EARTHQUAKE-RELATED DISASTER MITIGATION-
THE THAILAND EXPERIENCE

Panitan Lukkunaprasit

ABSTRACT

A brief account of major earthquake-related events in Thailand is given in this paper. Their impact on earthquake hazard mitigation and important milestones achieved in relevant undertakings are outlined. The valuable lessons learned from the devastating Indian Ocean Tsunami are highlighted with regard to structural aspects of building performance. Finally, seismic hazard assessment for Thailand, and for Bangkok in particular, is addressed.

Keywords: earthquake, Thailand, Indian Ocean Tsunami, structural performance, damage, brick infill, openings.

INTRODUCTION

The devastating Indian Ocean tsunami on December 26, 2004 has instantly changed the state of natural disaster in Thailand. Historical records prior to the event had shown that in the past century there had been 7 tsunamis in the Indian ocean, none of which developed into a destructive tsunami, except the one in 1883 which was caused by volcanic eruption of Krakatoa and killed around 36000 people in Indonesia [1]. The lack of historical records of destruction by tsunamis on Thai coastlines made the public, and even most academics, to be unaware of the possibility of tsunamis occurring along the coasts of the country. Consequently, the country was not prepared for the hazard, leading to great catastrophe and economic losses.

This paper presents a brief account of major earthquake-related events in Thailand. Milestones achieved and important lessons on structural aspects of buildings damage are outlined.

PAST EARTHQUAKE EVENTS AND BUILDINGS DAMAGE IN MODERN HISTORY

Thailand had long been believed to be a country of “low seismicity” until the occurrence of several moderate earthquakes back in 1980s. On April 22, 1983, an earthquake of magnitude 5.9 on the Richter scale erupted near a dam site, about 200 kilometers from Bangkok, the capital of Thailand. The main tremor of this earthquake was felt all over the western part and most of the central part of the country. This earthquake together with the foreshocks and aftershocks were later confirmed to be reservoir-induced. Five years later on November 6, 1988, an earthquake of magnitude 7.3 hit the southern part of China near the Myanmar border. This earthquake was felt in Bangkok even though the epicenter was more than 1,000 kilometers away, a consequence of the ability of Bangkok’s deep, soft-alluvial soil in amplifying the incoming seismic waves. Since then, moderate earthquakes seem to be frequent visitors in northern Thailand, the worst one being the Phan earthquake (M = 5.1) in Chiang Rai in 1994 which caused slight structural damage to a few dozen buildings (mostly schools and

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temples), with a few moderately damaged. In one hospital building (Fig. 1), severe shear cracks occurred in more than ten short columns [2]. It should be noted that all the buildings damaged were not designed for any earthquake loading.

Without any awareness of tsunami threat due to lack of knowledge of tsunami phenomenon, Thai people as well as tourists did not realize the imminent occurrence of tsunami after the sea suddenly receded for a long distance (Fig. 2) in the morning of 26 Dec, 2004. As a consequence, more than 5,300 people were killed on the western coasts of Thailand, the largest fatality caused by a natural disaster in Thai history. The 2004 Indian Ocean Tsunami was caused by an unprecedented earthquake in the region, with a moment magnitude $M_w$ of 9.0. The epicenter was located at 3.3° N and 95.9° E, which is off the west coast of Banda Aceh, North Sumatra Island, Indonesia (Fig. 3). According to the United States Geological Survey (USGS), the earthquake, the fourth largest in the world in modern history, was triggered by the India plate subducting into the Burma plate, causing the sea bed to rise by several meters [3]. As a consequence, tsunamis of 5-12 m in height were generated along the coasts of southern Thailand. Table 1 lists the major earthquake-related events in modern Thai history.

