LOAD DYNAMIC METHODS TO PREVENT LIQUEFACTION AT YOGYAKARTA INTERNATIONAL AIRPORT INDONESIA

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ABSTRACT

Liquefaction is a phenomenon loss the strength of the soil due to a cyclic load, like the load caused by an earthquake, which causes the soil to deform from solid to liquid. occurs in saturated soil due to increased pore water pressure and effective reduction of soil stress and also reduces the shear strength of the soil. This research has purpose to determine the potential of liquefaction that can occur and how to prevention it with Dynamic Compaction. This research is located in the Yogyakarta International Airport Development Project (YIA). This research starts from collect of SPT and CPT soil data and laboratory data runway, Development Project for testing CSR (Cyclic Stress Ratio) and CRR (Cyclic Resistance Ratio) and comparing results before and after compaction. The results showed that there was before soil reinforcement, some soil layers at each review point still have the potential for liquefaction. However, after soil compaction with dynamic compaction, it can be concluded that all points of observation are safe from liquefaction potential because all points have a Safety Factor > 1 and has a value $(N_1)_{60} \geq 30$ classified as unliquefied soil. The liquefaction zone is at varying depths ranging from 2 - 6 meters. Dynamic load method test can prevent liquefaction on sandy soil

Keywords: Liquefaction, Dynamic Compaction, CPT, SPT, Earthquake, Airport

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1. INTRODUCTION

The Indonesian government is currently building an international airport in Yogyakarta. The international airport is named Yogyakarta International Airport (YIA). The runway of the NYIA has a length of 3,250 meters, located 400 meters from the shoreline and has greater potential for liquefaction. The Yogyakarta International Airport (YIA) Development Project has the potential for liquefaction in the area, because the position of the runway which is 400 meters from the shoreline has a greater potential for liquefaction.

Liquefaction is the process of removing water from the soil pores caused by dynamic forces (earthquakes). As a result there is a reduction in the effective stress of the soil so that the carrying capacity of the soil will decrease.

Earthquakes cause cyclic loads, the potential for liquefaction will tend to occur in water-saturated fine grained soils. Referring to the liquefaction phenomenon that occurs, it is important to analyze this potential, where it is located on the beach. This is also the background for analyzing the potential for liquefaction in the Yogyakarta International Airport (YIA) Development Project. The soil investigation conducted at several points located at the YIA runway location (Figure 1.)

Figure 1 Location of the Geotechnical Survey
(Source : PPBIY, 2017)

This research took 12 points scattered in the airport area, but in this research only 2 points of DB01 test and CPT01 test are shown without dynamic load and dynamic load.

The research is located in the Yogyakarta Indonesia. Based on the Map of the Indonesian Earthquake Region SNI 1726-2012 the Yogyakarta area has a PGA value of 0.4 - 0.5 g and taken $PGA = 0.4$ g. Details can be seen in Figure 2 below.

Figure 2 Map of the Indonesian Earthquake Area
(Sumber: SNI 1726-2012)

The paper presents the research to evaluate the potential liquefaction based on SPT, CPT data before and after Dynamic Compaction Load applied.

2. LIQUEFACTION

Liquefaction is a phenomenon of loss of soil strength due to earthquake vibrations. At the time of vibration, the sand layer turns into liquid so that it is unable to support the building loads inside or above, which are caused by cyclic loads during an earthquake so that the pore water pressure rises near or exceeds the vertical stress. As the water pressure increases, the distance between sand particles becomes increasingly tenuous, so that the total strength decreases dramatically.

2.1. Method of Liquefaction Potential Evaluation

Evaluation of liquefaction potential by conducting cyclic load tests on undisturbed soil samples or by measuring the characteristics of liquefaction on soils using several test procedures in the field. This research aims to obtain the results of the potential value of liquefaction from field test results, namely SPT and CPT. Basically standard liquefaction evaluation procedures include cyclic stress ratio (CSR) and cyclic resistivity (CRR) values that can be obtained from CPT and SPT.

