Analysis on Soil Liquefaction Potential in Pangandaran Coastal Area West Java

Anida Chaerunisa, Asriana
Sultan Agung Islamic University, Department of Civil Engineering
Jl. Raya Kaligawe Km.04, Semarang, Jawa Tengah, Indonesia
anidachaerunisa@gmail.com; asriana.oni@gmail.com

Abstract- Pangandaran, West Java is well known as an earthquake prone area. The impact of an earthquake in a coastal area which contains saturated sand soil is liquefaction potential. This phenomenon occurs when earthquake hits, the water pore pressure increases and the effective stress becomes nil then the soil loss its shear strength. With the objective to study the liquefaction potential in Pangandaran coastal area, this analysis was conducted. Two kinds of analysis were performed by manually calculation method and using Quake Geostudio program. Seed's method based on safety factor as a key control to determine the liquefaction potential was used. This method requires N-SPT data. The result of the analysis showed that based on Seed method with a value acceleration of earthquake is 0,5g, FS value is 1,55. This value means that Pangandaran coastal area is not susceptible to liquefaction. From the analysis using Quake, as ground acceleration increases, pore water pressure also increases. It means the higher of ground acceleration can have liquefaction potential.

Keyword : *Liquefaction, Seed method, ground acceleration, Pangandaran*

1. Introduction

Indonesia is an earthquake prone country which is geographically located between the Asian continental plates, the Australian continent, the Indian Ocean plate and the Pacific ocean plate especially the western part of Sumatra island and south of Java island. Pangandaran coastal area, western Java is one of the areas that have coastal areas directly adjacent to the Indian Ocean in the southern part of which is one region located in the subduction zone which means the area prone to earthquakes. One of the consequences of earthquakes is liquefaction. The liquefaction occurs because the pore water pressure increases and makes the tension effectively decrease in the water saturated layer caused by earthquake vibrations. The liquid layer of soil will lose the ability to withstand the load on it. One example of the occurrence of liquefaction in some countries include Nigata (Japan) 1964, Alaska (USA) 1964, Flores 1992, Kobe 1995, Taiwan 1999, Aceh and Nias 2004.

1.1 research problem

Pangandaran coastal area, western Java is a meeting place between the eurasian plate and indo australia plate. Natural disasters, especially earthquakes, cannot be avoided so that we need to reduce the disaster potential, it is necessary to conduct a search to find out whether or not the potential of liquefaction in the coastal area of Pangandaran.

1.2 Research Problem

The coastal area of Pangandaran, West Java is an area geographically located at coordinates 7° 41° 10° S Latitude and 108° 39° 11° E Longitude. Natural disasters, especially earthquakes, is one of the inevitable condition thus we need to reduce the disaster potential. Pangandaran Coastal Area is known as a type of sandy soil with the same gradation. Therefore, it is necessary to investigate the possibility of the of liquefaction potential in the coastal area of Pangandaran.

1.3 Purpose

The purpose of this research is to analyze the potential of liquefaction toward sand density, to analyze the liquefaction potential for external load variations and to analyze the liquefaction potential for earthquake load variations.
It is expected that this research can be used as a reference to analyze the possible liquefaction hazard in coastal area of Pangandaran.

1.4 Limitation Problems

Limitations of the problem from the results of this study are:

1) Analyzing the potential of liquefaction to coastal areas in Pangandaran area after the earthquake.
2) Analyzes which is conducted based on test results of soil testand drill log which is available in the research area.
3) Calculation method used in analyzing liquefaction potential using manual method and Geostudio 2004

2. literature Review

2.1 the definition of liquefaction

The liquefaction according to Marcuson (1978) liquefaction is defined as the transformation of granular material from a solid to a liquid as a result of increasing the pore pressuresand the loss effective tension. The increasingof pore water pressure and the loss of effective tension can make the soil structure friable and cause the building above it collapse.

2.2 Factors that cause liquefaction

There are several factors that lead to liquefaction those areground shock, the ground water level, soil type, relative density of the soil (Rd), gradation of soil particle, sediment environmental conditions, drainage, form gradation of land, environmental history and the load building.