![Figure 1. The hospital building damaged in the Phan earthquake, 1994](image1)

![Figure 2. Great fatality caused by lack of knowledge of tsunami phenomenon-the 2004 Indian Ocean Tsunami on 26 December 2004](image2)
Figure 3. Epicenter of earthquake on December 26, 2004 (Source: USGS 2006)

Table 1. Major earthquake-related events in Thailand

<table>
<thead>
<tr>
<th>Date</th>
<th>Magnitude (Richter)</th>
<th>Epicenter</th>
<th>Brief Accounts of Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1545 A.D.</td>
<td>-</td>
<td>Chiang Mai</td>
<td>Strongly felt in Chiang Mai (The top of the Luang Pagoda toppled)</td>
</tr>
<tr>
<td>February 17, 1975</td>
<td>5.6</td>
<td>Myanmar-Thailand Border</td>
<td>Felt in Northern (V) and Central Region</td>
</tr>
<tr>
<td>April 22, 1983</td>
<td>5.9</td>
<td>Kanchanaburi</td>
<td>Felt in Kanchanaburi and Central Region (Reservoir-induced earthquake; minor damages reported)</td>
</tr>
<tr>
<td>October 1, 1989</td>
<td>5.3</td>
<td>Thailand-Myanmar Border</td>
<td>Felt in Upper Northern Region</td>
</tr>
<tr>
<td>September 11, 1994</td>
<td>5.1</td>
<td>Phan District, Chiang Rai</td>
<td>Felt in Northern Region (VI-VII)</td>
</tr>
<tr>
<td>July 12, 1995</td>
<td>7.2</td>
<td>Myanmar</td>
<td>Felt in Upper Northern Region and Bangkok (in high-rise buildings)</td>
</tr>
<tr>
<td>December 9, 1995</td>
<td>5.1</td>
<td>Phrae</td>
<td>Felt in Northern Region (Minor non-structural damage)</td>
</tr>
<tr>
<td>December 22, 1996</td>
<td>5.5</td>
<td>Loas-Thailand Border</td>
<td>Felt in Northern Region (V-VI)</td>
</tr>
<tr>
<td>January 22, 2003</td>
<td>6.5</td>
<td>Sumartra</td>
<td>Felt in Southern Region &amp; Bangkok (in high-rise buildings)</td>
</tr>
<tr>
<td>September 22, 2003</td>
<td>6.7</td>
<td>Myanmar (~850km from Bangkok)</td>
<td>Felt in the Northern Region and Bangkok; cracks in non-structural brick walls in 2 tall bldgs</td>
</tr>
<tr>
<td>December 26, 2004</td>
<td>9.0</td>
<td>Sumartra</td>
<td>Devastation in 6 southern Thai provinces on the Andaman coastline: ~5300 deaths, ~3000 missing, ~280000 fatalities over the whole Indian ocean region, estimated economic loss ~US$ 10 billion</td>
</tr>
</tbody>
</table>
Table 2 lists the chronology of important events and milestones related to earthquakes and tsunami affecting Thailand. In brief, the 1983 earthquake marks the beginning of seismic hazard mitigation undertakings, with the establishment of the National Earthquake Committee of Thailand in 1985, drafting of the Ministerial Regulations on seismic resistant design and set-up of the Earthquake Engineering and Vibration Research Laboratory at Chulalongkorn University in 1986, the first of its kind in Thailand.

The 1994 Phan Earthquake has brought up renewed public awareness. Minor to moderate buildings damage caused by the earthquake prompted policy makers to pass the long awaited Ministerial Regulations on Seismic Resistant Design, which had gone through deliberations and criticisms for about one decade.