2.1.1. CRR Method (Cyclic Resistance Ratio Method)

The steps that must be taken to get the CRR value from the SPT data in Equation 1.

$$(N_1)_{60} = N_m \times C_N \times C_E \times C_B \times C_R \times C_S \quad (1)$$

where :

(N1) 60 = N-SPT value corrected for the field testing procedure

Nm = Standard penetration resistance value

CN = factor normalization of Nm with overburden stresses in general (Table 1 and 2)

CE = correction hammer energy ratio

CB = correction for hole diameter

CR = length correction factor

CS = correction for the sample

Table 1 Correction Factors of SPT Value

Factor	Tool Variable	Symbol	Correction
Total Stress		C_N	$\left(\frac{Pa}{\sigma'_{vo}}\right)^{0,5}$
		C_N	C_n
Energy Ratio	Hammer Donat	C_E	0,5 - 1,0
	Safety Hammer	C_E	0,7 - 1,2
	Automatic Hammer	C_E	0,8 - 1,3
Hole Diameter	65 - 115 mm	C_B	1
	150 mm	C_B	1,05
	200 mm	C_B	1,15
Rod length	< 3 m	C_R	0,75
	3 - 4 m	C_R	0,8
	4 - 6 m	C_R	0,85
	6 - 10 m	C_R	0,95
	10 - 30 m	C_R	1

Table 2 Correction Factors of SPT Value

Factor	Variabel	Simbol	Corection
Sampling Method	Sampler Standard	C _s	1
	Sampler Standard	C _s	1,1 - 1,3

(Source : Youd dan Idriss, 1997)

This factor is generally calculated from Equation 2.

$$CN = (Pa / \sigma'_{vo})^{0.5} \quad (2)$$

where:

Pa = 1 atm is the same pressure used by σ'_{vo}

CN value cannot exceed 1.7

Calculate the CRR value with Equation 3 below

$$CRR_{7.5} = \frac{1}{34 - (N1)60} + \frac{(N1)60}{135} + \frac{50}{[10 \cdot (N1)60 + 45]^2} - \frac{1}{200} \quad (3)$$

Calculate the liquefaction safety factor with Equation 4 below.

$$FS = \frac{CRR}{CSR} \quad (4)$$

Normalization of CPT is obtained from Equations 5 and 6 as follows:

$$qc_{IN} = C_N(qc/Pa) \quad (5)$$

$$C_N = (Pa/\sigma'_{vo})^n \quad (6)$$

where:

qc_{1N} = Normalized cone values

qc = cone resistance

CN = normalization correction factor

Pa = Atmospheric pressure, around 100 kPa.

n = Exponents that vary with type, ranging from 0.5 (cleansand) to 1.0 (clay)

Normalized net sand equivalent of N-SPT (qc_{IN}) cs. The K_c value is defined from Equation 7 below.

$$(qc_{IN})_{cs} = K_c \cdot qc_{IN} \quad (7)$$

where:

K_c = correction factor for grain characteristics

Qc_{IN} normalized cone resistance, for clayey sand are corrected against net sand (cs) with price (qc_{IN})_{cs} with Equations 8 and 9 below.

$$\text{For } Ic \leq 1,64 \dots K_c = 1,0 \quad (8)$$

$$\text{For } Ic > 1,64 \dots K_c = -0,403 \cdot Ic^4 + 5,581 \cdot Ic^3 - 21,63 \cdot Ic^2 + 33,75 \cdot Ic - 17,88 \quad (9)$$

Calculation of Q value with exponent value n = 0.5 for pure sand and for clay type soil using exponent value use n = 1. After the type of soil tested has been clacified its type is calculated by Equations 10, 11, 12 and 13.

$$Ic = [(3.47 - \log Q)^2 + (1.22 + \log F)^2]^{0.5} \quad (10)$$

$$Q = [(q_c - \sigma_{vo})/P] (Pa/\sigma_{vo}')^n \quad (11)$$

$$F = [fs/(q_c - \sigma_{vo})] \times 100\% \quad (12)$$

If value of (qc_{IN})_{cs} < 211

$$CRR_{7,5} = \exp [((qc_{IN})_{cs}/540) + ((qc_{IN})_{cs}/67)^2 - ((qc_{IN})_{cs}/80)^3 + ((qc_{IN})_{cs}/114)^4 - 3] \quad (13)$$

If value of (qc_{IN})_{cs} > 211, so CRR_{7,5} = 2

2.2. Dynamic Compaction

This Dynamic Compaction method was discovered by Menard. This method can save costs in substituting the use of piles (piles) into shallow foundations until the use of certain loads in accordance with an increase in the carrying capacity of the soil. In Indonesia, this method is not widely known. But along with the information that is easily obtained and the comparative factor with other conventional methods that are known, this method can be an option worth considering.

