and propagates in northeastern Myanmar. It continues to the southwest and terminates near the northern tip of Mae Sai basin, which is developed as a pull-apart basin between the sinistral movements of the Nam Ma and Mae Chan faults. The total length of this fault is approximately around 150 km. Based on Thailand earthquake catalogue and its surrounding region from 1912, Nam Ma fault did not produce any earthquake greater than magnitude 6 for at least 100 years. So the 24 March 2011 earthquake was essentially filling the gap of relatively short instrumental earthquake catalogue in this region. The first motion focal mechanism of this tremor was determined with an almost pure left-lateral strike slip mechanism, confirming previous seismotectonic information. Moreover, the modeled focal mechanism by global CMT, which was based on long period waveform solution suggested similar fault orientations. This pattern suggested that the earthquake began at the southwestern part and ruptured toward northeast, where Tarlay and Mong Hpayak cities were located resulting in high casualties in the two towns.

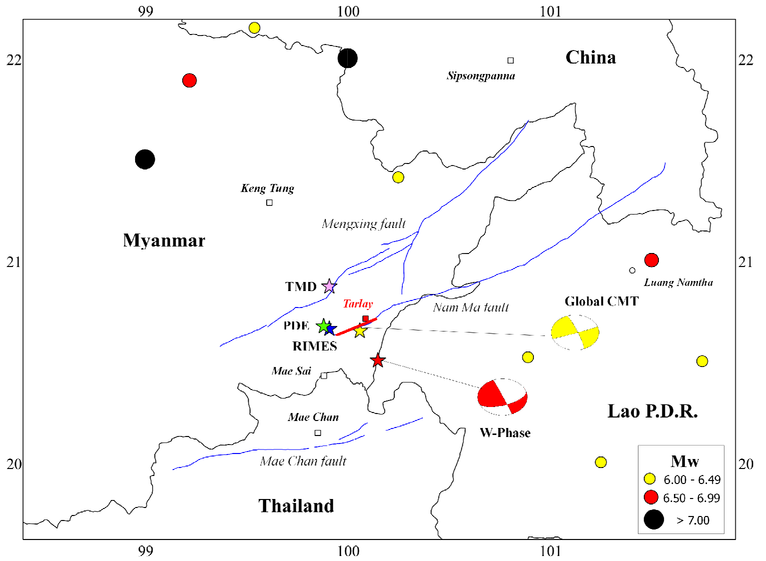
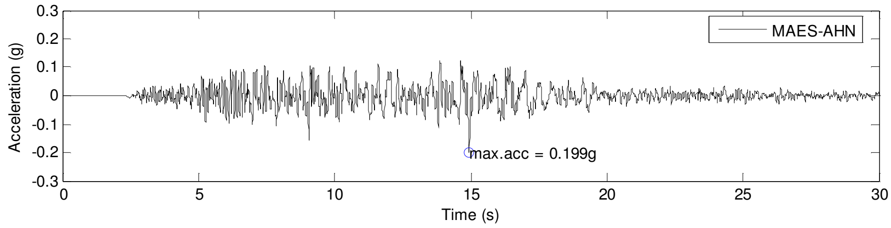


Figure 1. Location of Nam Ma and other surrounding active faults (blue lines) and epicenters of Mw 6.8 24 March 2011 determined by different agencies

