Literature Review: Potential of Liquefaction Hazards on Saturated Loose Sand with Shaking Table Large Scale Test

Siti Prizkanisa, Widjojo Adi Prakoso and Dandung Sri Harninto

July 28, 2020

Literature Review: Potential of Liquefaction Hazards on Saturated Loose Sand with Shaking Table Large Scale Test

Siti Prizkanisa[1*], Widjojo Adi Prakoso[1], Dandung Sri Harninto[1]

[1] Affiliation Faculty of Engineering, Universitas Indonesia, Depok 16424, Indonesia
*e-mail: siti.prizkanisa81@ui.ac.id

Abstract. *Liquefaction is the melting process of the soil due to excess pore water pressure in the soil cavity during an earthquake. There are many test methods to determine the potential hazards of liquefaction, one of them is the large scale shaking table test. The purpose of this literature study is to look at the potential hazards of liquefaction by conducting an experimental study modeling the liquefaction of saturated loose sand in a large scale shaking table test. From the existing literature study it was found that the large scale shaking table test had several advantages in seeing the potential hazards of liquefaction. With the addition of instrumentation such as an electric piezometer and an accelerometer mounted on the shaking table, it can help in quantifying the mechanism of liquefaction quantitatively as seen from the ratio of the increase in excess pore pressure and the maximum ground acceleration.*

Keyword: liquefaction, shaking table, excess pore water pressure, saturated loose sand

Introduction

Liquefaction is the process of melting of the soil due to excessive air pressure in the soil cavity due to an earthquake. When an earthquake occurs, saturated sand repeated shear stress from earthquake movements. This movement changes the state of the soil from solid to liquid when the effective stress disappears with increasing excess pore water pressure. When there is a cavity between grains of saturated sand that experiences repeated shear stress from earthquake motion, hollow sand will try to make it denser, reduce volume (Kansai University, 2017). Excess water pore pressure reduces shear strength in extreme soils. Seed and Lee (1966). Liquidation will occur compilation of pore water pressure ratio (r_u) of more than 1 ($U_{excess} = \sigma'_{3c}$ atau $r_u = 100$ %).

The United States Geological Survey (USGS) refers to a number of factors that are conditional on liquefaction in several areas, namely:

1. Loose sand 0.1-1.0 mm in diameter
2. Low density sedimentary soils (N-value <20-25).
3. A layer of soil that has been saturated with air
4. An earthquake occurred (100-150 Gal or more). Vertical vibrations of <50 Gal can also cause liquefaction.

Apart from excess pore water pressure due to the influence of soil behavior it is also very important to know in order to see the potential liquefaction hazards that can be caused. There are many test methods to determine the potential hazards of liquefaction, one of which is the large scale shaking table test. This literature study was carried out aimed at seeing how the potential danger of liquefaction by conducting an experimental study modeling the liquefaction for saturated loose sand in large scale shaking table tests.

Materials and Methods

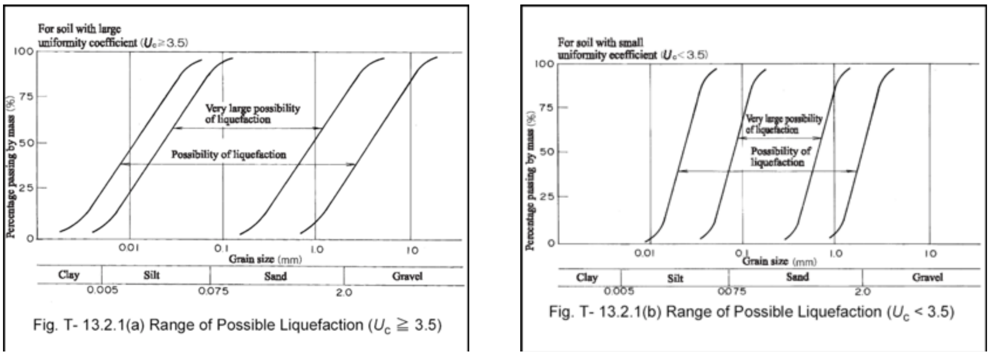
Saturated Loose Sand

The soil sample used in this test is saturated loose sand according to the criteria for potentially liquefied soil. One of the soil behaviors that affect the mechanism of liquefaction is the relative density of sand. It can be seen in Table 1. Soil types can be classified based on their relative density. Loose and very loose soils tend to have potential for liquefaction hazards.