The depth of significant influence on compaction can be estimated using Equation 14.

$$D = \left(\frac{1}{2}\right) \sqrt{WH \times h} \quad (14)$$

where:

D = depth of compaction (m)

WH = falling load (ton)

h = high load drop (m)

3. RESEARCH METHODOLOGY

3.1. Research Processing

The analysis and processing of data that has been taken (field test data and laboratory data) is then processed using the Microsoft Excel program for CSR and CRR calculations with the NCEER method.

3.2. Data Analysis

Procedure for analyzing SPT data.

1. The soil must be below ground water level (saturated)
2. The next step is to determine the value of the cyclic stress ratio (CSR),
3. By using the value of the soil parameter from the normalization correction factor (N1) 60, the cyclic resistance ratio (CRR) can be calculated.
4. In the end the safety factor value will be obtained which indicates the potential liquefaction of the land.
5. In this study 6 points of review were used based on SPT data.

CPT data processing analyzes the conus resistance (q_c) value of the sondir tool and the value of f_s or local friction, which is the resistance arising from friction between two surfaces that move relative to each other.

4. ANALYSIS AND DISCUSSION

4.1. Analysis of Liquidation Potential

Based on the Map of the Indonesian Earthquake Region SNI 1726-2012 the Kulon Progo area has a PGA value of 0.4 - 0.5 g and taken $PGA = 0.4$ g.

There are 6 points in the deep boring runway, namely DB-01, DB-02, DB-03, DB-04, DB-05, DB-06. Six sondir point samples are taken, namely CPT-01, CPT-02, CPT-03, CPT-07, CPT-09, CPT-11.

4.1.1. SPT Analysis

To find out the liquefaction potential, an analysis was carried out as below. The results are obtained as presented in the Table and Graph.

SPT Data

Depth of layer (z) : 14 meters
 Ground water level : 3.2 meters
 a_{max} : 0,4 g
 Gravity Acceleration (g) : $9,81 \text{ m/s}^2$
 Weight volume of water (γ_w) : $9,81 \text{ kN/m}^3$

1. Calculation of the Effective Stress

Total stress (σ_1) = $h \times \gamma$
 = $2 \times 12,438 = 24,876 \text{ kN/m}^2$
 Pore pressure(u) = 0 kN/m^2
 Effective stress (σ_1') = $\sigma - u$
 = $24,876 - 0 = 24,876 \text{ kN/m}^2$

2. Calculation of the stress reduction value (rd)

The stress reduction coefficient indicates the flexibility of the soil profile. To calculate the average price of rd (Whitmann, 1986)

Requirements:

$Rd = 1,0 - 0,00765z$ (for $z \leq 9,15 \text{ m}$)

$Rd = 1,174 - 0,0267z$ (for $9,15 < z \leq 23 \text{ m}$)

Layer 1.

$rd = 1,0 - 0,00765 \times z$
 = $1,0 - 0,00765 \times 2 = 0,9847$

3. Calculation ofCyclic Stress Ratio (CSR)

Seed and Idriss (1971) formulated the following equation:

$$CSR = \left(\frac{\tau_{av}}{\sigma'_{vo}} \right) = 0,65 \left(\frac{a_{max}}{g} \right) \left(\frac{\sigma_{vo}}{\sigma'_{vo}} \right) rd$$

Where :

a_{max} : earthquake acceleration in the horizontal direction

g: gravityacceleration due to

σ_v : total stress and effective stress

rd: stress reduction coefficient

Layer 1

$$CSR = 0,65 \left(\frac{a_{max}}{g} \right) \left(\frac{\sigma_{v1}}{\sigma'_{v1}} \right) rd$$

$$= 0,65 \times (0,4) \left(\frac{24,876}{24,876} \right) \times 0,9847 = 0,256$$

4. Calculation of Cyclic Resistance Ratio (CRR)

CRR values can be calculated with the following equation:

$$CRR = \frac{1}{34 - (N1)60} + \frac{(N1)60}{135} + \frac{50}{(10 \times (N1)60 + 45)^2} - \frac{1}{200}$$

where:

(N₁)₆₀: N value of SPT corrected to the field testing procedure

Before entering the main formula of the CRR must first calculate the value (N₁)₆₀ using the correction factors to the SPT value

For example.