To identify early liquefaction then relative density (Rd) can be used as a benchmark or a parameter for determining the vulnerability of the area to liquefaction. The gradation of homogeneous soil granules with a relative density of land classified as freeing up being a kind of granular particles which is potential liquefaction.

2.3 Liquefaction analysis methods

This analysis evaluation of potential liquefaction used the field data in the coastal area of Pangandaran that is N-SPT data. The method used in conducting liquefaction potential analysis is a simplified procedure as dictated by Seed and Idriss (1971).

2.3.1 Cyclic stress ratio

According to Blake in Youd et al (2001) Csr is a comparison between the shear stress of repeated (cyclic) in a soil saturated waterwith an effective voltage ground.

$$CSR = 0{,}65 \frac{a_{max}}{g} \frac{\sigma}{\sigma'} r \quad (1)$$

Where:

a_{max} = highest horizontal accelerationon ground surface caused by earthquakes.

g = Gravity cceleration
σ_{vo} = Total vertical stress
σ_{vo} = Effective vertical stress
r_d =Stress reduction factor

r_d coefficient is the coefficient of reduction factor used to assume the movement of soil. Rd value is also a function of depth can be calculated by using the formula

$$r_d = \frac{1{,}000-0{,}4113z^{0{,}5}+0{,}04052z+0{,}001753z^{1{,}5}}{1{,}000-0{,}4177z^{0{,}5}+0{,}05729z-0{,}0006205z^{1{,}5}+0{,}001210z^{2}} \quad (2)$$

where rd is the stress reduction coefficient and z is the depth of the soil. Reduction coefficient value (rd) at the surface is 1 and will be reduced based on the depth of soil.

2.3.2 Cyclic resistance ratio

Cyclic resistance ratio, there are several ways to evaluate the value of CRR one of them is using SPT. In the field tests of SPT value, the factors that affect the results of SPT value penetration were founded, these factors should be corrected according to equation 2 and the value of the correction can be seen in Table 1

$$(N_1)_{60} = N_m \cdot C_N \cdot C_E \cdot C_B \cdot C_R \cdot C_S \quad (3)$$

where:
$(N1)_{60}$ = N-SPT corrected by tools and overburden
N_m =N-SPT which is got from the field
C_N = Normalization of overburden pressure
C_E = Energy beater correction
C_B = Diameter borehole correction

Table. 1. Table of correction for $(N_1)_{60}$

Factor	Equipment variable	Term	Correction
Overburden pressure	-	C_N	$(P_a/\sigma'_{vo})^{0.5}$
Overburden pressure	-	C_N	$C_N \leq 1.7$
Energy ratio	Donut hammer	C_E	0.5 – 1.0
Energy ratio	Safety hammer	C_E	0.7 – 1.2
Energy ratio	Automatic-trip Donut-type hammer	C_E	0.8 – 1.3
Borehole diameter	65-115 mm	C_B	1.0
Borehole diameter	150 mm	C_B	1.05
Borehole diameter	200 mm	C_B	1.15
Rod length	<3 m	C_R	0.75
Rod length	3-4 m	C_R	0.8
Rod length	4-6 m	C_R	0.85
Rod length	6-10 m	C_R	0.95
Rod length	10-30 m	C_R	1.0
Sampling method	Standard sampler	C_S	1.0
Sampling method	Sampler without liners	C_S	1.1-1.3

The greater soil depths caused greater N-SPT value so that overburden correction is needed to decrease the value of N-SPT. Overburden normalization pressure put forward by Liao and Whitman (1986) in equation 2 where the value of C_N should not exceed 1.7.

$$C_N = \sqrt{\frac{P_a}{'\leq}}\, 1.7 \quad (4)$$

where:
C_N =overbuden normalization pressure
σ' = the effective vertical sand voltage (kN/m^2)
P_a = voltage reference or
Y = atmosphere pressure (100 kN/ m^2)

