SAFETY OF FOUNDATION IN LIQUEFY SOIL OF MAE SAI

Fargseingsa Krisda[1*] Tor-nuang Woranat[1] Ittisak Yenpetch[1] Suttisak Soralump[2]
Tadashi Yamada[3]

[1]Graduated Student, Dept. of Civil Engineering, Faculty of Engineering, Kasetsart University
(50 Lat Yao Chatuchak Bangkok 10900)
[2]Assoc. Prof., Dept. of Civil Engineering, Faculty of Engineering, Kasetsart University
(50 Lat Yao Chatuchak Bangkok 10900)
[3] Prof., Dept. of Civil and Environmental Engineering, Faculty of Science and Engineering, Chuo University
(1-13-27 Kasuga, Bunkyo-ku,Tokyo 112-8551)

[*]E-mail: k.fargseingsa@gmail.com

On the 24th of March 2011, the earthquake occurred in northern of Myanmar which had a strong impact on the 6.8 magnitude earthquake and affected the country. Areas affected, Mae Sai district, Chiang Rai province in the north of Thailand. The geological conditions of the area were loose sand and it caused damage which changed sand layer from solid state to liquid state. As a result, the buildings and grounds in this area were strongly damaged. In Thailand, there is no standard foundation design to prevent a liquefaction. If the building is located on a high risk liquefied area, it must set a standard design for shallow foundation and pile foundations in this area which has a chance to be going to be an urban area in the future due to expansion of the city.

Key Words : *Liquefaction, Safety of Foundation in Liquefy Soil*

1. INTRODUCTION

1.1 Background

The Mae Sai district, Chiang Rai province was affected by the earthquake in 2011. The earthquake caused a geological phenomenon called "Liquefaction" which means the soil change from a solid state to a liquid state. As a result, water pressure inside the soil will increases and effective stress of the soil will decrease. This phenomenon makes the foundation, which is an important part of the whole building, collapse and this will damage the safety factor and cause more serious disaster.

The authors recognized this problem, In order to solve it we have to explore and investigate the liquefaction in Mae Sai and the safety of the foundation of the building in that area. And the optimal design of shallow foundations and pile foundations.

1.2 Scope and Purpose

Investigate a field in Mae Sai by collecting the samples from the soil layer in that area, and test all qualification in the laboratory have the risk of liquefaction and see it. Check the conditions of the buildings were damaged due to the liquefaction in Mae Sai and study underground structures and pile foundation from blueprints.

2. INSTRUMENTS AND PROCEDURE

2.1 Instruments

- Hand Auger
- Kunzelstab Test

2.2 Procedure

Soil samples were collected in Mae Sai by Hand Auger and Kunzelstab. The soil samples that were tested by using Atterberg's Limit and Sieve Analysis in order to determine the possibility of liquefaction in different areas using Liquefaction Potential Index (LPI).

There are 2 methods to calculate shear strength of shallow foundation, the first is punching shear analysis, the second is terzaghi bearing capacity. In order to calculate shear strength of pile foundation without friction on the surface of the long column used the relationship between peak ground acceleration (PGA) and compressive shear failure of concrete. Design chart was developed to provide a standard design for the foundation in area with a risk of liquefaction.

3. LIQUEFACTION POTENTIAL AREA ANALYSIS

Liquefaction potential index (LPI) was developed by Iwasaki et al. in 1978 to predict the potential of liquefaction.