Table 2. Chronology of important events and milestones

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Impact / milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>M5.9 Kanchanaburi earthquake</td>
<td>- Set-up of National Earthquake Committee of Thailand in 1985</td>
</tr>
<tr>
<td>1986</td>
<td>- 1st draft of Ministerial Regulations on seismic resistant design.</td>
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<tr>
<td></td>
<td>- Set-up of Earthquake Engineering &amp; Vibration Research Lab. at Chulalongkorn University. (CU-EVR)</td>
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<tr>
<td>1994</td>
<td>M5.1 Phan earthquake</td>
<td>- Significantly raised public awareness</td>
</tr>
<tr>
<td>1997</td>
<td>- 1st Ministerial Regulations on Seismic Resistant Design (No. 49) promulgated (after about 10 years since 1st draft)</td>
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<td>- Earthquake engineering research started to increase significantly both in terms of man-power and funding</td>
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</tr>
<tr>
<td>1998</td>
<td>- TMD* seismograph network expanded to 11 digital seismograph stations and a central data acquisition system</td>
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</tr>
<tr>
<td>2000</td>
<td>- Some important active faults in the north found to be capable of generating a M7+ earthquake with a recurrence interval of about 2000 years or more</td>
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</tr>
<tr>
<td>2004</td>
<td>M9.0 Sumatra eqk.</td>
<td>- Worldwide impact (Indian Ocean Tsunami)</td>
</tr>
</tbody>
</table>

*TMD is the Meteorological Department of Thailand

IMPACT OF THE INDIAN OCEAN TSUNAMI ON THAILAND

The great 2004 Indian Ocean Tsunami has an impact worldwide, prompting serious international cooperations. Significant impact on Thailand includes:

a. Significant increased public alert concerning natural hazards including public relations by the mass media.
b. Establishment of the National Disaster Warning Center (NDWC) to oversee early warning for all major disasters, with immediate mission on tsunami early warning.
c. Set-up of the National Earthquake and Tsunami Disaster Mitigation Plans. The plans cover practically all important aspects of earthquake and tsunami hazards mitigation, excluding early warning system which is the direct responsibility of NDWC.
d. Amendment of the Ministerial Regulations No. 49 on Seismic Resistant Design. The existing regulations are in the process of being amended to include Bangkok and its vicinity as seismic prone areas. Moreover, buildings in southern provinces close to two major faults will be required to be provided with minimum seismic detailing. Incidentally, most of those provinces are vulnerable to tsunami hazard.
e. International collaborations:

There have been impressive international collaborations in terms of technical assistance from foreign governmental departments or agencies as well as joint research endeavors. A distant
Learning short course on disaster mitigation has been offered via video conferencing by the Center of Excellence in Urban Earthquake Engineering, Tokyo Institute of Technology.

**IMPORTANT OBSERVATIONS FROM THE 2004 INDIAN OCEAN TSUNAMI**

The following lessons with regard to structural aspects of buildings have been learned from the 2004 Indian Ocean Tsunami:

a. The damage caused by the tsunami clearly reveals inadequate design and construction of foundations, columns, joints, as well as retaining structures.

b. Scouring of cohesionless soil around and beneath spread shallow footings is a common cause of foundation failure (Fig. 4).

c. The current practice of weakly connecting infill masonry panels to the boundary reinforced concrete frames with widely spaced dowels has proved to work well in detaching the brick walls from the frames under excessive water pressure, thereby releasing the force transmitted to the building.

d. While isolated exposed columns allow free flow of waves which reduces pressure on the columns, they are vulnerable to damage by large floating objects carried by the strong currents (Fig. 5). Moreover, soft stories are a poor structural system for seismic resistance.

e. The superior performance of non-structural un-reinforced brick walls with openings has been observed (Fig. 6), and reinforced concrete frames with such walls should be advantageous in providing a sound low cost structural system with strength and robustness.

f. The majority of multi-story RC buildings have survived the Tsunami even though they were not designed for tsunami nor earthquake loadings. Figure 7 shows some of the survived RC buildings in water heights of up to 6 m. Of course, non-structural brick infill panels collapsed, but the structural frames are still in good condition. In fact, many people survived by seeking shelters on the upper floors of well engineered 3 (or more) story buildings. This suggests that it is possible to design tsunami resistant structures with reparable performance level. This assumes practical significance in that tsunami resistant buildings can be used as evacuation shelters for life saving in flat terrains.

Additional information has been reported by Ruangrasamee, et al. [4].