Youd et al (2001), developed a curve based on the SPT value for the sand grains with the Fitnes content value ≤ 5%, 15% and 35% on the earthquake magnitude 7,5. The SPT curve can be seen in the picture 1 below:

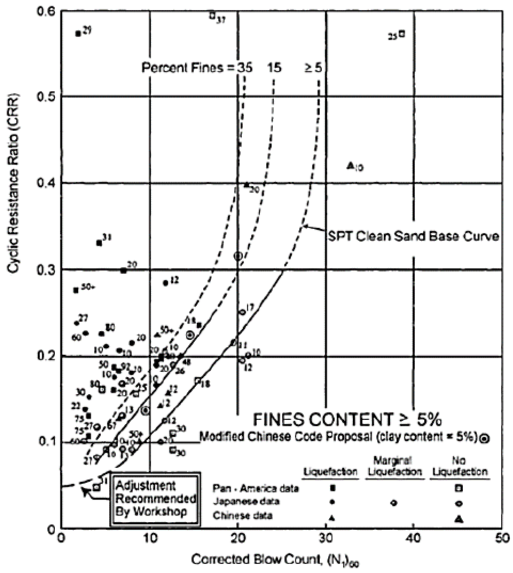

Fig. 1. SPT curve Clean Sand Base
for earthquake magnitude 7,5 (Youd et al,. 2001)

IM Idriss developed an equation for the correction factor $(N_1)_{60}$ the equivalent of clean and sand value can be seen in these three equations below:

$$(N_1)_{60cs} = \alpha + \beta\,(N_1)_{60} \quad (5)$$

Where:
$(N_1)_{60cs}$ = N-SPT corrected as Fitness Content
$(N_1)_{60}$ = N-SPT corrected as Overbuden and tools

α and β value are the coefficient as a result of the equation relationship below:

If $FC \leq 5\%$
$$\alpha = 0 : \beta = 1 \quad (6)$$
If 5% < FC < 35%
$$\alpha = \exp\left[1{,}76 - (190 / FC^2)\right]$$
$$\beta = \left[0{,}99 + \left(\frac{FC^{1,5}}{1000}\right)\right] \quad (7)$$
If FC > 35%

$\alpha = 5.0 \quad : \beta = 1.2$ (8)

CRR value is determined by using the N-SPT data result which was found from the field testing. A.F Rauch (1998) evolved a formula to determine the CRR value based on the curve shown on the picture 1 and drawn in these four equations 5 below:

$$CRR_{7,5} = \frac{1}{34 - (N_1)_{60cs}} + \frac{(N_1)_{60cs}}{135} + \frac{50}{[10.(N_1)_{60cs} + 45]^2} - \frac{1}{200} \quad (9)$$

Where:
CRR = Cyclic Resistance Ratio
$(N_1)_{60cs}$ = N-SPT corrected as fitnes content

The 5th equation is only used if the $(N_1)_{60cs}$ value< 30, whereas if the $(N_1)_{60cs} \geq 30$, the sand can be considered as the solid sand and the potential for the liquifaction supposed to be very small or even none. Thus, the CRR value $(N_1)_{60cs} \geq 30$ is considered equal to 1.

The CSR and CRR value are needed to find the safety factor value as the reflection of the sand force towards the earthquake burden. In other words, the safety factor value must not over than 1, because it can cause the liquifaction potential hazard. As shown in the equation below:

$$FS = \frac{CRR}{CSR} \quad (10)$$

Where:

If $FS = \frac{CRR}{CSR} < 1$ (liquifaction could happen)
If $FS = \frac{CRR}{CSR} = 1$ (critical condition)
If $FS = \frac{CRR}{CSR} > 1$ (no liquifaction)

3. Research Methodology

3.1 Flowchart Planning

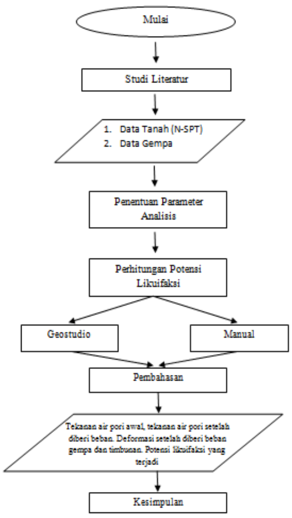

Fig. 2. Flowchart analysis on soil liquefaction potential in pangandaran coastal area west java.