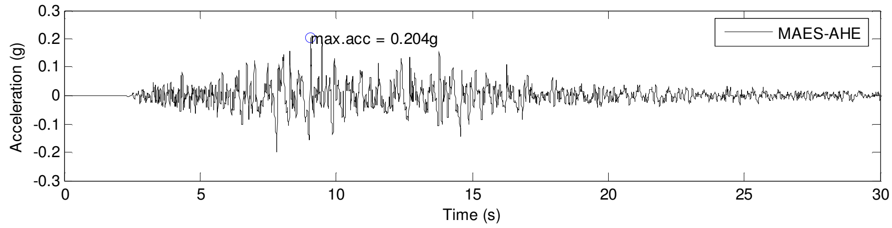
3. RECORDED STRONG GROUND MOTIONS

Strong ground motions of the Tarlay earthquake were recorded by 20 digital strong motion instruments of Thai Meteorological Department (TMD) network; however, only four of these instruments were located less than 200 km from the epicenter. The nearest accelerograph station was in Maesai District, located 28 km from the fault rupture (Fig. 1). At this station, the observed peak ground acceleration (PGA) in NS, EW, and UD reached 0.19g, 0.20g, and 0.11g, respectively as shown in Fig. 2. Currently, this record has the largest recorded PGA in Thailand. The soil condition of Maesai station is classified as soil type D based on NEHRP provisions. The observed horizontal peak ground velocity (PGV) is 15 cm/s. Fig. 3 compares the 5%-damped elastic response spectra at Maesai station with Thailand seismic design spectra. The observed spectral ordinates are less than that of design earthquake level for most natural periods, but they do exceed from 0.1 to 0.15 seconds.

Comparison of observed accelerations from the Mw 6.8 Tarlay earthquake to Next Generation Attenuation (NGA) equations and Sadigh et al. (1997) are shown in Fig. 4. The orientation of horizontal ground motion is in geometric mean with Joyner-Boore distance definition. Selected NGA equations are Boore and Atkinson (2008), BA08, Chiou and Youngs (2008), CY08, and Campbell and Bozorgnia (2008), CB08. CY08 is the updated equation of Sadigh et al. (1997). The selected Vs30 for rock in NGA equations is 520 m/s as indicated in Chiou and Youngs (2008) that the selected Vs30 from rock site in Sadigh et al. (1997) should be in this range. The 180 m/s Vs30 for soft soil site is to account for low Vs30 in Bangkok. From preliminary assessment without shear wave velocity profile of all stations, NGA equations, and Sadigh et al. (1997) could predict strong ground motion parameters within an acceptable accuracy. The observed 0.2g PGA at the Maesai station is relatively large but it is not unexpected comparing to BA08 equation for Vs30 = 180 m/s. It could be noticed that the soil amplification in Bangkok is much larger than that for about 2 to 3 times of similar distance.



(a) NS component



(b) EW component

Figure 2. Strong ground motion record at Maesai District

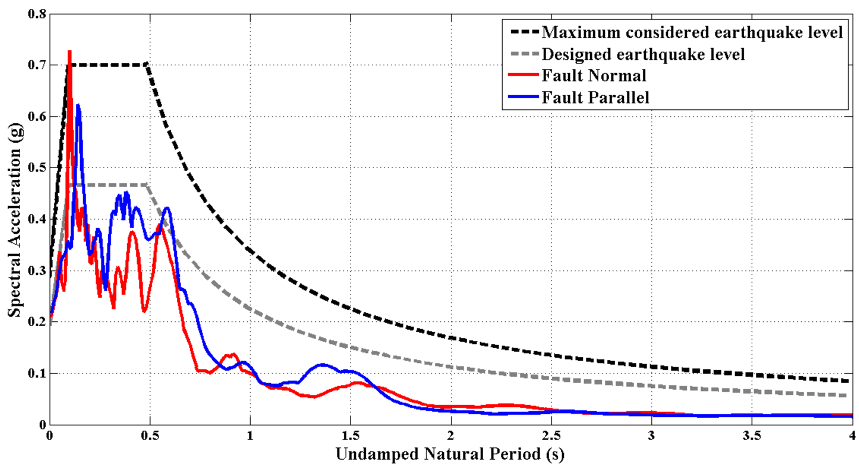


Figure 3. Comparison of recorded spectral acceleration spectra (at 5% damping) with Thailand seismic design spectra of soil type D

