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LIQUEFACTION POTENTIAL ASSESSMENT BASED ON LABORATORY TEST

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ABSTRACT: The physical properties of sand soil which give effect to the resistance of liquefaction include grain size and density. Those physical properties of sand soil associated to liquefaction resistance have been studied in laboratory. Based on that study, the method to assess the liquefaction potential then is proposed. In laboratory tests, the vibration source is given by using the shaking table. During the tests, the acceleration and settlement are recorded. It then concluded that there is a relationship between density and gain size particles associated with liquefaction resistance for certain acceleration of vibration. The cone penetration and relative density relationship has been developed based on experiments in laboratory. Based on the results of those laboratory tests, the liquefaction potential of a certain site then assessed. It is found that the relative density and mean gain size relationship can be used to assess liquefaction potential in sand deposits.

Keywords: Liquefaction, Earthquake, Soil particle size, Relative density, Laboratory test

1. INTRODUCTION

The liquefaction potential assessment in a soil deposit is an important aspect of geotechnical earthquake engineering practice since Niigata earthquake in 1964. Based on the occurrence of liquefaction and field test data a method named "simplified method" was proposed [1]. The liquefaction potential assessment at the coast of Padang using 'simplified method' has been presented [2]. The application of this method actually is not as simple as its name. It involves many factors that rarely used in civil engineering such as earthquake magnitude and depth factor. This procedure has been continuously improved based on a number of liquefaction histories around the world [3]. Based on these methods, further Shibata and Teparaksa [4] developed a method for evaluating the liquefaction potential based Cone Penetration Test results.

The analysis of liquefaction susceptible using Cone Penetration data at several locations in the city of Padang due to the 2009 earthquake has been presented [5]. Although these penetration-based methods (SPT and CPT) and cyclic stress ratio are well developed, but in the use still require advanced knowledge in choosing the parameters as discussed in [6].

The application of liquefaction potential by using the data of mean grain size and standard penetration test values has been demonstrated [7]. In this study, the mean grain diameter is used for determining in undrained cyclic resistance. The results of that study are presented in the liquefaction potential maps.

In the past it has been summarized that the newly deposited loose sands under the shallow ground water are susceptible to liquefaction [8]. Kramer in 1996 [9] has summarized a number of methods to evaluate the liquefaction potential of a soil deposit. Those are the liquefaction history, the geological process, the soil type and fine size particles, soil density and effective stress at the time it is subjected to shaking. It has been summarized number of factors that affect soil liquefaction resistance in [10], that are:

- Relative density, D_r
- Initial stress of the soil, S_i
- Mean grain size of the soil, D_{50}
- Applied peak acceleration, a_{max}
- Duration of the motion, t
- Over consolidation ratio, OCR
- Initial pore pressure, u_i

Even though historically, sands were considered to be the only type of soil susceptible to liquefaction, but observation showed that fine-grained soil also been suffered from liquefaction. The fine-grained soils may have a tendency to liquefy under a vibration load if they satisfy the Chinese criteria [11] that are:

- Fraction < 0.005 mm less than 15%
- Liquid Limit, LL less than 35%
- Natural water content more than 0.9 LL
- Liquidity Index less than 0.75

Based on the grain size analysis test from several location due to Kocaeli earthquake in Turkey in 1999 [12] and due to Padang earthquake 2009, it have been reported the results of sieve analysis tests of liquefied soil samples as shown in Figure 2 (shadowed). The soil gradation of Padang is just in the middle of liquefaction boundaries from Aydan. The distribution of liquefied soil particle in Padang generally composed fine sand more than 60%. The fine content of liquefies soil of Padang is less than 20%. The mean grain size D_{50} is about 0.15mm to 0.35mm.