Table 1: Description of soil grains based on relative density and porosity (Muni Budhu in Soil Mechanic 3rd Edition)

Dr (%)	Porosity, n (%)	Description
0 – 20	100 – 80	Very loose
20 – 40	80 – 60	Loose
40 – 70	60 – 30	Medium dense or firm
70 – 85	30 – 15	Dense
85 - 100	< 15	Very dence

Poorly graded sand will be more likely to experience liquefaction. In figure 1 (a). shows that silt to silty sand types have the potential to experience significant liquefaction for soils with Cu≥3.5, whereas soils with Cu <3.5 only sand type soils that have the potential to experience large liquefaction are shown in Figure 1 (b). The coefficient of uniformity is an important factor to be able to see the good or bad gradation of the soil.



(a) (b)

Figure 1: Grain size that allows liquefaction (a) for soils with large uniformity efficiency (b) for soils with low uniformity efficiency

Shaking Table Test Method

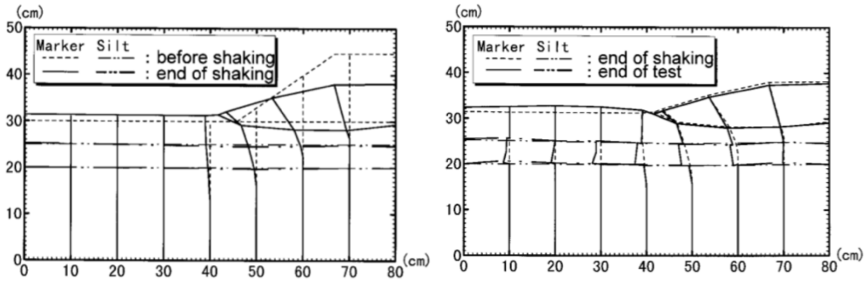
Shaking table test to see the mechanism of liquefaction has been carried out by several researchers, including by Kokusho (1999) and Bimawijaya Laia (2014). Both of them are modeling liquefaction in a container placed on a vibrating table. The importance of instrumentation that will be installed on the test equipment needs to be considered in more detail. One of the benchmarks to determine liquefaction in soil samples is to see the ratio of the increase in excess pore water pressure. To find out the ratio of the increase in excess pore water pressure, several electrical piezometers are installed in different depths in a container containing soil samples. Also on the shaking table is an accelerometer to determine the maximum ground acceleration produced due to the effects of the earthquake created. The vibration effect itself is produced from shaking tables that move automatically using electricity and can be controlled loading provided so that it can produce maximum ground acceleration that is stable and as desired.

The potential danger of liquefaction can also be seen from the physical condition of the soil sample. For this reason, it is necessary to make some differences from the soil sample, such as variations in grain grading and the relative density of the sample being tested.

Results and Discussion

The method of using a shaking table test is an effective way to see the mechanism of liquefaction. Both literatures use large scale shaking table test equipment with complete instrumentation to get results that resemble the field. Kokusho (1999) can show the deformation that occurs during a given vibration and after the vibration is complete which is shown in Figure 2. The trials conducted indicate the possibility that ground motion can still take place after the vibration is complete.

The excess pore water pressure is also shown at several different depth points by varying the relative density of the sample in each test. Can be seen in Figure 3. after the maximum pressure occurs the pore water pressure does not immediately decrease drastically to zero but slowly decreases and becomes lost.



(a) (b)

Figure 2:. Deformation of horizontal sand layer (a) During shaking (b) After shaking.

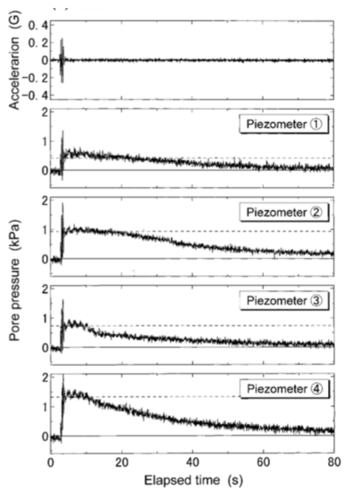


Figure 3: Effect of time history on excess pore pressure with a piezometer mounted at different depths.

In the research conducted by Bimawijaya Laia (2014), the results of analysis showed that sand with a relative density of 25% given a vibration of 0.3g has the potential to experience liquefaction, which is indicated by the continued increase in pore pressure (ru ≥1) as shown in Figure 4. The same thing happened in tests with a relative density of 35%, but in tests with a relative density of 45% and 55% there were no significant soil changes in sand during loading.