Energy ratio factor (C_E) : 1,2(Automatic Hammer)

Hole diameter factor (C_B) : 1

Rod length factor (C_R) : 0,85

Factor of sampling method (C_S) : 1

Layer 1

$$\begin{aligned}
 (N_1)_{60} &= N_M \times C_E \times C_B \times C_R \times C_S \\
 &= (N \times C_N) \times C_E \times C_B \times C_R \times C_S \\
 &= \left\{ N \times \left(\frac{2,2}{1,2 + \frac{\sigma'_{vo}}{P_A}} \right) \right\} \times C_E \times C_B \times C_R \times C_S \\
 &= \left\{ 18 \times \left(\frac{2,2}{1,2 + \frac{24,876}{101,325}} \right) \right\} \times 1,2 \times 1 \times 0,85 \times 1 \\
 &= 27,9431 \\
 CRR &= \frac{1}{34 - (N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{(10 \times (N_1)_{60} + 45)^2} - \frac{1}{200} \\
 &= \frac{1}{34 - 27,9431} + \frac{27,9431}{135} + \frac{50}{(10 \times 27,9431 + 45)^2} - \frac{1}{200} = 0,3676
 \end{aligned}$$

5. Calculation of FS

FS is a value that indicates the potential liquefaction in general is written with

$$FS = \frac{CRR}{CSR},$$

where:

If : $FS = \frac{CRR}{CSR} < 1$: means liquefaction

If : $FS = \frac{CRR}{CSR} = 1$: means critical condition

If : $FS = \frac{CRR}{CSR} > 1$: means there is no liquefaction

Layer 1

$$\begin{aligned}
 FS &= \frac{CRR}{CSR} \\
 &= \frac{0,3676}{0,2560} = 1,4357 \text{ (no liquefaction)}
 \end{aligned}$$

Based on the results of the calculation of SPT at point DB-01 obtained a graph like in Figure 3 which contains the x-axis consisting of 3 variables, namely the value of CSR, CRR, and FS and on the y axis is the depth of the bore hole test point on the SPT. Where if the FS value is less than 1 indicates that at that depth experienced a potential liquefaction. At this point the liquefaction potential occurs in soil layers 2 and 3 at depths of 4 - 6 meters.

Figure 3 Graph of CSR, CRR, FS vs. Depth (DB-01)

4.1.2. CPT Analysis

The field data obtained from the CPT test is cone tip resistance (q_c). From the existing q_c value, it can be calculated the friction value and the amount of sticking resistance in a soil layer. From the value of end resistance can be calculated CRR value which represents the value of soil resistance to cyclic loads due to earthquake.

For CPT-01

$$h = 0,2 \text{ m}$$

$$\gamma_d = 12,438 \text{ kN/m}^2$$

1. Calculation of effective stress (σ')

$$\text{Total stresses } (\sigma') = h \times \gamma = 0,2 \times 12,438 = 2,4876 \text{ kN/m}^2$$

$$\text{Pore water pressure } (u) = 0 \text{ kN/m}^2$$

$$\text{Effective stress } (\sigma_1') = \sigma - u = 2,4876 - 0 = 2,4876 \text{ kN/m}^2$$

2. Calculation of the stress reduction (rd)

$$rd = 1,0 - 0,00765 \times z$$

$$= 1,0 - 0,00765 \times 0,4 = 0,99694$$

3. Calculation of the Cyclic Stress Ratio (CSR)

$$CSR = 0,65 \left(\frac{a_{max}}{g} \right) \left(\frac{\sigma_{v0}}{\sigma_{v0'}} \right) rd$$

$$= 0,65 \times (0,4) \times \left(\frac{2,4876}{2,4876} \right) \times 0,99694 = 0,2592$$

4. *Q value Calculation*

The qc value is obtained from CPT-01 data.

$$q_c = 861,01948 \text{ kN/m}^2.$$

$$P_a = 101,325 \text{ kN/m}^2.$$

$$Q = \left[\frac{(q_c - \sigma_{vo})}{P_a} \right] \left[\left(\frac{P_a}{\sigma'_{vo}} \right)^n \right]$$

$$= \left[\frac{(861,0195 - 2,4876)}{101,325} \right] \left[\left(\frac{101,325}{2,4876} \right)^{0,5} \right] = 54,076409$$