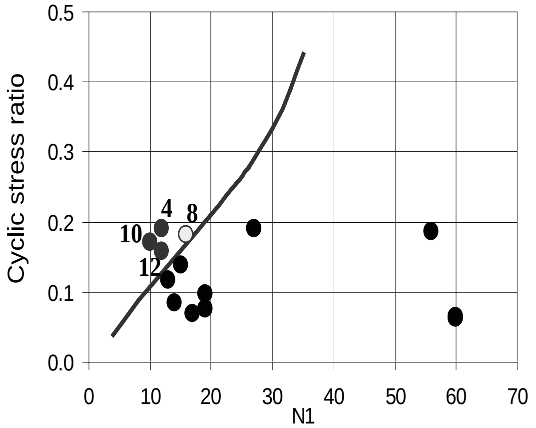

Fig. 1 Liquefaction using 'simplified method' [2].

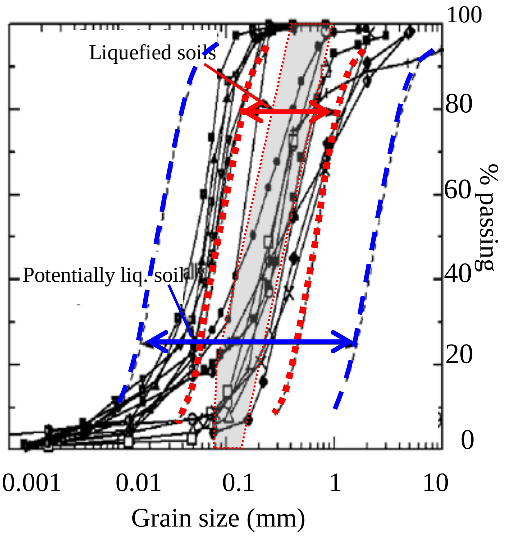

Fig. 2 Grain size limit for liquefaction [10].

Based on the field case histories on evaluation of liquefaction potential for 50-year around the world [13], mean grain size of liquefied soils are presented in Figure 3. It can be seen that from those 155 occurrences of liquefaction, 78% of liquefaction happened on the soil with mean grain size between 0.113 to 0.338 mm.

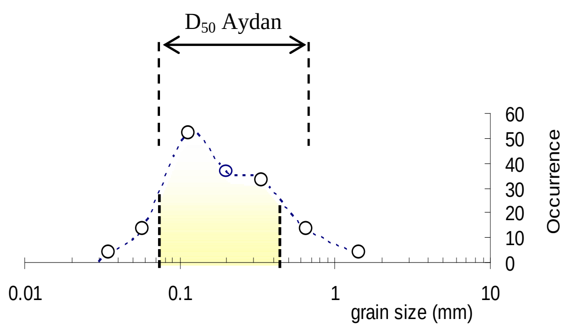

Fig. 3 D_{50} for liquefied soils, based on [12].

Therefore, this study is conducted to find out a relationship between density and gain size particles associated with liquefaction resistance for certain acceleration of vibration which is simply can be used to assess liquefaction potential of soil deposits. The simple liquefaction potential assessment is important to have good estimation of the liquefaction problem. In this paper, the application of liquefaction potential assessment based on laboratory experiments is presented. The factors have been considered in the laboratory experiments are:

- Relative density, D_r
- Cone resistance of the soil, q_c
- Mean grain size of the soil, D_{50}
- Applied peak acceleration, a_{max}
- Duration of the motion, t

2. LABORATORY TEST RESULTS

A series of laboratory testing has been done by placing indicator bar on soil samples in the round container. In these tests the relative density D_r and the mean grain size D_{50} are varied. The samples are placed on the shaking table and then vibrated for 0.3g and 0.6g accelerations. During the testing the acceleration and the settlement of the indicator bar are recorded. The acceleration of 0.3g is the same as the maximum acceleration of the Padang earthquake in 2009. Meanwhile the value of 0.6g is the maximum acceleration for Padang city according to Indonesian code.

In field liquefaction, a seismic shaking can cause sand deposit to loose its contract and increase the water pore pressure. It happens because the seismic shaking occurs relatively fast and the soil performs an undrained loading. If soil has reached liquefaction condition then the effective stress in soil mass is decreased hence its shear strength can drop. In the liquefaction the individual soil particles are released from any confinement [14].

