

IOP_Conf.Ser.Earth_Environ.2021_-_Tri_Harianto_2_.pdf

by

Submission date: 29-Jan-2022 10:25AM (UTC+0700)

Submission ID: 1750409950

File name: IOP_Conf.Ser.Earth_Environ.2021_-_Tri_Harianto_2_.pdf (925.34K)

Word count: 1971

Character count: 10114

PAPER · OPEN ACCESS

Evaluation of potential liquefaction based on Cone Penetration Test (CPT) data

To cite this article: R Amaliah *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **921** 012061

View the [article online](#) for updates and enhancements.

You may also like

- [Liquefaction Resistance of Sand Mixed with Fines-Grained for Reclaimed Land](#)
Yelvi, Handi Sudardja and Shany Elizabeth

- [Study of Liquefaction Potential at Sabo dam Construction on Poi and Bangga River, Sigi Regency, Central Sulawesi](#)
Fauzan, A Rifa'i and S Ismanti

- [STUDY GRADATION AND MOISTURE CONTENT OF SAND EMBANKMENT ON PEAT SUBJECTED VIBRATION POTENTIAL LIQUEFACTION](#)
Soewignjo Agus Nugroho, Agus Ika Putra and Muhamad Yusa

Evaluation of potential liquefaction based on Cone Penetration Test (CPT) data

R Amaliah^{1,*}, T Harianto², and A B Muhiddin²

¹Master Student, Department of Civil Engineering, Faculty of Engineering, University of Hasanuddin, Gowa 92172, Indonesia

²Department of Civil Engineering, Faculty of Engineering, University of Hasanuddin, Gowa 92172, Indonesia

*Corresponding author: rezkiamaliah08@gmail.com

Abstract. An earthquake can inflict a liquefaction hazards which can damage buildings and infrastructure. Furthermore, earthquakes are difficult to predict when and where earthquakes will occur and happen suddenly without being preceded by signs. Therefore, we must do a geological investigation before building a construction to evaluate the potential liquefaction in that area. Evaluation of the potential liquefaction using Cone Penetration Test (CPT) is one method can be used because repeatable, provided a continuous profile, and economic. This method needs peak ground acceleration (a_{max}) value at an interval of 0.1 g to 0.6 g and earthquake magnitude of 6.2 scale richter. Based on the results of the research was obtained in this research area, there were potential liquefactions when the peak ground acceleration (a_{max}) value was above 0.3 g.

1. Introduction

Indonesia is an earthquake-prone region because it is passed by the encounter path of 3 plate tectonics, namely, Indo-Australian Plate, Eurasian Plate, and Pacific Plate. This resulted in shocks caused by the earthquake that can damage everything on the earth's surface. Furthermore, the soil will lose shear strength, with the result that initially solid soil behaves like liquid material due to the load of the earthquake so fast. So that the pressure of pore water will increase. Therefore, seeing the potential for liquefaction that is very harmful and can cause fatalities, it requires to evaluate the potential liquefaction in building construction.

Identification of potential liquefaction using CPT data is one way to know the consistency of soil layer to potential liquefaction. This CPT method is repeatable, provided a continuous profile, can be calculated and economic. The results of this identification can be used as a recommendation for policymakers in designing more disaster-resistant buildings in the future.

2. Methods

The first step in evaluating liquefaction was to determine whether area can melt when given vibrations. Most of the soil vulnerable to liquefaction is non cohesive soil. Geographically, the area of this research was located at coordinates 5°09'30.4"S 119°24'55.7"E. This area is formed by alluvium rocks, the soil layer generally consists of thick sand, silt, and clay materials with deep bedrock that causes seismic wave resonance during an earthquake. To obtain the required data in the evaluation of potential liquefaction, we did a geological investigation of engineering in the form of Cone



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd

Penetration Test (CPT) testing in 5 points spread over this research area and the coordinates as in Table 1.

Table 1. Coordinates on Research Area

Code	Coordinate		Ground Water Level (m)
	Longitude	Latitude	
S-01	767656	9429329	1.4
S-02	767757	9429204	1.6
S-03	767748.62	9429403.32	1.4
S-04	767741.39	9429303.28	1.4
S-05	767816.33	9429306.43	1.4

Table 1 shows that based on the Cone Penetration Test results, ground water level in this area was at an interval of 1.4 to 1.6 m. Soil profiles of this area varied between clay and loose sand. The presence of water-saturated sandy soil in this area allowed for liquefaction, especially when there was an earthquake, loose sand undergoes a large shear strain, which can result in large vertical and horizontal deformations. The strength of loose sand also could be lost during an earthquake resulting in landslide flows with extensive deformations based on drainage and soil geometry [1].