5. *F value Calculation*

The fs value is obtained from CPT-01 data in Appendix 2.

$$f_s = 20,59386 \text{ kN/m}^2.$$

$$F = \left[\frac{f_s}{q_c - \sigma_{vo}} \right] \times 100\%$$

$$= \left[\frac{20,5939}{861,0195 - 2,4876} \right] \times 100\% = 0,023987$$

6. *Calculation of the value of Ic*

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

$$= [(3,47 - \log 54,076409)^2 + (1,22 + \log 0,023987)^2]^{0,5} = 1,78246$$

7. *Cq value calculation*

$$C_q = \left(\frac{P_a}{\sigma'_{vo}} \right)^n = \left(\frac{101,325}{2,4876} \right)^{0,5} = 6,382165$$

8. *Calculation of the value of qcIN*

$$q_{cIN} = C_q (q_c/P_a) = 6,382165 (861,01948/101,325) = 54,2331$$

Normalized N-SPT net sand mixing coefficient (qcIN) cs

QcIN normalized detergent prices, for concentrated sand were corrected against net sand (cs) with price (qcIN) cs as follows.

$$(q_{cIN})_{cs} = K_c \cdot q_{cIN}$$

where:

Robertson and Wride (1998) shows the value of Kc.

For : $I_c \leq 1,64$ $K_c = 1,0$

For, $I_c > 1,64$ $K_c = -0,403.I_c^4 + 5,581.I_c^3 - 21,63.I_c^2 + 33,75.I_c - 17,88$

In the calculation of the value of Ic above, obtained value of $I_c = 1.78246$

$I_c > 1,64$

$$K_c = -0,403.I_c^4 + 5,581.I_c^3 - 21,63.I_c^2 + 33,75.I_c - 17,88$$

$$= -0,403.1,78246^4 + 5,581.1,78246^3 - 21,63.1,78246^2 + 33,75.1,78246 - 17,88$$

$$= 1,09408$$

$$(q_{cIN})_{cs} = K_c \cdot q_{cIN}$$

$$= 1,09408 \times 54,2331 = 59,3353$$

9. CRR value calculation

$$\begin{aligned} \text{CRR} &= \exp \left[\left(\frac{(q_{cIN})_{cs}}{540} \right) + \left(\frac{(q_{cIN})_{cs}}{67} \right)^2 - \left(\frac{(q_{cIN})_{cs}}{80} \right)^3 + \left(\frac{(q_{cIN})_{cs}}{114} \right)^4 - 3 \right] \\ &= \exp \left[\left(\frac{59,3353}{540} \right) + \left(\frac{59,3353}{67} \right)^2 - \left(\frac{59,3353}{80} \right)^3 + \left(\frac{59,3353}{114} \right)^4 - 3 \right] \\ &= 0,087122 \end{aligned}$$

Based on the value $(q_{cIN})_{cs}$ obtained is 59.3353, according to Idriss and R.W. Boulanger (1996) is obtained the CRR7.5 value is as follows:

If : $(q_{cIN})_{cs} < 211$

$$\text{CRR}_{7,5} = \exp \left[\left(\frac{(q_{cIN})_{cs}}{540} \right) + \left(\frac{(q_{cIN})_{cs}}{67} \right)^2 - \left(\frac{(q_{cIN})_{cs}}{80} \right)^3 + \left(\frac{(q_{cIN})_{cs}}{114} \right)^4 - 3 \right]$$

If : $(q_{cIN})_{cs} > 211$, so $\text{CRR}_{7,5} = 2$

10. FS Calculation

$$\text{FS} = \frac{\text{CRR}}{\text{CSR}} = \frac{0,087122}{0,25920} = 0,33611 < 1 \text{ (lequefaction)}$$

Based on the results of the calculation of CPT at the CPT-01 point, the graph as shown in Figure 4.

Figure 4 Graph of CSR, CRR, FS vs. Depth (CPT-01)

4.1.3. Analysis of Potential Liquidation after Load Dynamic Compaction

1. Calculation for SPT

The results of the analysis of liquefaction potential for SPT after load dynamic co(DG-01)mpaction are presented in Table 3 and Figure 5 below

Figure 5 Graph of CSR, CRR, FS vs. Depth (DB-01)

2. Calculation for CPT-01

The results of the analysis of liquefaction potential for CPT-01 after load dynamic compaction are presented in Table 4 and Figure 6 below.