The same phenomenon in these experiments when liquefaction occurs in the sample, the shear strength of the soil dropped thus the indicator bar will settle down during the shaking. The rate of settlement during shaking is approximately 0.1 cm/sec is taken as the separation criterion of settlement rate values. The rate settlement more than 0.1 cm/sec indicated that liquefaction has happened in this saturated soil samples. The general results of the tests are shown in Figure 4. The linear boundary line is made up for each acceleration 0.3g and 0.6g.

Since Cone Penetration Test is very famous in practice, the q_c – D_r relationship become essential for liquefaction potential analysis based on Cone Penetration Test (CPT). The calibration studies of the q_c is effected by sand density, in-situ effective stress and sand compressibility. Sand compressibility is controlled by grain characteristics, such as grain size, shape and mineralogy. The q_c – D_r relationships for sand then is written as follows [15]:

$$Dr = C_2^{(-1)} \ln Q/C_0 \qquad (1)$$

Where C_0=15.7, C_2=2.41 and $Q=(q_c/p_a)/(s'/p_a)^{-0.5}$. Here p_a is reference pressure taken as 100kPa, in the same unit as q_c and s'.

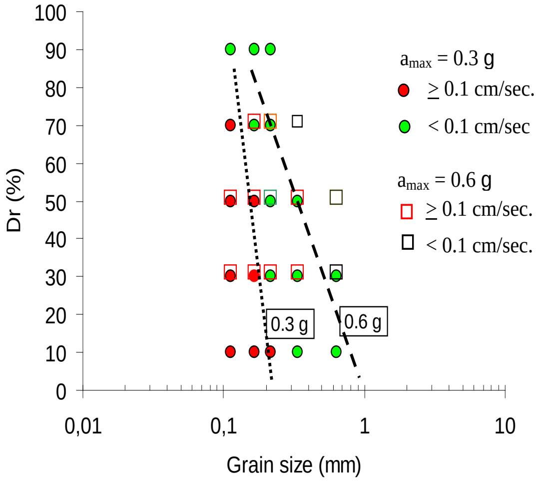

Fig. 4 D_r – D_{50} for liquefaction test.

3. LIQUEFACTION ASSESSMENT

During Padang earthquake 2009 with the maximum acceleration of 0.3g, there are many locations along the shore suffered from liquefaction. Soil liquefaction induced by the M7.6 of Padang earthquake has contributed to damage of houses dan many facilities including roadway, river bank, sport court and play ground. The liquefactions on sites of Padang were indicated by sand boils right after the earthquake were observed on a number of sites as shown in Figure 5.

One of those location is Pasir Jambak district where has sand deposit and very shallow water table. The field soil testing using Cone Penetration Test (CPT) has been conducted. The soil samples also have been taken from the site to investigate soil particle distributions. The test results are presented in Figures 6 and 7.

Table 1 shows the mean grain size of sand which is determined from the grain distribution chart and relative density is calculated using equation (1) with the unit volume of 12 kN/m^3.

Both values of Relative density, D_r and Mean grain size, D_{50} are then plotted in the 'Liquefaction Chart' as shown in in the Figure 8. The maximum acceleration of Padang earthquake is about 0.3g. It shows that point $D_{0.5}$ just in the 0.3g line which confirmed that the liquefaction happened during the 2009 earthquake.