From the results of the Cone Penetration Test (CPT) in the field, we got the parameters of ground layer penetration resistance in the form of cone resistance (q_c), shear resistance (f_s), resistance ratio (R_f), and total adhesion resistance (T_f). These parameters will be used to evaluate potential liquefaction at the research area.

In a potential liquefaction analysis, a handle value was required to determine whether liquefaction occurs or not. The value of this hand was called the safety factor which is a comparison between Cyclic Stress Ratio (CSR) and Cyclic Resistance Ratio (CRR) [2]. The equations used to evaluate the potential liquefaction in this area were as follows:

2.1. Calculation of Cyclic Stress Ratio (CSR)

The following steps to obtain CSR (Cyclic Stress Ratio) value from CPT (Cone Penetration Test) data:

$$CSR = \frac{\tau_{avg}}{\sigma_v} = 0.65 \left[\frac{a_{max}}{g} \right] \left(\frac{\sigma_v}{\sigma'_v} \right) r_d \quad (1)$$

with,

CSR = Cyclic Stress Ratio. τ_{avg} = average shear stress, σ_v = total stress (kg/cm^2), σ'_v = effective stress (kg/cm^2), a_{max} = peak ground acceleration (m/s^2), r_d = coefficient of reduction force, g = gravity acceleration 9.81 (m/s^2).

To calculate the coefficient of reduction force, there are equations to estimate reduction force. The coefficient of reduction force can be calculated based on the equation below or using a graph of the relationship between the coefficient of reduction force and the depth as shown in Figure 1 [3].

$$r_d = 1.0 - 0.00765 z \text{ for } z \leq 9.15 \quad (2)$$

$$r_d = 1.174 - 0.0267 z \text{ for } 9.15 \text{ m} < z \leq 23 \text{ m} \quad (3)$$

$$r_d = 0.774 - 0.008 z \text{ for } 23 \text{ m} < z \leq 30 \text{ m} \quad (4)$$

$$r_d = 0.5 \text{ for } z > 30 \text{ m} \quad (5)$$

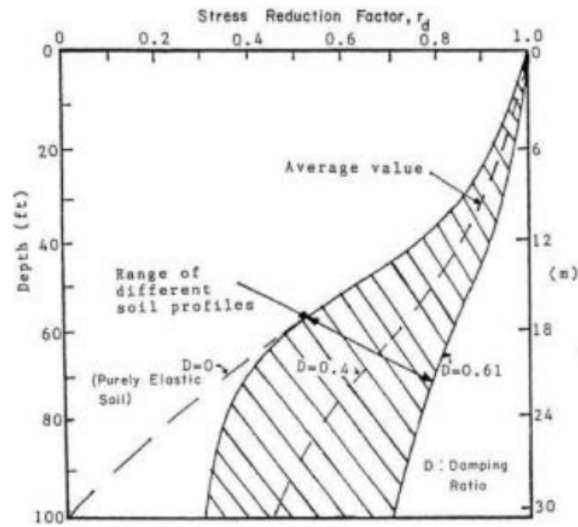


Figure 1. Coefficient of Reduction Force dan Depth [2]

2.2. Calculate of Cyclic Resistance Ratio (CRR)

The following steps to obtain CSR (Cyclic Stress Ratio) value from CPT (Cone Penetration Test) data:

2.2.1. Estimate of Unit Weight

Estimate of unit weight can be used a graph of soil behavior based on CPT data, then the results of the graph are correlated to Table 2 to obtain the estimated unit weight based on the zone obtained from Figure 2.