4. Analysis

Liquifaction potential calculation

1. Cyclic Stress Ratio

a. Finding the total voltage value and sand effective voltage

- Total voltage

$$\sigma = (\gamma_{satl} \times z_{lapl})$$
$$\sigma = (18{,}61 \times 2)$$
$$= 37{,}22 \text{ kN/m}^3 \quad (11)$$

- Effective voltage

$$\sigma' = (\gamma_{satl} - \gamma_w) \times z_{lapl}$$
$$\sigma' = (18{,}61 - 9{,}81)2$$
$$= 17{,}6 \text{ kN/m}^3 \quad (12)$$

b. Finding the coefficient stress reduction (r_d)

$$r_d = \frac{1{,}000 - 0{,}4113z^{0,5} + 0{,}04052z + 0{,}001753z^{1,5}}{1{,}000 - 0{,}4177z^{0,5} + 0{,}05729z - 0{,}006205z^{1,5} + 0{,}001210z^2}$$

$$r_d = \frac{1{,}000 - 0{,}4113(2)^{0,5} + 0{,}04052(2) + 0{,}001753(2)^{1,5}}{1{,}000 - 0{,}4177(2)^{0,5} + 0{,}05729(2) - 0{,}0006205(2)^{1,5} + 0{,}001210(2)^2}$$

$$r_d = 0{,}96 \quad (2)$$

c. Determining the Cyclic Stress Ratio value (CSR)

$$CSR = 0{,}65 \frac{a_{max}}{g} \frac{\sigma}{\sigma'} r_d = 0{,}65 \frac{0{,}5g}{g} \frac{37{,}22}{17{,}6} 0{,}96 = 0{,}66 \quad (1)$$

2. Cyclic Resistance Ratio (CSR)

a. Overburden correction

$$C_N = \sqrt{\frac{P\alpha}{\sigma'}} = \sqrt{\frac{100}{17{,}6}} = 2{,}38 > 1{,}7 \quad (4)$$

b. Correction of N-SPT towards the testing field procedure

$$(N_1)_{60} = N_m . C_N . C_E . C_B . C_R . C_S$$
$$(N_1)_{60} = 17 \times 1{,}7 \times 1 \times 1 \times 1 \times 1 = 28{,}9 \quad (3)$$

c. Fitness content correction

Untuk 5% < FC <35%

$$\alpha = \exp[1{,}76 - (190/FC)^2$$
$$\beta = \left[0{,}99 + \left(\frac{FC^{1,5}}{1000}\right)\right]$$
$$\alpha = \exp[1{,}76 - (190/FC)^2$$
$$\alpha = \exp[1{,}76 - (190/9{,}064)^2 = 0{,}58$$
$$\beta = \left[0{,}99 + \left(\frac{9{,}064^{1,5}}{1000}\right)\right] = 1{,}017$$

$$(N_1)_{60cs} = \alpha + \beta . (N_1)_{60c}$$
$$(N_1)_{60cs} = 0{,}58 + 1{,}017 . 28{,}9 = 29{,}97 \quad (7)$$

d. Determining the Cyclic Resistance Ratio value (CRR)

$$CRR_{7,5} = \frac{1}{34-(N1)60cs} + \frac{(N1)60cs}{135} + \frac{50}{[10.(N1)60cs+45]^2} - \frac{1}{200}$$

$$CRR_{7,5} = \frac{1}{34-29,97} + \frac{29,97}{135} + \frac{50}{[10.29,97+45]^2} - \frac{1}{200} = 0,46 \quad (9)$$

3. Factor of Safety (FS)

a. The Magnitude Scaling Factor (MSF)

$$\mathrm{MSF} = \frac{10^{2.24}}{\mathrm{M}^{2.56}}$$

$$\mathrm{MSF} = \frac{10^{2.24}}{5{,}51^{2.56}} = 2{,}20$$

b. Factor Of Safety Evaluation (FS)

$$\mathrm{MSF} = \frac{\mathrm{CRR}_{7,5}}{\mathrm{CSR}} \times \mathrm{MSF}$$

$$\mathrm{MSF} = \frac{0{,}46}{0{,}66} \times 2{,}20 = 1{,}53$$

From the equation above, it summed up the value of FS in every layer on the BM-02 point on the tab 1 below.