**SEISMIC HAZARD ASSESSMENT**

Hazard assessment is pre-requisite to hazard mitigation. In Thailand there is a lack of seismologists who are experienced in seismic hazard assessment. It is not surprising to get different results (from different researchers) even though they are based on practically the same set of data. Estimates of peak ground accelerations (PGA) have been proposed by Nutalaya and Shrestha [5], Lukkunaprasit and Kuhatasanadeekul [6], and Warnitchai and Lisantono [7]. The corresponding maximum PGA values (at rock sites) associated with a probability of exceedence of approximately 10% in 50 years in Thailand obtained by those researchers are 0.11g, 0.14g and 0.27g, respectively. Discrepancies in the predicted PGA’s can be attributed to different assumptions made in the analyses. Moreover, significant uncertainties exist due to paucity of “good” data.
Figure 4. Scouring of cohesionless soil

Figure 5. Column damaged by impact from floating object (Courtesy A. Ruangrassamee)

Figure 6. The superior performance of non-structural un-reinforced brick walls with openings

a. Patong beach (water height of about 3 m. above ground level)

b. Khao Lak (water height of about 6 m. above ground level) (Courtesy A. Ruangrassamee)

Figure 7. Survived RC buildings
AMENDMENT OF MINISTERIAL REGULATIONS

Since Bangkok is the center of public administration, trade, defense, education, etc., it is important to consider earthquake events with very low probability of occurrence. Before the occurrence of the devastating Indian Ocean Tsunami, it had been practically impossible to convince the public to be aware of and get prepared for the earthquake hazard in Bangkok caused by long distance earthquakes. Following the event, with the recommendation of a sub-committee of the Building Control Committee, the latter has requested the Ministry of Interior to amend the Ministerial Regulation No. 49 requiring buildings in Bangkok and its vicinity to be designed for an appropriate seismic resistance. The limited geological and seismological data available pose obstacle to reliable assessment of seismic hazard in Bangkok. Nevertheless, a rough estimate based on a deterministic worst scenario is in order for practical purposes. Assuming that the western U.S. attenuation relationship can be adopted for Thailand [8] and applying the attenuation model by Boore, et al. [9], the peak ground acceleration (PGA) at the rock base can be estimated to be 2\%g based on an M7.0 earthquake at the active fault nearest Bangkok which is about 200 km. away [10]. The PGA in Bangkok, accounting for amplification of ground motion caused by the soft soil strata underlying Bangkok, is 4 times PGA, or 8\%g. The spectral acceleration response spectrum proposed based on the study of Ashford et al. [11] is shown in Figure 8. It is interesting to note that the proposed spectrum is close to the Mexico 2004 curve corresponding to a predominant period of ground motion of 1 sec. Of course, a more refined analysis is needed.

It is worth noting that USGS is undertaking a project funded by USAID to develop a regional seismic hazard map in Southeast Asia, with capacity building for self reliance aimed at as one of the main objectives of the project. With the technical assistance of experts from USGS, it is hoped that more refined and reliable seismic hazard assessment would be accomplished in the future.

![Figure 8. The spectral acceleration response spectra](image-url)
CONCLUSIONS

The great Indian Ocean Tsunami once again indicates that natural hazard is unpredictable and lack of historical record cannot rule out the possibility of a natural hazard with a very low probability of occurrence. It is important that we learn from past events and make use of those valuable lessons for mitigating the effects of hazards. The survival of a large number of non-seismic, non-tsunami resistant buildings in Thailand does point out that it is a practicable possibility to design buildings to resist tsunamis of moderate heights with reparability performance. This is important with regard to fast recovery, life safety and minimizing of economic loss. Furthermore, it indicates that evacuation shelters can be constructed without excessive costs to save lives in the event of future tsunami of moderate height.

The Tsunami has significantly raised public awareness of natural hazards. The Ministerial Regulation No. 49 is under amendment as a result.

ACKNOWLEDGEMENTS

The Indian Ocean Tsunami tragedy has brought countries closer together. The contributions and collaborations of all overseas communities toward relief, restoration as well as capacity building in Thailand are highly appreciated by Thai citizens.

REFERENCES

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