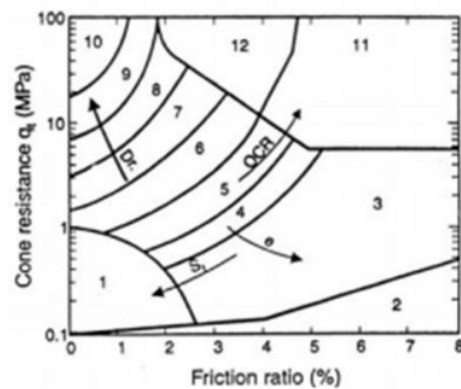


Figure 2. Soil Behavior Graph Based On Data [4]

Table 2. Approximate of Unit Weight [4]

Zone	Zone Approximate of Unit Weight (kg/cm ³)
1	0.00175
2	0.00125
3	0.00175
4	0.00180
5	0.00180
6	0.00180
7	0.00185
8	0.00190
9	0.00195
10	0.00200
11	0.00250
12	0.00190

2.2.2. Calculate q_{c1N}

In the Youd and Idriss method (2001) the procedure of analyzing using CPT requires normalization of the cone resistance (q_c). This normalization returns a value of q_{c1N} that can be calculated using the equation below.

$$q_{c1N} = c_q \times \left(\frac{q_c}{P_a} \right) \quad (6)$$

with: q_{c1N} = correction of cone resistance, c_q = factor of cone resistance normalization, q_c = cone resistance (kg/cm²), P_a = Pressure at 1 atm

2.2.3. Calculate I_c

To calculate I_c can be using the equation below [2]:

$$I_c = [(3,47 - \log \log Q)^2 + (1,22 + \log \log F)^2]^{0,5} \quad (7)$$

To calculate the value of Q , for the type of clean-sand $n = 0.5$, for silt and silty sand $n = 0.5 - 1$ and for the type of clay exponents $n = 1$ [2]:

$$Q = \left[\frac{(q_c - \tau_{v0})}{P_a} \right] \left[\left(\frac{P_a}{\tau_{v0}} \right)^n \right] \quad (8)$$

To calculate the value of F using the equation below [2]:

$$F = \left[\frac{F_s}{Q_c - \tau_v} \right] \times 100 \% \quad (9)$$

2.2.4. Calculate $(q_{c1N})_{cs}$

Robertson and Wride (1998) suggested to correct the value (q_{c1N}) using the equation below

$$(q_{c1N})_{cs} = K_c \times q_{c1N} \quad (10)$$

where K_c , correction factor for grain characteristic, specified by the equation below

$$\text{If } I_c \leq 1.64 \quad K_c = 1.0 \quad (11.1)$$

$$\text{If } I_c > 1.64 \quad K_c = -0.403 I_c^4 + 5.581 I_c^3 + 21.63 I_c^2 + 33.75 I_c - 17.88 \quad (11.2)$$

2.2.5. Calculate value of Cyclic Resistance Ratio (CRR)

The following equation is used to determine the CRR value,

If $(q_{c1N})_{cs} < 50$

$$CRR_{7.5} = 0.833 \left[\frac{(q_{c1N})_{cs}}{1000} \right] + 0.05 \quad (12.1)$$

If $50 < (q_{c1N})_{cs} < 160$

$$CRR_{7.5} = 93 \left[\frac{(q_{c1N})_{cs}}{1000} \right]^3 + 0.08 \quad (12.2)$$

2.3. Calculate Safety Factor

Moreover, the safety factor against liquefaction defined as [2]:

$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF \quad (13)$$

If,

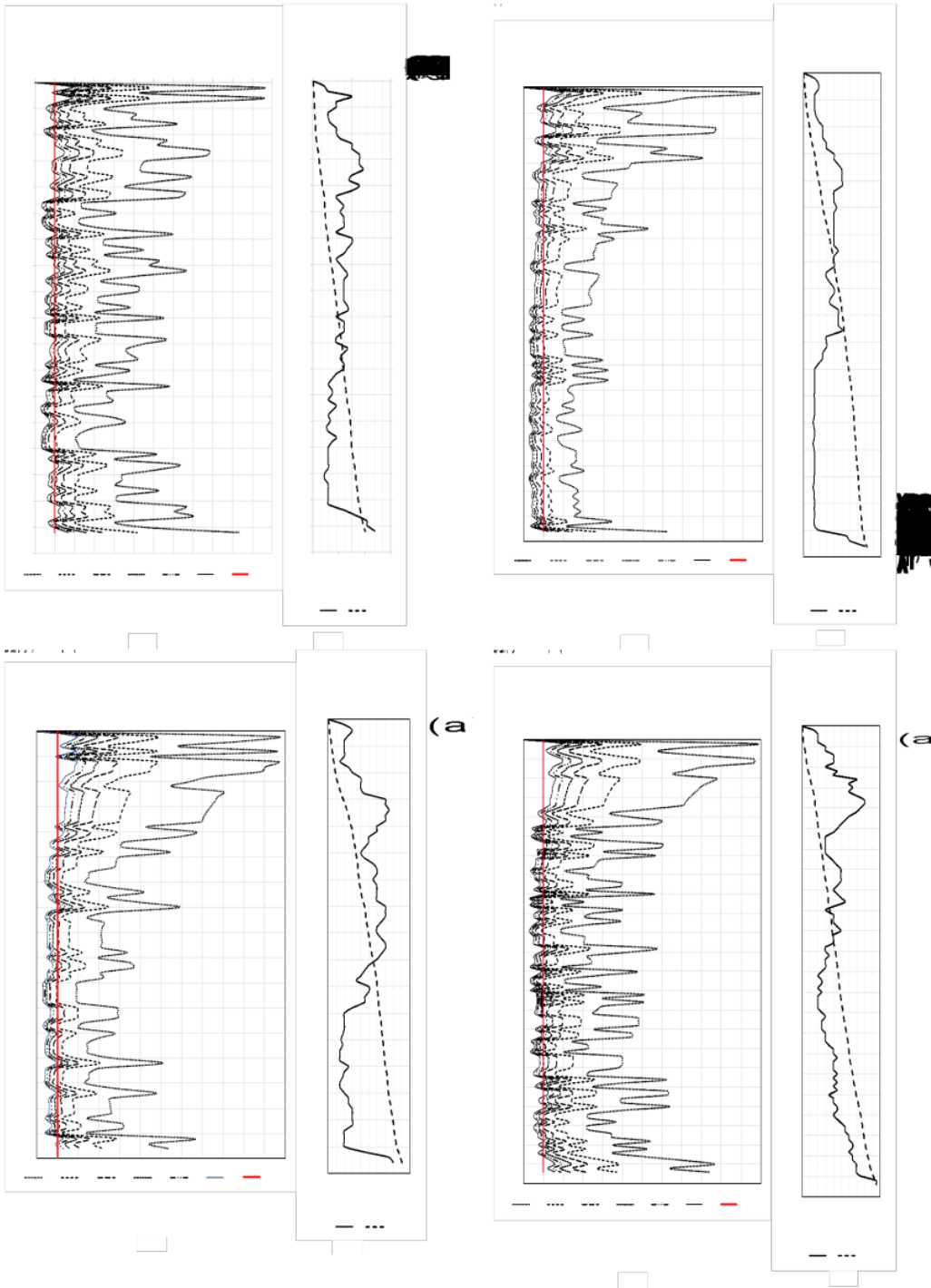
$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF < 1 \text{ (liquefiable)} \quad (14.1)$$

$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF = 1 \text{ (critis)} \quad (14.2)$$

$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF > \text{(non-liquefiable)} \quad (14.3)$$

3. Results and Discussion

After obtaining the Safety Factor (SF) value in each layer of soil, In Figure 3 is presented a graph of the relationship between soil depth and safety factor (SF) value is obtained that shows the potential value of liquefaction at that point. Moreover, a comparison graph of safety factor (SF) value and peak ground acceleration (a_{max}), CPT graph and interpretation of soil layering at CPT point S-01 to S-05 that is integrated up to the end of 250 kg/m² or until hard soil. The peak ground acceleration value of the research area at an interval of 0.1 g to 0.6 g