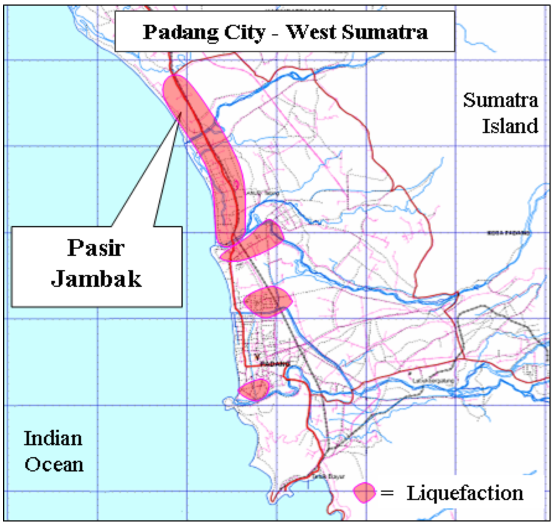

Fig. 5 Liquefaction in Padang due to earthquake 2009.

Table 1 Parameter for liquefaction assessment

Name	Dept (m)	D_{50} (mm)	q_c (kg/cm^2)	D_r (%)
$D_{0.5}$	0.5	0.2	17	3
$D_{1.0}$	1.0	0.25	25	5
$D_{1.5}$	1.5	0.25	50	25
$D_{2.0}$	2.0	0.25	65	30

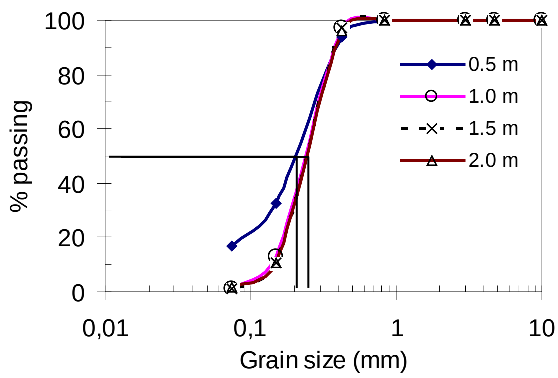

Fig. 6 Particle distribution of Pasir Jambak sand.

In the same chart it also shows the line of acceleration of 0.6g which the maximum acceleration for Padang city in Indonesian Code. The points are under the line of 0.6g which indicated that the site is prone to liquefaction in case of future earthquake according to the code.

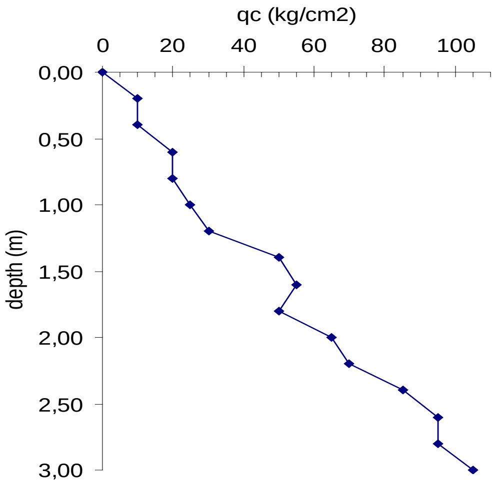

Fig. 7 CPT of Pasir Jambak.

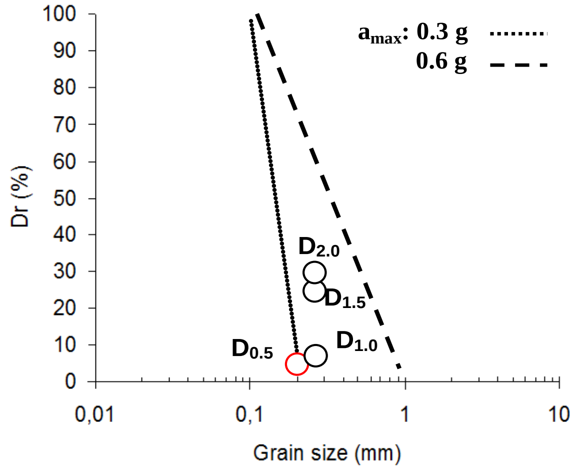

Fig. 8 D_r – D_{50} for Pasir Jambak assessment.

4. CONCLUSION

This paper presented that relative density and mean particle size can be associated with the liquefaction susceptibility of soil deposits. Liquefaction resistance of the sands increases with the relative density and mean particle size. Both relative density and mean particle size give unique relationship for resistance of sand soil against shaking.