Table. 1. Value of Factor of Safety (FS) in every layer on the BM-02 point.

No	Depht (m)	N-SPT (Blow/m)	CSR	$CRR_{7,5}$	*FS*	Keterangan
1	-2	17	0,66	0,47	1,55	Tidak likuifaksi
2	-4	15	0,6	0,33	1,19	Tidak likuifaksi
3	-6	35	0,49	1	4,41	Tidak likuifaksi
4	-8	56	0,39	1	5,53	Tidak likuifaksi
5	-10	60	0,3	1	7,25	Tidak likuifaksi
6	-12	60	0,23	1	9,36	Tidak likuifaksi
7	-14	56	0,18	1	12,13	Tidak likuifaksi
8	-16	30	0,18	0,33	4,11	Tidak likuifaksi
9	-18	19	0,16	1,99	27,41	Tidak likuifaksi
10	-20	18	0,14	0,67	10,15	Tidak likuifaksi
11	-22	10	0,16	0,19	2,62	Tidak likuifaksi
12	-24	17	0,16	0,47	6,41	Tidak likuifaksi
13	-26	16	0,14	0,38	5,7	Tidak likuifaksi
14	-28	23	0,14	0,14	2,05	Tidak likuifaksi
15	-30	34	0,15	1	14,25	Tidak likuifaksi
16	-32	32	0,15	1	14,87	Tidak likuifaksi
17	-34	33	0,15	1	14,87	Tidak likuifaksi
18	-36	37	0,15	1	14,38	Tidak likuifaksi
19	-38	40	0,15	1	14,38	Tidak likuifaksi
20	-40	42	0,15	1	14,38	Tidak likuifaksi
21	-42	43	0,15	1	14,67	Tidak likuifaksi
22	-44	43	0,15	1	14,79	Tidak likuifaksi

In the table above explain the results using seed method at the point of BM-02 from the land surface to a depth of 22m, the FS is >1 where the value of FS is indicated that on the soil in Pangandaran area is not potentially liquefaction.

Table. 2. Value of liquefaction analysis in Pangandaran coastal area Jawa Barat

Tanah Timbunan	Kecepatan Gempa	Sub Bab	Hasil		Nilai Deformasi
			Tekanan Air Pori Tertinggi	L/NL	
1m	0,2	4.5.1	100 kPa	L	0,120
1m	0,3	4.5.2	180 kPa	L	0,179
1m	0,4	4.5.3	180 kPa	L	0,239
1m	0,5	4.5.4	180 kPa	L	0,299
5m	0,2	4.5.5	120 kPa	L	0,124
5m	0,3	4.5.6	195 kPa	L	0,240
5m	0,4	4.5.7	200 kPa	L	0,248
5m	0,5	4.5.8	200 kPa	L	0,311

It can be seen from the table that on the sandy soil that were given 1m ground heap with the 0,2g acceleration of earthquake yielding to pressure pore water up to 100 kPa with the deformation rate to a horizontal direction of 0,120m.

2. Conclusions:

1) The result of an analysis of sandy soil's result of FS from 1-22m depth the FS is >1 where the value of FS is indicated that there is no potentially liquefaction in the Pangandaran area's soil.
2) Pangandaran's coastal areas that has given varying quake, with 0,2g-0,5g acceleration of earthquake. The 1m and 5m ground heap are given, where pressure of pore water after the initial load and earthquake of pore water pressure height increasing along with the bigger PGA. With an increase in the pore water it can cause potential liquefaction.

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