A Study of Liquefaction Potential in Chiang Rai Province Northern Thailand

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Outline

• Introduction
• Study Area
• Methodology
• Results and Discussion
• Concluding remarks
Introduction

- Earthquake on 24 March 2011 (Magnitude of 6.8 Mw)
- Earthquake on 5 May 2014 (Magnitude of 6.1 Mw)
- Hit The Northern Thailand
- Liquefactions and other geotechnical hazards near the border were found as reported by Ruangrassamee et al. (2012), Soralump and Feungaugsorn (2013), Soralump et al. (2014)
- Intensive study of earthquake (liquefaction site response) was performed
- This study was focused on the first earthquake event (Tarlay Earthquake in 2011)
Impacts of the earthquakes in Northern Thailand

Liquefaction site response was performed to investigate soil behaviour during earthquake
Performing Site Investigation including SPT-N (boring log test) and Seismic Downhole (to generate shear wave velocity) in CR-1, CR-2, CR-3
Briefly explanation of the site investigation results

Sandy soils were dominant in the Northern Thailand. Loose to Medium Sands were found on depth of 0 to 15 m. Shallow ground water level at 1 to 3 m depth. Low Soil Resistance at the shallow depth ($N_1$)$_{60}$ less than 15. Site Class of the sites are classified as Class D (Stiff Soil) based on NEHRP (1998)
Methodology

Start

Literature Review

Data Collection
- Site Investigation Data (SPT-N, Soil Profile, and Shear Wave Velocity Data)
- Earthquake event data from TMD (2015)

One dimensional seismic ground response analysis using effective stress model (Cyclic 1D) proposed by Elgamal et al. (2006)

Results
- Soil behaviour during earthquake
- Liquefaction time stages (initial time, pore pressure dissipation, liquefaction duration)
- Prediction of impacted depth

Conclusion

Finish
One-dimensional modeling of 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 assumed as the fixed boundary
- Engineering bedrock is estimated at the bottom of borehole with $V_s > 760$ m/s
- Vertical deformations are allowable
- Horizontal displacements at both sides are the same
- Lateral normal stress on boundaries are able to generate

Mesh width derivation
- $d_{mesh}$ = $\frac{V_{s(min)}}{f_{min}}$
- $d_{mesh}$ = $\frac{329}{140}$ m
- $d_{mesh}$ = 0.588 m
- $d_{mesh}$ = 0.5 to 0.6 m
- $d_{mesh}$ = 0.5 m

Modelling assumption for seismic response analysis through to liquefiable layer

Illustration of effective stress path on granular material (After Elgamal et al. (2006))

Multi-yield surface of kinematic hardening yield locus in principal stress plane and deviatoric plane (After Parra, 1996)
Table 1 Input material in this study.

<table>
<thead>
<tr>
<th>BH</th>
<th>Material</th>
<th>Thickness (m)</th>
<th>$\gamma$ (kN/m$^3$)</th>
<th>$c$ (kPa)</th>
<th>$\phi$ (°)</th>
<th>FC (%)</th>
<th>$k$ (m/s)</th>
<th>$V_{s(ave)}$ (m/s)</th>
<th>$K_o$</th>
<th>$p'_\text{ref}$ (kPa)</th>
<th>$\gamma_{\text{max}}$ (%)</th>
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</table>

Note
- $\gamma$ and FC is saturated soil density and fines content, respectively
- $c$ and $\phi$ are soil cohesion and internal friction angle, respectively
- $k$ is permeability coefficient
- $G_s$ is saturated soil density
- $c_1$ and $c_2$ are contractive parameter
- $K_o$ is lateral earth pressure at rest
- $\gamma_{\text{max}}$ is peak shear strain
- $p'_\text{ref}$ is effective confinement pressure reference
- Liq is liquefaction parameter
- $V_{s(ave)}$ is the average shear wave velocity of soil layer
- $d_1$ and $d_2$ dilative parameter
Liquefaction Resistance for SP-SM and SC-SM Layers in Chiang Rai

“First and second layers vulnerable to undergo liquefaction”
Result and Discussion

- Maximum excess pore water pressure during the excitation
- Initial vertical effective stress of soil
- Pore water pressure 10s after the completion of excitation