Here, the liquefaction assessment of Pasir Jambak deposit due to the Padang earthquake 2009 is presented. It is shown that the sand deposit in a certain depth is potential to liquefaction due to 0.3g earthquake. The sand on the site for all depth is also predicted may be liquefied due to the earthquake with the maximum acceleration of 0.6g.

This analysis shown in this paper is practically simple to estimate the liquefaction potential. Thus the relationship Relative density and Mean grain size chart further can be used to assess liquefaction potential in any certain sand deposits.

5. REFERENCES

[1] Seed, H. B., and Idriss, I. M., ‘‘Simplified procedure for evaluating soil liquefaction potential.’’ J. Geotech. Engg. Div. , ASCE, 97(9) , 1971, pp 1249–1273

[2] Hakam, A. and Darjanto, “Liquefaction potential assessment of Padang Beach Based on grain size and standard penetration resistance” (in Indonesia: Penelusuran Potensi Likuifaksi Pantai Padang Berdasarkan Gradasi Butiran dan Tahanan Penetrasi Standar), Jurnal Teknik Sipil – ITB, Vol. 20 No. 1, April 2013, pp. 33-38

[3] Seed, H. Bolton dan Idriss I.M., Ground Motion and Soil Liquefaction During Earthquake, Earthquake Engineering Research Institute, Berkeley, 1982

[4] Shibata, T. and Teparaksa, W., “Evaluation of liquefaction potential of soils using cone penetration tests”, J. Soils and Foundations, Vol. 28., N0. 2, 1998, pp. 49-60

[5] Hakam, A., “Soil Liquefaction of Padang due to Padang Earthquake 30s’09”, The Journal of Civil Engineering Dimension, Volume 14, no 2, 2012, pp. 64-68

[6] Youd, T. L. and Idriss, I. M. (2001). “Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshop on evaluation of liquefaction resistance of soils”, J. Geotechnical and Geoenvironmental Engg., ASCE, April 2001, pp. 297-313

[7] Habibullah B Md. , Pokhrel, R. M. , Kuwano J. and Tachibana S. , “GIS-Based Soil Liquefaction Hazard Zonation due to Earthquake Using Geotechnical Data”, Int. J. of GEOMATE, March, 2012, Vol. 2, No. 1 (Sl. No. 3), pp. 154-160

[8] Day R. W., , Geotechnical Earthquake Engineering Handbook, The McGraw-Hill Comp., 2002

[9] Kramer,S.L., Geotechnical Earthquake Engineering. Prentice Hall, Englewood Cliffs, N.J., 1996

[10] Das, BM., , Fundamental of Soil Dynamics, Elsevier Pub., New York, 1983

[11] Wang, W. S., “Some Findings in Soil Liquefaction”, Report Water Conservancy and Hydroelectric Power Scientific Research Institute, Beijing, China, August 1979, pp. 1-17.

[12] Aydan, O., Ulusay, R. and Atak, VO., “Evaluation of ground deformations induced by the 1999 Kocaeli earthquake (Turkey) at

selected sites on shorelines", Environ Geol (2008) 54. , 2008, pp. 165–182

[13] Cetin K. O., Seed R. B., Moss R. E. S., Der Kiureghian A., Tokimatsu K., Harder, Jr. L. F., and Kayen R. E., , Field Case Histories for SPT-Based In Situ Liquefaction Potential Evaluation, Geotechnical Engineering Research Report No. UCB/GT-2000109, Department of Civil and Env. Engineering, California University, Berkeley., 2000

[14] Ishihara. K., "Stability of Natural Deposits during Earthquakes", Proc. The 11th International Conf. on Soil Mechanics and Foundation Engineering, San Francisco, 1985, Vol. 1. pp. 321-376

[15] Robertson P. K. and Cabal K.L., Guide to Cone Penetration Testing, GREGG inc., 2010.

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