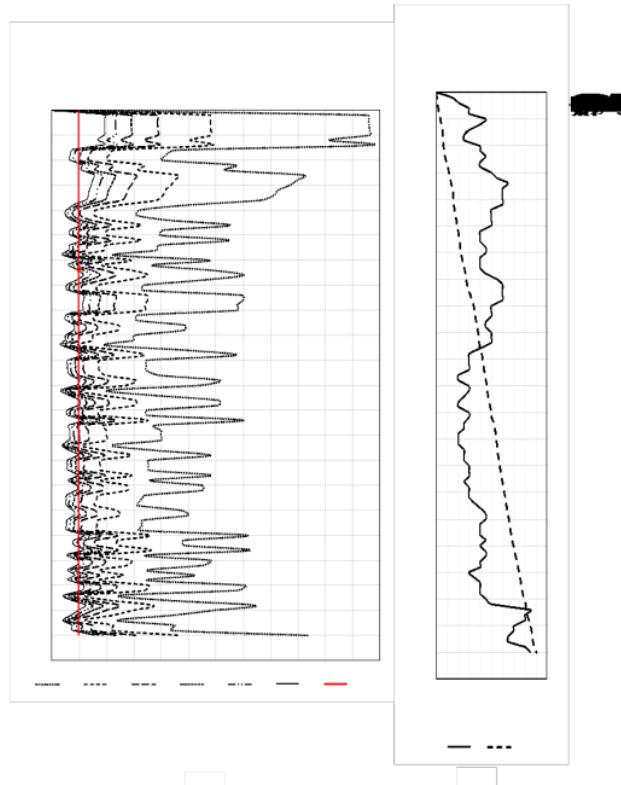


Figure 3. (a) Graph of Relation Between Depth and Safety Factor Value
(b) Graph of Cone Penetration Test

3.1. Evaluation of potential liquefaction

When there is an earthquake, the soil was deformed, cyclic load occurred quickly and pore water pressure of soil increased. That's why the soil was given vibration would be liquefiable. The potential of liquefaction would be increased with the intensity of the earthquake and the duration of the shock. Earthquakes that had the highest strength would produce peak ground acceleration value that affects the occurrence of liquefaction [5].

4. Conclusion

Based on the results of field investigation analysis can be concluded, soil data obtained through Cone Penetration Test (CPT) test shows location of the research area is sandy soil with clay inserts. The results of the evaluation of potential liquefaction showed that as peak ground acceleration value (a_{max}), the liquefaction potential increased. Areas indicated liquefaction when the maximum earthquake acceleration value was given above 0.3 g.

Reference

- [1] Seed et al 1975 Summary Report on Influence of seismic history of the liquefaction characteristics of sands, Earthquake Engineering Research Institute, Berkeley, California Report no. EERC 75-25.
- [2] Youd T L, et al 2001 Liquefaction resistance of soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils

- Journal of Geotechnical and Geoenvironmental Engineering* **127** pp 817-833.
- [3] Seed H B and Idriss I M 1971. Simplified procedure for evaluation soil liquefaction potential. *Journal of the Soil Mechanics and Foundations Division ASCE* **97** (SM9) pp 1249-1273.
- [4] Robertson P K and Wride C E 1998 Evaluating cyclic liquefaction potential using the CPT. *Canadian Geotechnical Journal*, **35** pp 442-459.
- [5] Kramer S L 1996 *Geotechnical and Earthquake Engineering* (New Jersey:Prentice Hall)

ORIGINALITY REPORT

6%

SIMILARITY INDEX

%

INTERNET SOURCES

6%

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

- 1** Arief Alihudien, Suhartinah, Dwa Desa Warnana. "Analysis of soil liquefaction potential in Puger coastal area, Jember Regency, East Java using CPT data", AIP Publishing, 2018 2%
Publication

- 2** António Joaquim Pereira Viana Da Fonseca. "Liquefacção - conceitos e avaliação - UC-Fundacoes MIEC", Repositório Aberto da Universidade do Porto, 2013. 1%
Publication

- 3** Chen, J.-W.. "The penetration experiment to predict liquefaction resistance of reclaimed soils", Ocean Engineering, 200803 1%
Publication

- 4** Hsein Juang, C.. "Characterization of the uncertainty of the Robertson and Wride model for liquefaction potential evaluation", Soil Dynamics and Earthquake Engineering, 200410 1%
Publication

5

"Structural Integrity Cases in Mechanical and Civil Engineering", Springer Science and Business Media LLC, 2022

Publication

1 %

6

Engineering Computations, Volume 24, Issue 1 (2007-06-27)

Publication

<1 %

7

P. K. Robertson. "Evaluation of Flow Liquefaction and Liquefied Strength Using the Cone Penetration Test", Journal of Geotechnical and Geoenvironmental Engineering, 2010

Publication

<1 %

Exclude quotes On

Exclude matches < 5 words

Exclude bibliography On