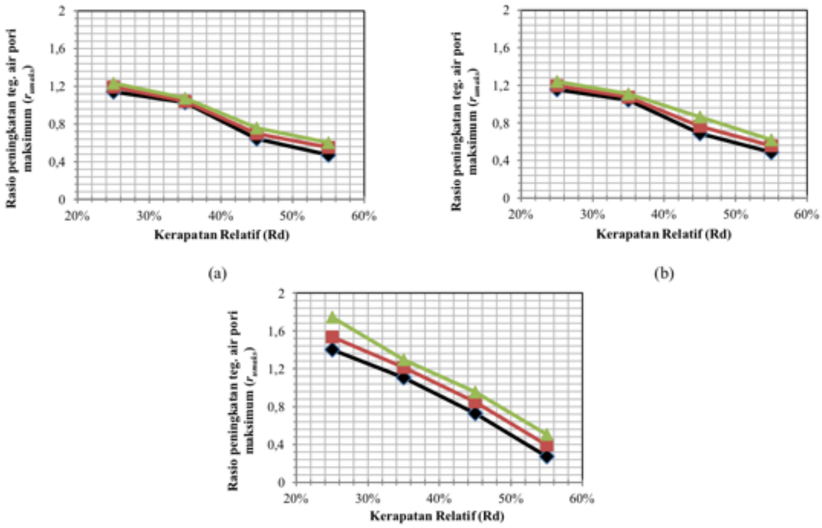


Figure 4: Effect of relative soil density (Rd) on the ratio of maximum pore water tension increase (rumaks) to the reader: (a) pressure transducer I (PT I); (b) pressure transducer II (PT II); (c) headmeter (HM)

Figure 5 shows that there is a change in soil volume when the relative density of the soil changes. Soil volume will decrease significantly along with the reduction in the relative density of the soil marked by a decrease in land surface. Conversely, soils that have a high density of soil volume do not decrease as much as soils with relatively low density.

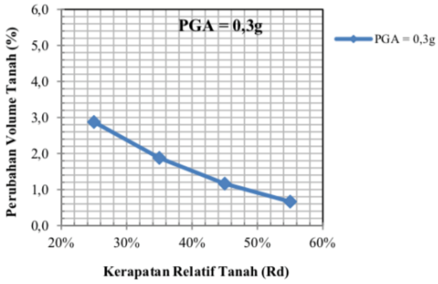


Figure 5: the effect of relative soil density on changes in soil volume (%)

Both literatures have described how a large scale shaking table test can show detailed test results. The characteristic of volume change in the soil sample being tested is one of the benchmarks to see the liquidation mechanism that occurs. In this large scale shaking table test, it is more pronounced, namely the specific behavior of the soil when volumetric changes occur after the shift occurs.

Conclusion

Potential liquefaction hazard is usually known by shaking table test which varies the relative density of the soil sample. If the size of container for the sample is too small, it will be difficult to make the desired relative density, otherwise using a large medium of soil will be easily compacted to get the planned relative density. By looking at some of the literature studies that have a large-scale shaking table test have several advantages in seeing the potential danger liquefaction. Like soil samples can be easily put into a container, with a large enough container used for testing soil samples can also be compacted easily for get the desired relative density during testing.

This large scale shaking table test model can also be easily seen from a variety of different perspectives during the test. With the addition of instrumentation such as an electric piezometer and an accelerometer mounted on the shaking table, it can help in quantifying the mechanism of liquefaction quantitatively as seen from the ratio of the increase in excess pore water pressure and the maximum ground acceleration resulting from the vibrating effect created.

Reference

[1] B. Laia, "Pengaruh Kerapatan Tanah Pasir Kali Opak Pleret Yogyakarta Terhadap Potensi Likuifaksi Berdasarkan Uji *Shaking Table*", *Jurnal Universitas Gajah Mada,* 2014.

[2] H. B. Seed, K. L. Lee, "Liquefaction of saturated sands during cyclic loading", *Journal of the Soil Mechanics and Foundations Division, v*ol. 92 no. SM6, pp. 105-134, 1966.

[3] H. B. Seed, P. P. Martin, and J. Lysmer, "Pore-water Pressure Change During Soil Liquefaction", *Journal of Geotechnical Engineering Division*, vol. 102 no. 4, pp. 323-346, 1976.

[4] H. Tsuchida, "Prediction and countermeasure against the liquefaction in sand deposits*", Abstract of the seminar in the Port and Harbor Research Institute*, pp. 3.1-3.33 (in Japanese), 1970.

[5] Kansai University, "The Fukushima dan Tohoku Disaster Chapter 8 : Liquefaction With The Great East Japan Earthquake*,* Kansai University, School of Societal Safety Sciences 147-159, 2018.

[6] M. Budhu, "Soil Mechanics and Foundation 3rd Edition*"*, 2010.

[7] T. Kokusho, "Water Film in Liquefied Sand and Its Effect on Lateral Spread*, Journal of Geotechnical and Geoenviromental Engineering*, vol .125, no. 10, pp. 817-826, 1999.

[8] S. L. Kramer, "Geotechnical Earthquake Engineering*", Prentice-Hall International series in Civil Engineering and Engineering Mechanics*. Upper Saddle River, New Jersey 07458, 1996.

[9] USGS, "Landsat 8 Fact Sheet". Amerika Serikat: U. S. Geological Survey, 2013.