Soil Dynamics and Earthquake Engineering 114 (2018) 113–126

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Analysis of seismic ground response caused during strong earthquake in Northern Thailand

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ARTICLE INFO

Keywords:
Seismic response analysis
Peak ground acceleration
Next generation attenuation model
Northern Thailand
Tarlay earthquake

ABSTRACT

This paper presents a site-specific analysis of ground response during the Tarlay Earthquake on March 24, 2011 in Northern Thailand. In this study, the NGA (Next Generation Attenuation) models were selected to predict ground motions due to the earthquake event. The equivalent linear and non-linear approaches were employed in the one-dimensional ground response analysis. Furthermore, the spectral responses produced by the equivalent linear and non-linear approaches were compared with the seismic design code of Thailand. The results showed that the ground motion from the NGA models agree with the strong motion parameters of Tarlay Earthquake. Peak ground acceleration (PGA) at ground surface obtained from both equivalent linear and non-linear approaches certainly results in the high amplification factor. In general, the study results could bring an attention to the local engineer to consider the seismic design value for Northern Thailand, particularly if the stronger earthquake happens in the future.

1. Introduction

Northern Thailand has experienced many earthquakes in the past; however, most of them did not cause extensive damage since they were low in magnitude and their epicentres located primarily in neighbouring countries (i.e., Myanmar and Laos). Nevertheless, on March 24, 2011, a strong (M_w 6.8) earthquake triggered by the Nam Ma Fault (Fig. 1) struck Tarlay in Myanmar. This earthquake is generally known as Tarlay Earthquake. The epicentre of this earthquake was located about 30 km from the Mae Sai border of Thailand. The measured acceleration recorded at the Mae Sai station (MSAA Station in Fig. 1) of Chiang Rai Province was 0.207 g [1]. Fig. 2 presents the acceleration caused by Tarlay earthquake recorded at the Mae Sai station.

Ruangrassamee *et al.* [3] and Soralump and Feungausorn [4] reported that the earthquake caused considerable damage (e.g., loss of life, loss of property, and temple collapse) in Northern Thailand. The epicentre of the earthquake was only 30 km from the Mae Sai District station in Chiang Rai Province, and the earthquake caused the most damage in that district. Other districts in Chiang Rai Province, such as Mueang and Wiang Pa Pao, also experienced some damage. In Chiang Mai, the ground shaking was felt by the people, although it was not as intensive as in Chiang Rai. Even though the central city of Chiang Mai lies far from the epicentre (about 235 km away), Chiang Mai could experience significant damage if a stronger earthquake were to hit this area in the future. Thus, because Chiang Mai is the largest city in Northern Thailand and is both economically and socially important, it is critical to consider the potential impacts of future earthquakes in this region.

With the goal of learning from Tarlay Earthquake, this study presents an analysis of seismic ground response in Northern Thailand. The objective of this study is to observe the seismic response in Chiang Rai and Chiang Mai to Tarlay Earthquake based on wave propagation analysis and attenuation model analysis. The recorded spectral acceleration at each site was also compared with the spectral acceleration design of Thai Design Seismic (TDS) [5] for those areas. The results describe the ground response in Northern Thailand to Tarlay Earthquake and are expected to be applicable to other research related to ground-shaking phenomena in Northern Thailand related to Tarlay Earthquake (e.g., liquefaction). In general, this study presents the site specific analysis of ground response and attenuation model analysis during Tarlay Earthquake 2011. Since the geotechnical earthquake engineering information in this region is still very limited, the results could provide a better understanding on the seismic ground response.

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https://doi.org/10.1016/j.soildyn.2018.07.006
Received 17 March 2017; Received in revised form 4 July 2018; Accepted 10 July 2018

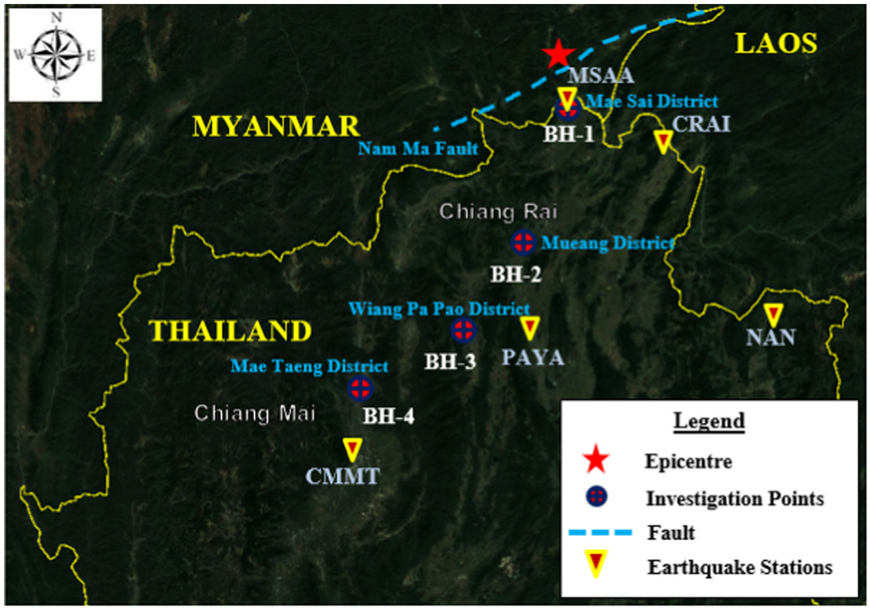

Fig. 1. Locations of Nam Ma Fault, epicentre of Tarlay earthquake in 2011, site investigations, and surrounding seismic stations [2].