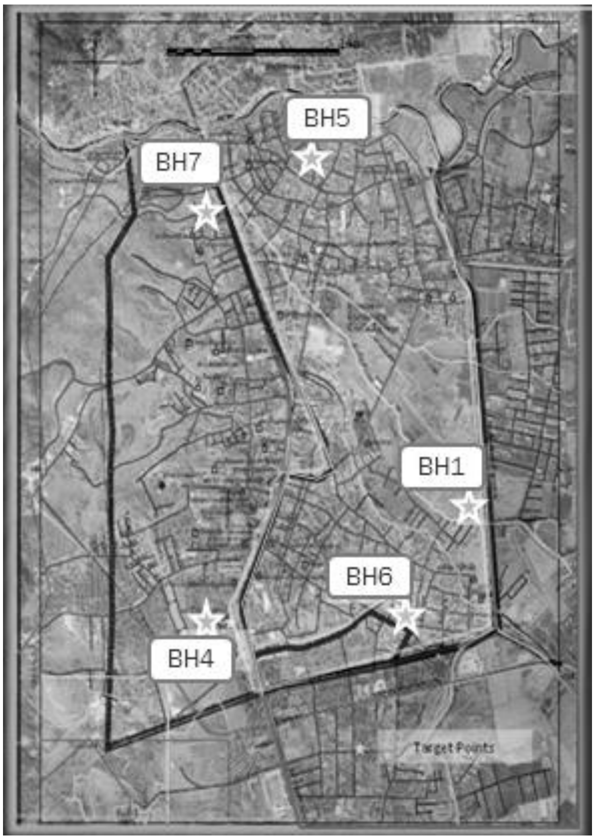


Fig.1 Investigation borehole (BH) in Mae Sai district, Chiang Rai province

Table.1 Liquefaction potential index with a risk of liquefaction occurrence

LPI	Iwasaki et.al (1982)	Luna & Frost (1998)	MERM (2003)
LPI > 15	Very High	Major	High
5 < LPI < 15	High	Moderate	Medium
0 < LPI < 5	Low	Minor	Low
LPI = 0	Very Low	Little to none	None

Table.2 Liquefaction potential index in each borehole

BH	LPI
1	Non – Liquefy
2	12.43
3	Non – Liquefy
4	CL
5	Non – Liquefy
6	6.378
7	CL

LPI values were found in the area of Mae Sai and the type of soil, there is mainly clay. Therefore, liquefaction hardly happens in this area. BH-2 is the place where liquefaction happened in 2011. Because LPI value at BH-2 is high, liquefaction frequently happens there.

4. DESIGN AND ANALYSIS OF SHALLOW FOUNDATION IN LIQUEFATION AREA

4.1 Analysis of the former foundations in the liquefaction.
Foundations in liquefied soil were analyzed in 2 cases
Case 1: Punching Shear Analysis by means of punching shear of foundation that vertically are given the liquefied soil, which the data of force and foundation's size from the field investigatation.
Case 2: Terzaghi Bearing Capacity by determine in the way of 2 layers of soil, the shear strength due to friction and the weight of the soil over the foundations have very light and assuming liquefied soil layer has $c_2 = 0$.

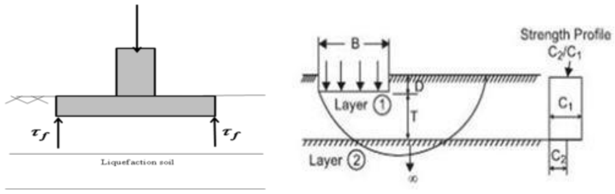


Fig.2 Shallow Foundation Analysis in Liquefied Soil

where *Layer1* is soil layer, which liquefaction does not occur. *Layer2* is liquefied soil layer. *T* is perpendicular distance between the bottom of foundation and the surface of liquefied soil layer. *B* is foundation width.

The results in both cases considered about foundations of one-storey building, which measures in 0.8 × 0.8 m^2. Load to the foundations are 6 tons per column. BH-2 is the place where liquefaction happened, both Punching Shear Analysis and Terzaghi Bearing Capacity and found that the safety factors are 0.953 and 0.667 respectively, which are too low.

4.2 The design of foundation for 1-3 storey house in liquefaction area

At present, there is no standard design of optimal size for building foundations analyzing both punching shear analysis and the terzaghi bearing capacity. The authors develop the design chart for the design and construction in liquefaction area, Mae Sai.

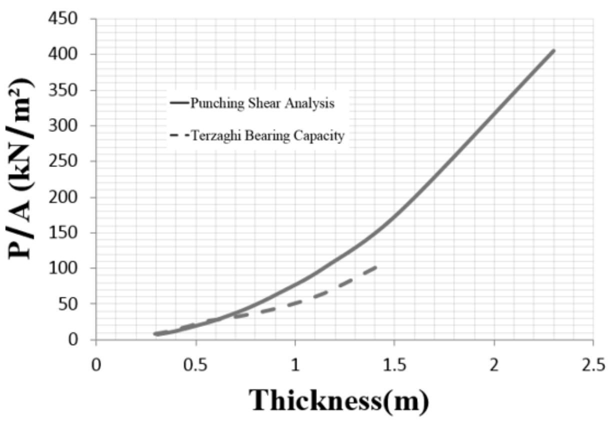


Fig.3 One-storey house relationship graphs between stress and thickness of soil layer under the bottom of the footing to the surface of liquefied soil