Figure 6 Graph of CSR, CRR, FS vs Depth (CPT-01)

The results of the analysis for the SPT test and CPT test were carried out without dynamic loading (before compaction) and with dynamic loading (after compaction) are presented in Table 3 below

Table 3 Recapitulation of SPT-01 Calculation Before and After Compaction

DB-01	Depth	Original soil			Status	Depth	After Compaction			Status
		CSR	CRR	FS			CSR	CRR	FS	
	2	0,256	0,367	1,435	NL	0,65	0,258	1,188	4,592	NL
	4	0,296	0,174	0,589	L	1,65	0,256	0,206	0,804	NL
	6	0,372	0,282	0,757	L	2,65	0,254	0,043	0,170	NL
	8	0,420	0,747	1,777	NL	3,65	0,315	0,126	0,401	NL
	10	0,443	0,379	0,855	NL	4,65	0,367	0,232	0,633	NL
	12	0,444	0,352	0,792	NL	5,65	0,403	0,466	1,155	NL
	14	0,446	0,339	0,761	NL	6,65	0,432	0,449	1,040	NL
	-	-	-	-	-	7,65	0,000	0,439	0,952	NL
	-	-	-	-	-	8,65	0,461	0,429	0,882	NL
	-	-	-	-	-	9,65	0,000	0,419	0,834	NL

Table 4 Recapitulation of CPT-01 Calculation before and After Compaction

I	Depth	Soil Original			Status	After Compaction			Status
		CSR	CRR	FS		CSR	CRR	FS	
	0,2								
	0,4	0,259	0,087	0,336	L	0,259	2,000	7,716	NL
	0,6	0,259	0,147	0,569	L	0,259	2,000	7,728	NL
	0,8	0,258	0,192	0,742	L	0,258	2,000	7,740	NL
	1	0,258	0,273	1,057	NL	0,258	2,000	7,752	NL
	1,2	0,258	2,000	7,764	NL	0,258	2,000	7,764	NL
	1,4	0,257	1,316	5,117	NL	0,257	2,000	7,776	NL
	1,6	0,257	2,000	7,788	NL	0,257	2,000	7,788	NL
	1,8	0,256	0,431	1,679	NL	0,256	2,000	7,800	NL
	2	0,256	0,330	1,290	NL	0,256	2,000	7,812	NL
	2,2	0,256	1,254	4,906	NL	0,256	2,000	7,824	NL
	2,4	0,255	2,000	7,836	NL	0,255	2,000	7,836	NL
	2,6	0,255	0,507	1,990	NL	0,255	2,000	7,848	NL
	2,8	0,254	0,215	0,846	L	0,254	2,000	7,861	NL
	3	0,254	0,561	2,209	NL	0,254	2,000	7,873	NL
	3,2	0,254	2,000	7,885	NL	0,254	2,000	7,885	NL
	3,4	0,266	0,249	0,937	L	0,266	2,000	7,518	NL
	3,6	0,278	0,212	0,762	L	0,278	2,000	7,202	NL
	3,8	0,289	0,283	0,979	L	0,289	2,000	6,926	NL
	4	0,299	0,228	0,764	L	0,299	2,000	6,685	NL
	4,2	0,309	0,402	1,300	NL	0,309	2,000	6,471	NL
	4,4	0,318	0,255	0,800	L	0,318	2,000	6,281	NL
	4,6	0,327	0,365	1,116	NL				
	4,8	0,336	2,000	5,957	NL				
	5	0,344	0,439	1,277	NL				

L = Liquefaction happened , NL = No Liquefaction

5. CONCLUSION

- Based on the SPT data, the result shows that the comparison between CRR and CSR values in several layers of land at each point of view has a liquefaction potential at a depth of 2-6 meters.
- Based on the CPT data, the result shows that the liquefaction potential occurs at a depth of - 0.4.m to - 4.8 m from the ground level

- Based on the SPT and CPT data after compaction , the result shows that all points of view obtained is safe results from potential liquefaction.
- Dynamic load method test can prevent liquefaction on sandy soil

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