Progress report on
“Liquefaction study in Chiang Rai Northern Thailand”
(Geotechnical Earthquake Engineering)

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Objectives

1. To investigate liquefaction occurred in Northern Thailand (NT) (seismic records, field investigations)
2. To understand subsurface soil conditions in NT (borehole and microtremor observations)
3. To evaluate structural vulnerability against liquefaction in NT (site response analysis by FEM, FDM, or physical model testing)
4. To contribute to build safer and secure society through geotechnical earthquake engineering study
Progress

2011
After the 2011 earthquake, liquefaction in Thailand was observed for the first time

Starting by Preliminary Analysis (comparing two large areas in Northern Thailand i.e. Chiang Mai and Chiang Rai)

Site Response Analysis considering the 2011 Earthquake in Chiang Mai and Chiang Rai (Using Non-linear and Equivalent Linear Method)

2014
Preliminary conclusion:
After field investigation and detailed analysis, Chiang Rai Site is more vulnerable in terms of Liquefaction. More attention must be paid in Chiang Rai Province

2016
March 2016: Microtremor observation in Mae Lao (Center of Chiang Rai Province) and Mae Sai (Border of Thailand-Myanmar) where liquefaction occurred.

Detailed site response analysis by the FEM (FLIP) and FDM (Elgamal Model, and NERA)

Present
Structure specific analysis base on the results of site response analysis

2017 - 2019
Provide guidance for safer and secure society against liquefaction in Northern Thailand
Introduction

- Earthquake on March 24, 2011
- Magnitude of 6.8 Mw
- Hit Border of Thailand-Myanmar
- Liquefactions near the border
- Liquefaction study should be one of the priority issues.
Fig. 3 Acceleration record of Mae Sai Station during the 6.8 $M_w$ earthquake on 24 March 2011\textsuperscript{6).}
Liquefaction Study in Northern Thailand is started

Soralump (2011)
Microtremor observation in Northern Thailand (Chiang Rai Province) (March, 2016)
Microtremor observation in Mae Sai (in March 2016) (@ expected borehole locations)
Field evidence of liquefaction in Mae Sai, Chiang Rai, Thailand
- Dominated by Sandy Soils
- Small value of (N1)60
- Fines Content less than 12%
- Higher Ground Water Level
- Liquefaction is probable
H/V spectrum by microtremor survey in Mae Sai
Comparison of the calculated HVSR and 2011 HVSR recorded at the closest station to epicenter
Inversion of HVSR (comparison of measured Vs and calculated Vs)

Comparison of Site HVSR and Inversed HVSR based on Vs data
Local site observation in Mae Lao (in March 2016)
H/V spectrum by microtremor survey in Mae Lao
Numerical analysis

This study focuses on Chiang Rai Province. 3 sites are investigated by SPT test and SASW test (TMD 2015). The sandy soils including SP, SM, SP-GM are dominant in this area with lower SPT value, and shallow ground water table. The distribution of grain size of these sandy soils are in range of liquefaction susceptible zone.

Simulate the propagated wave of maximum ground motion recorded at closest station (CR-3) using effective stress model (Elgamal et al., 2006).
METHODOLOGY

• Preliminary Analysis (desk study) : soil type, interpretation of soil layer, SPT value, Vs, and empirical analysis
• Ground motion of 2011 earthquake recorded at the closest station i.e. Mae Sai, with PGA maximum of 0.2g
• 1D Finite Element Effective Stress Model proposed by Elgamal et al. (2006)
• Predict the behavior of soil liquefaction, time histories analysis
Fig. 3 Acceleration record of Mae Sai Station during the 6.8 M\(_w\) earthquake on 24 March 2011\(^6\).
METHODOLOGY

- Effective Stress Model (Elgamal et al., 2006)

Effective stress path of shear strain model for sand under cyclic mobility (Elgamal et al., 2006)

Stress-strain curve of shear strain model for sand under cyclic mobility (Elgamal et al., 2006)

