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paper text:

Behavior of Expansive Soil under Water Content Variation and Its Impact to Adhesion Factor on Friction Capacity of Pile Foundation [6]

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Abstract In the active zone, expansive soil could change from liquid to solid state due to evaporation and from solid to liquid state due to water infiltration. This situation affected the carrying capacity of the friction pile, as well as all the soil parameters, especially the value of soil cohesion and adhesion factor between soil and pile material.

In this study, a series of laboratory experiment were conducted considering variation of water content and the effect on pile [1]

adhesion factors in expansive soil. Adhesion factor measurement was performed using pile model, made from steel and concrete, in the laboratory. The results showed that, in saturated condition, the adhesion

factor of concrete pile had a relatively constant value (the value of about 0.9). This value decreased slightly sharp (at value of about

> **0.6) at the time of Air Entry Value** state **(AEV) when soil** was changed **from saturated to unsaturated condition. The** value **of adhesion factor** again **increased** (at **value of** — **2**

about

> **0.8) until soil water content** exceeded the plastic **limit,** where soil was **in** — **2**

semi solid state. After that, this value constant remained until soil water content reached the shrinkage limit. On the other hand at the same range where the adhesion factor on concrete pile showed a decline, adhesion factor on steel pile material sharply increased. This value dropped back to coincide with the adhesion factor value of a concrete pile as soil water content reached the plastic limit and soil enter into semi solid phase. Keywords: Water Content Variation, Expansive Soil, Adhesion factor Introduction Adhesion factor is an important parameter in determining the carrying capacity of friction piles when pile foundation is embedded on the clayey soil. Errors in determining the adhesion factor may cause miscalculation in

> **the friction capacity of pile foundation.** — **5**

There were several charts develop by some studies such as

> **American Petroleum Institute, Tomlinson, Peck, Woodward, Kerisel, Dennis** and **MacCharty.** — **3**

It showed

> **the relationship between undrained shear strength** and **adhesion factor.** The graphs **is shown in Figure** — **5**

1 [1]. In determining soil undrained shear strength, soil could be in saturated or unsaturated conditions. The graph on Figure 1, which was proposed by some authors, was not clearly explained the soil condition. On the other hand, undrained shear strength of clayey soil greatly depend on variations in soil water content [2-6]. The presence of water into soil could lead soil into liquid, plastic, semi-solid, or solid condition, which was ranged with liquid, plastic or shrinkage limit. In that condition, soil could undergo a phase of saturated, unsaturated or completely dry condition. This condition affected the adhesion factor value. Beside of that, the adhesion factor graphs shown at Figure 1 also was not distinguished pile material such as concrete or

steel material. This research tried to understand the

> **behavior of expansive soil** when subjected to **water content** variations **and** also the **impact to adhesion factor** value **on friction capacity of pile foundation.**
>
> **6**

The experimental research was conducted by pile modelling at laboratory under drying and wetting process. Figure 1. Adhesion Factor [1] Research Methodology and Experimental Procedure

> **In this research, laboratory experimental was conducted using soil sample taken from Citraland, West Surabaya, Indonesia. The initial characteristics of soil sample such as: water content, specific gravity, liquid limit, plastic limit, soil particle, and soil classification by Unified Soil Classification System (USCS)** were **shown in TABLE 1.**
>
> **5**

> **TABLE 1. Initial** Characteristics **of Soil Sample** [7] Soil Properties **Initial Characteristics Water Content (%) 44.5 Specific Gravity 2.65**
>
> **2**

Liquid Limit (%) 109 Plastic Limit (%) 30 % Sand 0.11 % Silt 23 Undrained Shear Strength, cu (kg/cm2) % Clay 76.8 0.26 Soil Classification (USCS) CH 15 cm

> **Proving ring Dial gauge Pile Model,** = 1 **cm Soil sample Plate Tube 6"**
>
> **1**

= 15.24 cm To understand the general characteristics of soil when water content variation occurred on expansive soil at Citraland, drying-wetting cycle experiments were performed by Badawi and Indarto [5]. The initial state of the liquid condition was started when

> **water content** was **1.5 times the liquid limit** of **the**
>
> **11**

soil (WL = 114 %, PL = 32 %, PI = 82 %). Characteristics of variation of water content on expansive soil was compared with the variation

> **of water content of the** undisturbed expansive **soil specimen at**
>
> **7**

Citraland area. In order

to determine the bearing capacity of friction pile, [5]

a loading test model was conducted at the laboratory as shown in Figure 2.

Undisturbed soil sample was taken by pipe tube with a diameter of 15.24 cm (6") and a length of 15 cm. [1]

Concrete and steel model piles were made with a diameter of 1 cm and a length of 30 cm. As shown in Figure 2, a model pile was inserted to the soil sample tube to only investigate its friction capacity [7]. The soil sample tube was made by PVC with 15.24 cm in diameter considering the boundary effect of 15 times the pile diameter [1]

[8-9]. Laboratory pile modeling was done on expansive soil with water content variation to investigate the effect on adhesion factors.