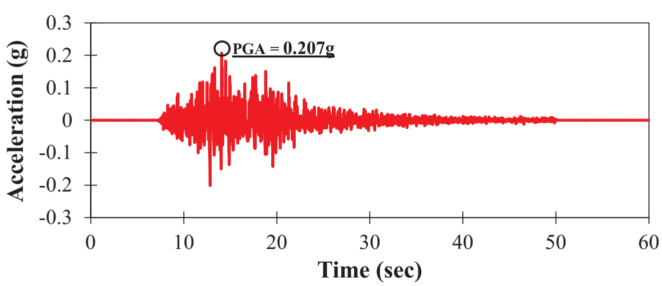

Fig. 2. Acceleration record at Mae Sai station due to Tarlay earthquake on March 24, 2011 [1].

2. Geologic characteristic

The site investigation including the standard penetration test (SPT) and the seismic downhole test used to obtain the shear wave velocity (V_S) profile, were conducted at three sites in Chiang Rai (BH-1, BH-2, BH-3) and one site in Chiang Mai (BH-4). The results of site investigation conducted in the study area are presented in Fig. 3. In Chiang Rai, sites BH-1, BH-2, and BH-3 were located in the Mae Sai, Mueang, and Wiang Pa Pao districts, respectively. The coordinates for the investigated sites is presented in Table 1. In Chiang Mai, site BH-4 is located in the Mae Taeng district. The consideration why those areas are selected is because Chiang Rai and Chiang Mai are the trading gate and the economic centre of Northern Thailand, respectively. This area is also considered as the centre of social-economy aspect in Golden Triangle, which is encompassing Laos, Myanmar, and Thailand.

In terms of the soil resistance, $(N_1)_{60}$ or the corrected SPT value related to the type of hammer (a donut hammer was used in this study) and overburden pressure was calculated by using Skempton [6] method. In addition, the V_{S30} (the time-averaged of V_S profile up to a depth of 30 m) were analysed. The formulations of $(N_1)_{60}$ are expressed as follows:

$$(N_1)_{60} = C_N \cdot N_{60} \tag{1}$$

$$N_{60} = \frac{ER}{60} N \tag{2}$$

$$C_N = \left(\frac{p_a}{\sigma_v'}\right)^{0.784-0.0768\sqrt{(N_1)_{60}}} \leq 1.7 \tag{3}$$

where $(N_1)_{60}$ is the corrected standard penetration, C_N is the SPT correction factor [7], N_{60} is the blow count for an energy ratio of 60% (in blow/feet), ER is the ratio of energy efficiency (assumed to be 45% for a donut hammer and 60% for a dropped hammer), N is the measured SPT (in blow/feet), p_a is atmospheric pressure (100 kPa), and σ_v' is the effective stress (in the same units as p_a).

The calculation of V_{S30} is determined using the following formulations:

$$V_{S30} = \frac{30(m)}{\sum_{i=1}^{n} \frac{di}{V_{Si}}} \quad \text{(for total depth = 30m)} \tag{4}$$

where, di is the thickness of each layer, V_{Si} is the shear wave velocity in each layer and n is the number of layers.

In general, the shear wave velocity profile on each investigated site increases with depth and it should be consistent with the SPT-N value. In this study, the comparisons of the measured V_S values from seismic downhole tests with the predicted V_S values based on the empirical method proposed by Mayne [8] are made as shown in Fig. 4. It can be found that the measured values and the predicted values are well consistent. Therefore, the measured shear wave velocity can be confidently used in the seismic ground response analysis.

According to the geologic characteristics, the subsoil conditions for the investigated locations in Chiang Rai and Chiang Mai are dominated by granular materials. SP (poorly graded sand), SC (clayey sand), and SM (silty sand) dominantly exist in the first 15 m deep, with FC (fines content) in the range of 5–40%. These soil layers are followed by GC-SC (clayey gravel to clayey sand), GM (silty gravel), and GP (poorly graded gravel) until 30–32 m depth, with FC in the range of 10–30%. Even though granular material is dominant in this area, thin layers of clay are also found in several areas, particularly in BH-3 (depth = 0–2 m) and BH-2 (depth = 29.5–32 m). This soil is classified as CL (low plasticity clay) with FC up to 90%. The groundwater depth in this area ranges from 1.2 to 3.16 m deep. The distribution of $(N_1)_{60}$ in this area ranges from 3 to 30 blows/feet, whereas V_{S30} ranges from 324 to 353 m/s. The value of V_{S30} is used to determine the site class of the investigation area based on the National Earthquake Hazards Reduction Program (NEHRP) criteria [9]; the site class of the investigated locations is categorised as stiff soil (Site Class D).