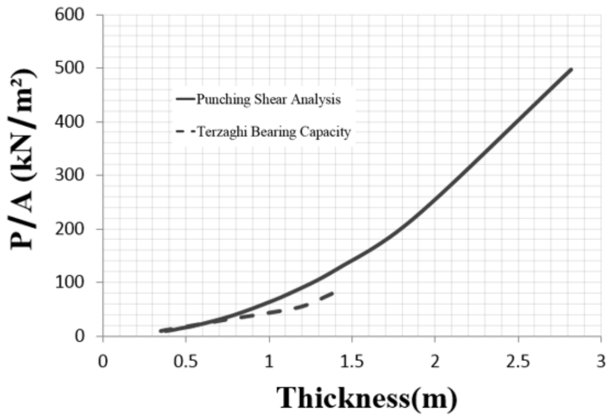


Fig.4 Two-storey house relationship graphs between stress and thickness of soil layer under the bottom of the footing to the surface of liquefied soil

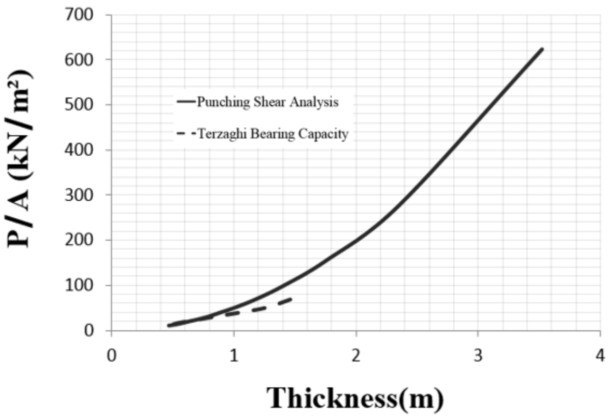


Fig.5 Three-storey house relationship graphs between stress and thickness of soil layer under the bottom of the footing to the surface of liquefied soil

5. DESIGN AND ANALYSIS OF PILE FOUNDATION IN LIQUEFATION AREA

5.1 Design of pile foundation

In case of Mae Sai district, Any building in this area do not have pile foundation. A case study for pile foundation, the authors used the data of existing four-storey building which is 35 tons load to the column as shown in **Fig.6**. The result of the optimal pile foundation is 0.45 m^2 cross section and 6 m length.

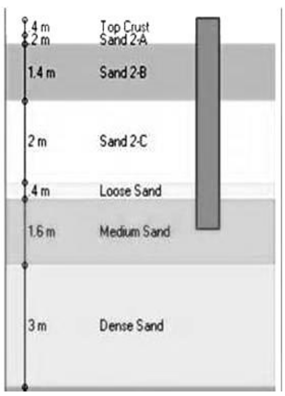
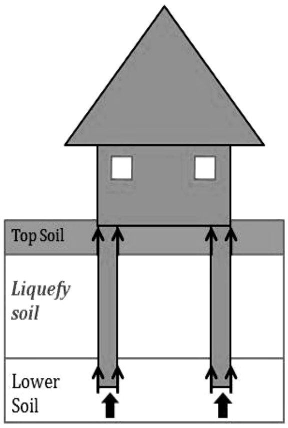


Fig.6 The design of pile foundations



In addition, the liquefied soil layer has no friction against the surface of the pile foundation. Therefore, it is necessary to design by regarding the pile in the liquefied soil similar to the long column as reinforced concrete design method. The calculation results shows that the design of pile can be supported up to 410.1 tons

Fig.7 Pile foundation analysis in liquefied soil

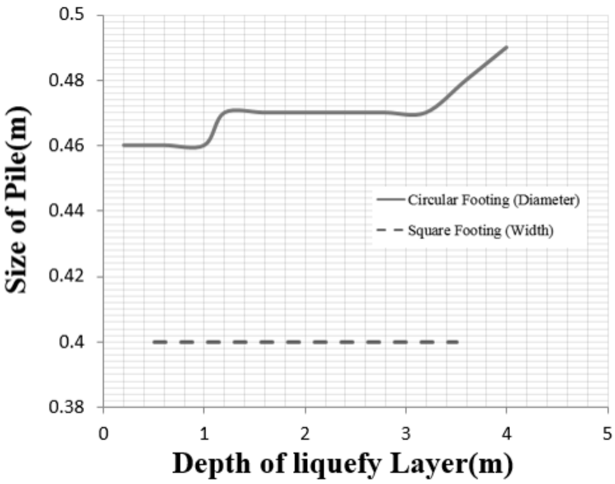


Fig.8 Relationship graph between optimal pile width and thickness of liquefy layer

Design chart in Fig.8 is a result of the analysis of single pile in the liquefied soil that will not make the pile failure. Thus, a pile with 0.159 m^2 cross section, a pile with 0.45m diameter and rectangular pile with a minimum width of 0.40m, can be applied to the design.