Pressure (kPa)

Settlement due to liquefaction (cm)

CR-1

Depth (m)

Depth (m)

CR-1 (30 m)

GWL -0.0 m

CL

SC-SM

SP-SM

SM, SP-SM, SM-GM

30.00 m
Soil behaviour at CR-1 (SC-SM Layer) (3.5 m)
Maximum excess pore water pressure during excitation

Initial vertical effective stress of soil

Pore water pressure 10s after the completion of excitation

- Settled due to liquefaction (cm)

CR-2
Soil behaviour at CR-2 (SP-SM Layer) (4.5 m)
Soil behaviour at CR-2 (SP-SM Layer) (12.75 m)
Maximum excess pore water pressure during the excitation
Initial vertical effective stress of soil
Pore water pressure 10s after the completion of excitation

Settlement due to liquefaction (cm)

Depth (m)

Pressure (kPa)

CR-3

GWL -0.0 m

SP-SM

CR-3 (30 m)

3.00 m

15.00

30.00 m

SP-SM, SM-GM
Soil behaviour at CR-3 (SP-SM Layer) (1.5 m)
Soil behaviour at CR-3 (SP-SM Layer) (12 m)
Excess Pore Water Pressure Ratio ($r_u$) at Sites CR-1, CR-2, and CR-3 during the excitation and 10 s after the completion of the excitation.

- **During the excitation**
  - CR-1: 1.0
  - CR-2: 1.0
  - CR-3: 1.0

- **10 s after the completion of the excitation**
  - CR-1: 1.0
  - CR-2: 1.0
  - CR-3: 1.0
<table>
<thead>
<tr>
<th></th>
<th>Layers</th>
<th>Soil Type</th>
<th>Time taken in build-up liquefaction (sec)</th>
<th>Finished time of liquefaction (sec)</th>
<th>Duration of liquefaction (sec)</th>
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<td>CL</td>
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<td>0</td>
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<td>SC-SM</td>
<td>10</td>
<td>50</td>
<td>40</td>
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<td>Layer 1</td>
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<td>52</td>
<td>39</td>
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<td>Layer 2</td>
<td>SP-SM</td>
<td>17</td>
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<td>43</td>
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<td>SM-GM,GP</td>
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<td>SC</td>
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<td>60</td>
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</table>
\[
\text{Percentage of } r_u \text{ in sand layer} = \frac{N \text{ of mesh for } r_u}{N \text{ of total mesh}} \times 100\% 
\]

<table>
<thead>
<tr>
<th>( r_u ) criteria</th>
<th>( r_u \geq 1 )</th>
<th>( 0.9 &lt; r_u &lt; 1 )</th>
<th>( 0.8 &lt; r_u &lt; 0.9 )</th>
<th>( 0.7 &lt; r_u &lt; 0.8 )</th>
<th>( 0.6 &lt; r_u &lt; 0.7 )</th>
<th>( 0.6 &lt; r_u &lt; 0.5 )</th>
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**Table 4** Impacted depth based on \( r_u \).

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<th>( r_u ) criteria</th>
<th>Total Impacted depth (m)</th>
<th>CR-1</th>
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<td>( r_u \geq 1 )</td>
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<td>19.84</td>
<td>12.78</td>
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\[
H_{\text{impact}} = r_u \text{Percentage} \times H_{\text{total}} \text{ of sand layers}
\]
Concluding remarks

- Loose sandy soils with low soil resistance and shallow ground water level were found.
- Settlement due to liquefaction is about 1.8 to 4 cm at ground surface.
- The first and second sand layers were possibly impacted significant effect of liquefaction.
- The pore pressure after excitation was not easily drained (almost no significant difference in $r_u$ before and after excitation).
- The attention to the possibility of stronger earthquake in the future (the impacted depth might be possibly deeper).
- The countermeasure effort to shallow foundation should be performed to minimise the impact of liquefaction.
Acknowledgement

• Assoc. Prof. Dr. Suttisak Soralump from Dept of Civil Engineering, Kasertsart University for the relevant data and valuable suggestion
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Thank you very much for the attention (^^^^)