1D site response analysis

Modeling Criteria:
- The same size of each mesh, i.e. 0.5 m
- Only vertical seepage flow
- Water Table at ground surface
- Input Motion applied at base soil column
- No drainage on both lateral and base sides
- Soil column bottom is an elastic half space according to bedrock estimation from shear wave velocity
- Vertical and Horizontal deformation are allowable
- Lateral normal stress on boundaries are able to generate

\[ V_s = \lambda \cdot f = 4 \cdot d \cdot f \]
\[ f_{min} = \frac{V_{(shear)}}{4 \cdot d} \]
\[ f_{min} = \frac{V_{(shear)}}{4 \cdot d} \]
\[ f_{m} = \frac{140}{1} \]
\[ f_{m} = 140 \text{ Hz} \]

\[ d_{m} = \frac{\lambda \cdot f}{4 \cdot f_{min}} \]
\[ d_{m} = \frac{320}{140} \]
\[ d_{m} = 0.588 \text{ m} \]
\[ d_{m} = 0.5 \text{ to } 0.6 \text{ m} \]
\[ d_{m} = 0.5 \text{ m} \]
## Input material parameters

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<th>Thickness (m)</th>
<th>γ (kN/m³)</th>
<th>c (kPa)</th>
<th>φ (%)</th>
<th>FC permeability (k) (m/s)</th>
<th>Vs (m/s)</th>
<th>Ko (-)</th>
<th>p’ ref (kPa)</th>
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</table>

### Footnotes:
- Thickness values are in meters (m).
- γ represents the material density in kN/m³.
- c is the cohesion in kPa.
- φ is the internal friction angle in °.
- FC denotes the friction coefficient.
- Vs is the shear wave velocity in m/s.
- Ko is the effective stress parameter.
- p’ ref is the reference pore pressure in kPa.
- γmax is the maximum shear strain.
- Liq 1 is the liquid parameter.
- c1 and c2 are coefficients related to the material properties.
- d1 and d2 are additional parameters specific to each category.
Fig. 7 Liquefaction resistance curve comparison for all liquefiable layers from element simulations.
Pore water pressure and settlement due to liquefaction

CR-3

Liquefied depth
Maximum-minimum excess pore water pressure ratio

Maximum excess pore water pressure ratio during and after shaking

Minimum excess pore water pressure ratio during and after shaking
Conclusions (Numerical analysis)

Due to 24 March 2011 earthquake or Tarlay earthquake;

- Northern Thailand experienced heavy damage and catastrophic hazard. Liquefaction might be one of the major causes of disaster.
- Liquefaction was probable at upper 14 m layer of SP and SM with lower SPT-N value at CR-3 site.
- Based on the parametric studies, there are several factor influencing the excess pore water pressure ratio, such as fines content of soil type, and effective confining pressure.
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- Detailed site response analysis by the FEM (FLIP), Elgamal model and FDM (NERA)

Present
- Structure specific analysis based on the results of site response analysis

2017

2018 - 2019
- Provide guidance for safer and secure society against liquefaction in Northern Thailand
Possible future direction

KG-R Geotechnical Database for Osaka area
(SPT-N, soil classification, density, fines content with depth)

図9 関西地盤情報ライブラリー8)保存されている深度分布図と本研究で対象とする範囲(赤色網掛け)

Distribution of borehole depths in KG-R database

図15 最下端深度分布
Distribution of AVS30 obtained from the KG-R database

図19 AVS30から求められる地震応答倍率の分布
2016 Kumamoto Eq. K-Net (KMM005)

Site amplification factor by numerical analysis

図18 地震応答倍率の分布
Thank you for your attention.
RESULTS and DISCUSSION

- Liquefaction duration

  Liquefaction duration on liquefiable layer

<table>
<thead>
<tr>
<th>Site</th>
<th>Liquefaction Duration (s)</th>
<th>Maximum</th>
<th>Minimum</th>
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<td>40</td>
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<tr>
<td>CR-2</td>
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<td>39</td>
</tr>
<tr>
<td>CR-3</td>
<td>50</td>
<td>39</td>
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- Percentage of total $r_u$ on overall sand layers and impacted depth

  Percentage of $r_u$ in sand layer.

  Impacted depth based on $r_u$.

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<th>Total $r_u$ in overall sand layer (%)</th>
<th>Sites</th>
<th>CR-1</th>
<th>CR-2</th>
<th>CR-3</th>
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