Practically, a pile with 0.159 m^2 cross section and pile with 0.45m diameter are quite rare. In general, pile type I18 and I22 are used popular but those types cannot support strength the building to the pile. Thus, we designed both types into pile group as shown in **Fig.9** and **Fig.10**

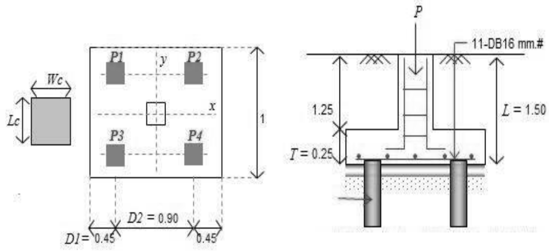


Fig.9 I18 pile group designation

It is necessary to use 4 columns of I18 type instead of a single rare pile.

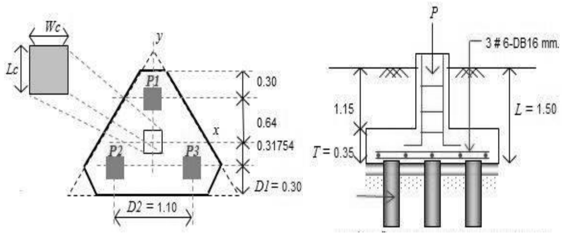


Fig.10 I22 pile group designation

It is necessary to use 3 columns of I22 type instead of a single rare pile.

Case 2: Liquefaction phenomenon is caused by a massive earthquake. The authors considered about the shear force in pile due to peak ground acceleration (PGA) that shown in **Fig.11**, the appropriate sectional dimension is computed by the Shear Stress, which less than ultimate compressive stress of concrete shown in **Fig.12**.

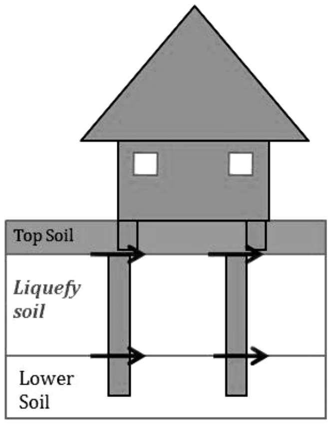


Fig.11 The failure of the pile from shear force

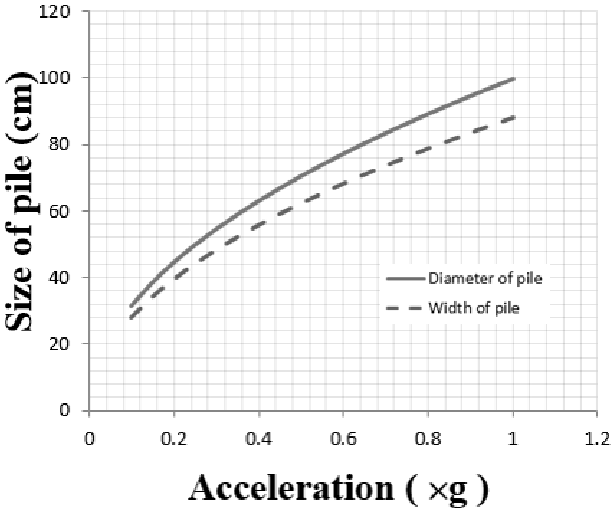


Fig.12 Relationship graph between peak ground acceleration and optimal pile width

6. CONCLUSIONS

1. From testing in laboratory with grain size analysis, specific gravity theory and using liquefaction potential rate (LPI). As a result, only hole at BH-2 was liquefied and in accordance with this area, liquefaction occurred in 2011.
2. From analysis of with punching shear analysis and Terzaghi bearing capacity. The model design of a house was analyzed and found that the building foundation will be damaged when liquefaction occurs

REFERENNCES

1) Geological Engineering Research and Development Center, *The 6.8 Magnitude of Earthquake in the Union of Myanmar*, Faculty of Engineering, Kasetsart University, 2013
2) Ukritchon Boonchai, Sangkhawilai Tawatchai, *Analysis of liquefaction potential for Bangkok First Sand Layer*, Chulalongkorn University, 2011
3) Kamalesh Kumar, *Basic Geotechnical Earthquake Engineering*, Birla Institute of Technology and Science, 2008
4) Alisha Kaplan, *Soil Liquefaction*, Mid-America Earthquake Center and Georgia Institute of Technology, 2004
5) Horpicul Sukson, *Foundation Engineering*, 2003