SOIL STIFFNESS FOR JAKARTA SILTY AND CLAYEY SOILS

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ABSTRACT

The upper layer of Jakarta soil is mostly silty and clayey types, which is very compressible and very sensitive to the loads applied that could caused damages to the building. These problems are usually not caused by the strength but more on the deformation properties of the soil. This research is aim to help the engineers in predicting the soil deformation modulus by getting the right E-value from an empirical correlation.

In this research, data are collected from the soil investigation companies in Jakarta. The excel spreadsheet program was used in data processing and also to develop the correlation to find the E-value. At the end of the research the relevant conclusion were drawn to get the proposed correlation between E vs N value and E vs PI.

Keywords: Silty and Clayey Soils, Deformation Modulus, Empirical Correlation.

1. INTRODUCTION

There are many projects developed on clayey soil in Jakarta, very often it is also built on soft clay layer, especially in north Jakarta. As ones may know that apart from shear strength, the compressibility properties of the clayey soils need to be studied prior to the construction of the intended structures, as the deformation of the structures will largely depends on how compressive the soil is. It can be seen that there are many damages in the building around Jakarta. For example, we could see the building cracking, the separation of the main building structure and soil around it, the waving road and the floor popping up inside buildings. These serious problems usually not caused by the strength but more on the deformation properties of the soil. Therefore, one should predict soil response to the anticipated loads before the building is built, so one could see how far the deformation will take place.

To predict soil deformation to the applied loads, soil stiffness needs to be accessed in a reasonable way. However, it is not easy to get the right stiffness parameter, which is also known as modulus of deformation, termed as E-value.

Many correlations to estimate the soil deformation modulus are available. However, those correlations come from oversea soils, and, to the authors knowledge, none has been develop for Indonesian local soil conditions. It will be beneficial if similar correlations can be developed for local soil conditions as this will be able to give guidelines for engineers in estimating the local soil deformation modulus. This study was aimed to develop such correlations. However, due to the time limitation, the research was limited to:

- Clayey soils in Jakarta only, especially, Senayan, Sudirman, Pluit and some other areas.
- The correlation developed were based on oedometer, triaxial, pressuremeter, standard penetration test, and atterberg limit test.

2. DATA PROCESSING

2.1 Deformation Modulus of Soil

Deformation modulus of soil (E), a property of elastic material, is defined as a constant of proportionality between stress and strain as

$$E = \frac{\Delta\sigma}{\Delta\varepsilon} \qquad \text{... (1)}$$

This soil parameter is most commonly used in the estimation of settlement from static loads. It describes the tendency of an object to deform along an axis when forces are applied along that axes which is defined as the ratio of compressive stress to compressive strain. It is used to measure the stiffness of a material.

2.2 Pressuremeter Test

Deformation modulus from pressuremeter test (E_{PMT}), is determined through the theory of expansion of an infinitely thick cylinder.

Thus,

$$E_{PMT} = 2 \cdot (1+\mu_s) \cdot (V_0 + V_m) \cdot \left(\frac{\Delta p}{\Delta V}\right) \quad \dots (2)$$

where:

$$V_m = \frac{V_0 + V_f}{2}$$

$$\Delta P = P_f - P_0$$

$$\Delta V = V_f - V_0$$

μ_s = Poisson's Ratio ~ 0.33 for drained condition

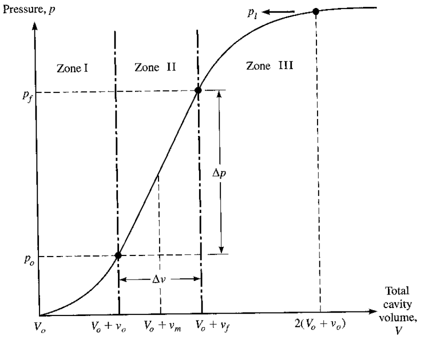

Fig.1 Plot of pressure vs. total cavity volume (After Das. 2008)