The influence of variations in water content on [5]

expansive soil was represented by two different pile materials, i.e. concrete and steel. Soil water content under drying and wetting process can be seen at TABLE 2. TABLE 2. Drying and Wetting Condition Drying-Wetting Condition Water Content (%)

Wetting 15 % 51.18 Wetting 10 % 48.95 Wetting 5 % 46.73 Initial 44.50 [2]

Drying 10 % 40.05 Drying 20 % 35.60 Drying 30 % 31.15 Drying 40 % 26.70 Drying 50 % 22.25 Figure 2. Loading Test at Laboratory [7] Experimental Result General Characteristic of Expansive Soil under Water Content Variation The graph in Figure 3 was the result of a general experiment of drying-wetting cycles in expansive soil at Citraland area. This graph was generated by Badawi and Indarto [5]. Representative model as shown in Figure 3, was firstly proposed by Biarez et al. [10], which aimed to study the general characteristics of soil from liquid state in drying- wetting cycle. During the drying process, the liquid soil had water content below the liquid limit, which then soil become plastic. After reached the plastic limit, soil turned into a semi- solid condition, which then passed through the shrinkage limit so that the soil state becomes solid. During this process, soil was changed from saturated into unsaturated condition. Results of the experiment were represented in five graphs as shown in Figure 3. The parameters was to explain the state of the specimen during the drying-wetting cycle. There were

water content (w), void ratio (e) and the degree of saturation (Sr). Saturated [9]

zone of soil was characterized by a linear relationship of void ratio, e = (s/ w)w, where in the expansive soil Citraland was

described by a straight line in the graph 7

of e-w. In a straight line, the degree of saturation was 100%. At the point, where the straight line began to turn into the curve line (associated with the three other charts), saturated and unsaturated zone was defined, as well as pF desaturation pressure point in the drying cycle. This point was also known as

the Air Entry Value (AEV). **On the** 8

contrary, in the wetting cycle could be obtained at pF saturation point.

Figure 4 shows the results **of the water content** 8

variation on undisturbed Citraland soil. When it was placed in the general soil material, it showed that the position of that points lied in the plastic state approaching the solid state. Beside of that, soil was within the range of saturated, then passed through the transition condition until the soil become unsaturated. These soil conditions had close relationship with the way to determine the adhesion factor of pile foundation. Figure 3. Drying-Wetting Cycle of Remolded Expansive Soil at Citraland [5] Figure 4. Drying-Wetting Cycle of Undisturbed Expansive Soil at Citraland [5]

The Effect of Water Content Variation on Adhesion Factor Results **of** 2

adhesion factor experiments on steel and concrete piles can be seen in Figure 5. Adhesion factor was gained

by dividing friction capacity of pile **with undrained shear strength and** surface **area** of **pile** 5

model. In general, at the beginning, adhesion factor of both materials showed similar values, especially when soil in saturated condition, which was about 0.9. But a different value was then happened at the time when soil changed from saturated into unsaturated conditions. In this phase, adhesion factor for concrete material was declined to about 0.6. This value was relatively constant until the degree of saturation reached about 90%. This value was then increased up to a value of 0.8 with decreasing the degree of saturation. This value remain constant even though the degree of saturation continued to decline. For steel material in the transition phase of soil from saturated to unsaturated, adhesion factor value was significantly increased up to .

After that, adhesion factor value was progressively decreased **with** decreasing degree **of** `2`

saturation then had a horizontal asymptote with adhesion factor of concrete material in the value . These value remain constant for concrete material, even if the degree of saturation continued to decrease. Adhesion factor value

between soil and steel material was higher **than** the value **between soil and concrete material.** `1`

This phenomenon was contrary to the understanding of physics and previous studies as disclosed by Tan [11] and Tiwari [12], which stated that the roughness of the surface material affected the friction capacity between soil and materials. Concrete material, which had a greater surface roughness, had greater value of adhesion factor. Results of adhesion factors in this study had a different value from the ordinary facts. However, this result was actually the same to what was investigated by Signor [13]. In this study, friction capacity of steel material was 42% greater than friction capacity of concrete material. Signor (2012) mentioned that the friction capacity of steel pile was 33% to 50% greater than friction capacity of concrete pile. This phenomenon was unusually behavior of steel material, which had lower roughness than concrete material. The greater value of adhesion factor in steel material was not enough only considering the surface roughness. The behavior of expansive soil itself should be well understood. First, expansive soil had a high plasticity behavior. High plasticity behavior was obviously increased the soil cohesive. It must be remembered that in this experiment, the soil state was changed from plastic into solid condition. Water content reduction from saturated to unsaturated conditions changed the density of soil. Very high adhesion factor occurred when cohesiveness of this expansive soil was approaching like cement material which had a strong adhesion with steel material. Second, expansive soil as unsaturated soil, which its

pore water pressure was a **negative pore water pressure** that **potentially increased effective** soil **stress. So that** the adhesiveness **between soil and** steel **material** was gradually **stronger,** `2`

especially in conditions of pseudo saturation. Learning from the phenomenon of expansive soil at Citraland, the value of adhesion factors was affected by the undrained shear strength. Beside of that, adhesion factor was also greatly influenced by several behavior factors when subjected to water content variations such as: soil plasticity, degree of saturation of the soil and pile material roughness. Thus, the properties of the soil must be observed carefully in order to obtain proper adhesion factor values. (a) (b) Figure 5. (a)

Relationship between Undrained Shear Strength and Adhesion Factor for `2`

Steel and Concrete Pile (b)

Relationship between Undrained Shear Strength and Degree **of** 12

Saturation Conclusion From the study of the variation of soil water content on expansive soil at Citraland, it can be concluded that: 1. By doing a general studies of the water content variation, several important things for clayey soil can be determined, such as: shrinkage limits, air entry value, saturated and unsaturated zone. 2. Adhesion factor of clayey soil, especially for expansive soil, was strongly influenced by soil plasticity, saturation levels and also roughness of pile material. 3. In expansive soil, steel pile had greater adhesion factor when it compared with concrete pile, especially when soil condition changed from saturated into unsaturated and soil state changed from plastic into solid state. However, in saturated and unsaturated condition with degree of saturation under 80%, adhesion factor

of steel and concrete piles were almost the same. 1

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