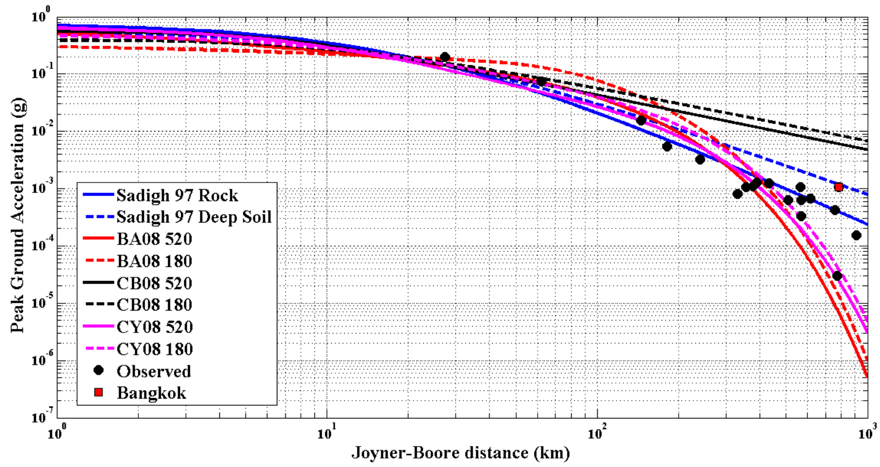


Figure 4. Comparison of observed PGA with NGA and Sadigh et al. (1997) equations

4. OBSERVED DAMAGE

Damage in two districts in Chiang-rai Province namely Maesai and Chiang-saen Districts was investigated. Damage observed can be summarized as follows:

4.1 Damage to historical structures

In Chiang-saen District located about 60 km from the epicenter, damage to historical structures was found at some sites. As seen from Fig. 5, the top portion of a pagoda fell down. Pagodas are generally constructed using masonry brick.

Figure 5. Damage to a pagoda in Chiang-saen District

4.2 Damage to building columns

The causes of damage to columns can be grouped into three categories: short column mechanism, small columns, and load transfer from masonry walls.

4.2.1 Damage due to short column mechanism

The shear failure of short columns was observed in some buildings as shown in Fig. 6. Masonry walls with openings at boundary columns lead to short column mechanism. This type of damage occurs in some buildings in past earthquakes in Thailand.

Figure 6. Shear failure of a short column

4.2.2 Damage due to small columns

A reinforced-concrete building with small columns can be damaged by earthquakes due to low flexural capacity. Fig. 7 shows a building with elevated floor slabs. The size of columns was 0.15m x

0.15m. Flexural cracks occurred at all column heads. It is recommended that the size of columns should be larger than 0.2m x 0.2m.

Figure 7. Damage of a building with small columns in Chiang-saen District

4.2.3 Damage due to force transfer from masonry walls

Diagonal cracks in masonry walls occur in several buildings (Fig. 8). In some buildings, masonry walls formed compression struts and induced forces in columns near joints. Finally, it led to the shear failure of columns as shown in Fig. 9. Buckling of longitudinal bars also occurred, indicating the loss of gravity load carrying capacity.

Figure 8. Diagonal cracks in a masonry wall

Figure 9. Damage due to load transfer from masonry walls

4.3 Pounding of structures

Two structures with different dynamic properties constructed close to each other may have pounding damage if gaps provided between two structures are not large enough to accommodate relative displacement. Fig. 10 shows a 5-story building of a provincial hospital. The building comprises two structures: 1) the structure supporting a water tank, 2) the main building. Pounding occurred at joints between two structures in upper floors.

Figure 10. Damage due to pounding

4.4 Liquefaction

Loose to dense sands with corrected SPT N value of about 5-20 are generally present in top layers in Chiang-mai and Chiang-rai Provinces. This earthquake caused liquefaction in paddy fields in Maesai District. Liqufaction-induced lateral spreading also caused damage to roads as shown in Fig. 11.

Figure 11. Liquefaction and damage to a road

5. CONCLUSIONS

This earthquake caused the most damage to structures in Thailand in the recent history. It was the first time that liquefaction was observed after earthquakes. Ground motion records showed the maximum peak ground acceleration of 0.2g in Maesai District located 28 km from the epicenter. The lessons learned from this event paved the way for improvement of seismic design and earthquake preparedness in Thailand and neighboring countries.

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