2.3 Oedometer Test

Deformation modulus from oedometer test, (E_{oed}), is determined by the following formulation:

$$m_v = \frac{\Delta e}{\Delta P \cdot (1+e_1)} \quad \dots (3)$$

$$E_{oed} = \frac{1}{m_v} \quad \dots (4)$$

Where

$$\Delta P = P_2 - P_1$$

$$\Delta e = e_1 - e_2$$

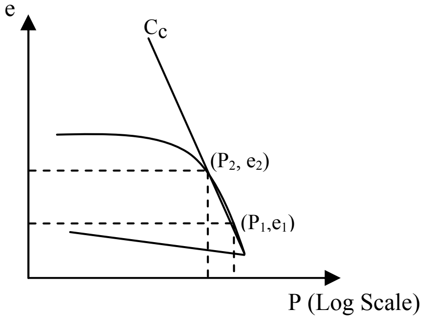

Fig.2 Typical curve of oedometer test

2.4 Triaxial Test

Deformation modulus from the triaxial test (E_{50}), is derived by the stress-strain curve obtained from the laboratory testing as shown in Fig. 3 below:

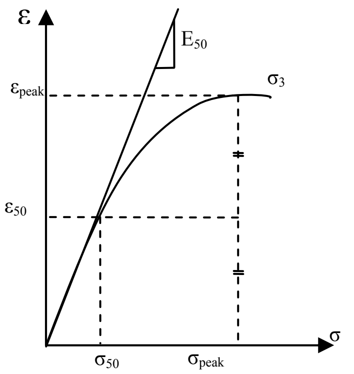

Fig.3 Stress-Strain Curve for E_{50}

Find the peak deviator stress, σ_{peak} , from the test curve, divide the σ_{peak} into two equal parts, to get σ_{50}. Then, read the corresponding strain value, ε_{50} along the curve from the σ_{50}. The Deformation modulus value will be determined as

$$E = \frac{\sigma_{50}}{\varepsilon_{50}} \quad \dots (5)$$

In the triaxial test, usually the tests are done by varying the confining pressure, σ_3. And it appears that the E value varies with the confining pressure. The greater the confining pressure the greater the E. Therefore, it is necessary to take an E value at a referenced confining pressure, which is usually taken at 100kPa. This referenced E value is termed as $E_{50\text{-}ref}$, and it is determined as shown below:

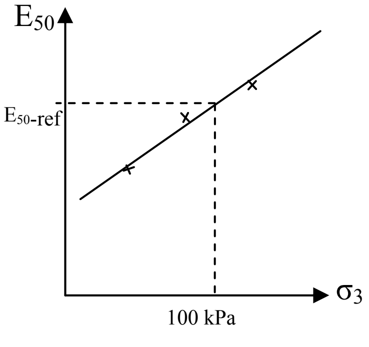

Fig.4 Deriving $E_{50\text{-}ref}$

2.5 SPT test

The SPT values vary and largely depend on the devices and the execution method. Therefore, to develop a good correlation the SPT field values were corrected to a standard effective SPT energy of 60%. Below is the correction formula:

$$N_{60} = \alpha \cdot \beta \cdot \gamma \cdot N_{\text{field}} \cdot \left(\frac{E_r}{E_{60}} \right) \qquad \dots (6)$$

Where:

N_{60} = Normalized N-SPT value to an effective hammering energy of 60%

α = Rod length correction

β = Standard sampler correction

γ = Borehole diameter correction (see Table 1 for α, β, γ)

N_{field} = Field SPT blow count (N value)

E_r = SPT effective energy

Table 1. Correction Factors for Field N value

Rod length: (α)	> 10m	1.00
	6 – 10 m	0.95
	4 – 6 m	0.85
	3 – 4 m	0.75
Standard Sampler (β)		1.00
US sampler without liners (β)		1.20
Borehole diameter: (γ)	65 – 115 mm	1.00
	150 mm	1.05
	200 mm	1.15

The N-value is further normalized to an effective overburden pressure of 1 kg/cm^2 (100 kPa) as follow:

$$N_{1(60)} = C_N \cdot N_{(60)} \qquad \dots (7)$$

Where

$$C_N = \sqrt{\frac{10}{\sigma_v'}} \qquad \dots (8)$$

3. RESULTS

The results of the research are presented below:

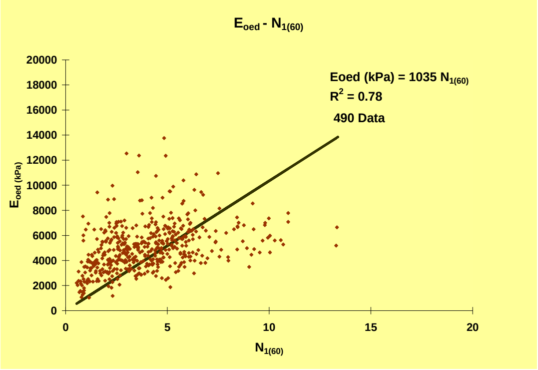

Fig.5 E_{oed}-$N_{1(60)}$

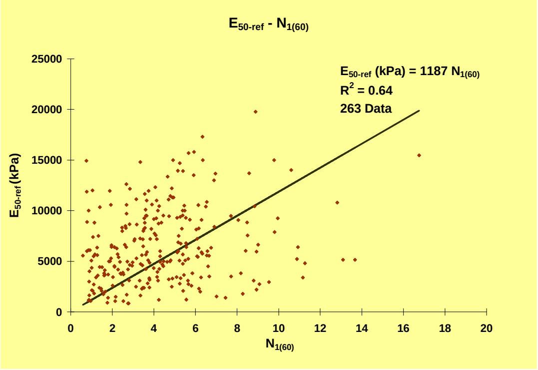

Fig.6 $E_{50\text{-ref}}$ -$N_{1(60)}$

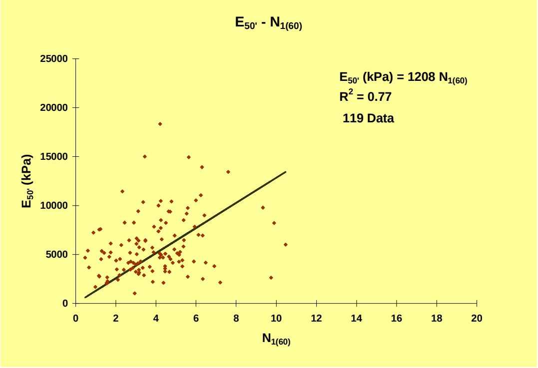

Fig.7 $E_{50\text{-ref}}$ -$N_{1(60)}$

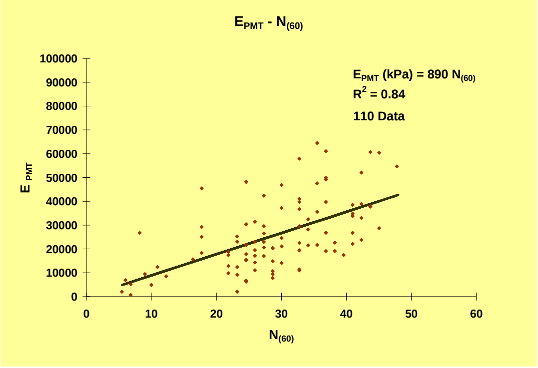

Fig. 8 E_{PMT}–$N_{(60)}$

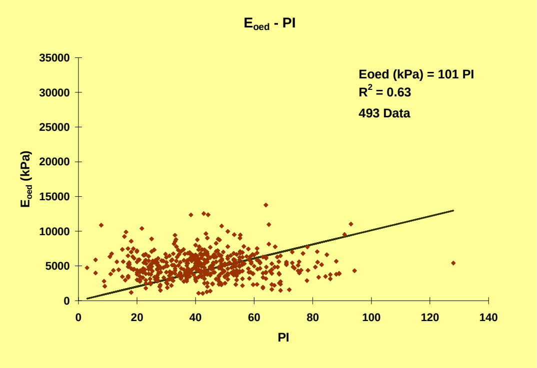

Fig. 9 E_{oed} vs. PI

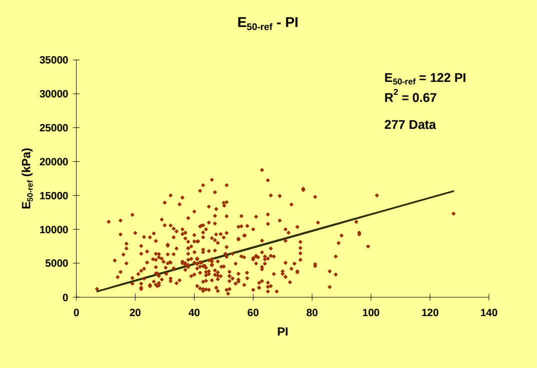

Fig. 10 $E_{50\text{-ref}}$ - PI

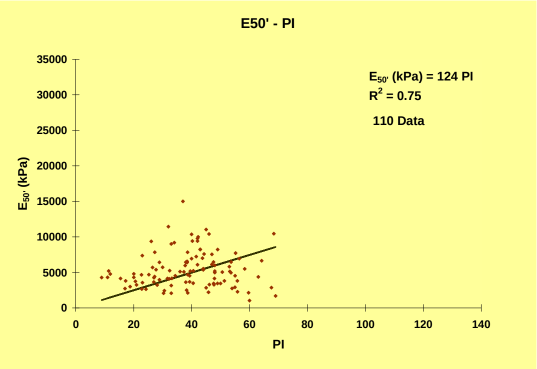

Fig.11 $E_{50'}$ - PI

4. CONCLUSION

After all the data that are carefully analyzed, below are the resulting correlations:

Correlation to $N_{(60)}$

- E_{oed} (kPa) = $303 \cdot N_{(60)}$ ... (9)
  ($0< N_{(60)} <46$, $R^2 = 0.64$)
- $E_{50'}$ (kPa) = $354 \cdot N_{(60)}$ … (10)
  ($0< N_{(60)} <41$, $R^2 = 0.64$)
- $E_{50\text{-ref}}$ (kPa) = $292 \cdot N_{(60)}$ … (11)
  ($0< N_{(60)} <50$, $R^2 = 0.46$)
- E_{PMT}(kPa) = $890 \cdot N_{(60)}$ … (12)
  ($0< N_{(60)} <48$, $R^2 = 0.84$)

Correlation to $N_{1(60)}$

- E_{oed} (kPa) = $1035 \cdot N_{1(60)}$ ... (13)
  ($0 < N_{1(60)} < 20$, $R^2 = 0.78$)
- $E_{50'}$ (kPa) = $1208 \cdot N_{1(60)}$ … (14)
  ($0< N_{1(60)} <10$, $R^2 = 0.77$)
- $E_{50\text{-ref}}$ (kPa) = $1187 \cdot N_{1(60)}$ … (15)
  ($0< N_{1(60)} <17$, $R^2 = 0.64$)

Correlation to PI

- E_{oed} (kPa) = $101 \cdot PI$ … (16)
  ($0< PI <128$, $R^2 = 0.63$)
- $E_{50'}$ (kPa) = $124 \cdot PI$ … (17)
  ($0<PI<69$, $R^2 = 0.75$)
- $E_{50\text{-ref}}$ (kPa) = $122 \cdot PI$ … (18)
  ($0<PI<128$, $R^2 = 0.67$)

From the correlation coefficient, it can be seen the correlations which are developed by correcting the N(60) to N_1(60) give the better results, as shown by the higher value of R^2. This is due to the consideration of the effective overburden pressure of the soil.

5. RECOMMENDATIONS

1. Further data collection is suggested to improve the reliability of the correlation.
2. Further research is recommended to develop other corelation for Jakarta soils, and other localities in Indonesia. This will be very useful for local engineering practice.
3. A Proper soil investigation procedure is recommended in order to get a better data, therefore, the extracted correlation can be more reliable.
4. One must be very careful in using the the correlation for the geotechnical engineering job as the correlation may depends on the local soil condition.
5. The proposed correlation shall only be used as a guideline only. It is suggested to carry out the relevant test to determine the right soil stiffness, especially in a project that have high degree of importance.

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