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COUPLE CONSTRUCTION MODEL AS AN ALTERNATIVE OF IMPROVEMENT METHOD DUE TO FAILURE AND DEFECT OF COHESION PARAMETER (C)

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ABSTRACT

Road or highway system as an important part for development infrastructure program is a very critical and crucial problem for increasing the people's economic resources. Traffic of people and goods would have some disturbances if the road service damaged. One of main problems out of order the road is a groundwater movement in uncontrolled condition at study area. Therefore, a method of ground improvement has to be implemented at the road margin area. This study is going to focus on a couple model of construction systems implemented to avoid all slope sliding factors. From some laboratory and field data observations, clay layers as soil foundation during the road life time service plan at the study site indicated that there were some reductions of soil shear strength due to cohesion (c) values decreased. Fast alteration of water content (w) was the main cause of failure and defect of cohesion parameter, especially for expansive soil layers. From stability analysis using some geotechnical data and calculated by PLAXIS application software, the existing slope sliding was found in unsafe condition with safety factor (SF) ≤ 1.25. However, one option of design criteria using a couple construction model was obtained the better of safety factor with (SF) > 1.25.

Keywords: Expansive Soil; Laboratory and field data; Safety factor; Soil improvement; Stability analysis

INTRODUCTION

Tangerang Regency, Banten Province, West Java, Indonesia is a plain of Cisadane river basin. In terms of geological, this area was occured rising fault with elongated of direction fault lines as long as the riverbank. These faults cause some weakness planes; cracks; and or ground fissures which is easily passed by a ground water flow. Velocity of ground water flow increases not only caused by the seepage through ground fissures, but also the Tangerang Regency area actually exists at the below of mean sea level and this area was always influenced by high tide or rob from the sea. Several methods are used to identify the subsurface layer. They are geological methods, gravity methods, magnetic methods, seismic methods, and geoelectric methods (Hasan et al., 2019). Even regulations No. 24/2007 and No. 10/2014 have been issued from goverment for disaster prevention as an effort to eliminate and reduce the landslides. In February 2015 during the big flood, but all road margin areas were slided for the third time. This study purposes to evaluate the real safety factor (SF) as the basis to select ground improvement method and choice for suitable construction system for study area. Thus, the implementation for all regulations and

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basic law at study area could be running properly.

Location of road link observed for this study as shown as Figure 1 is the shortcut road toward the western and southern of Tangerang Regency. Some problem is a combination of climate changes; alteration of land use and also soil behavior with permeable layers caused by the seepage. At the site often produces some damages and collapses of road construction which has been made and repaired. Some methods by excavation and backfilling for soil improvement are always conducted as long as the increasing load. However, some differential settlements and slope slidings are occured sustainably at several points of the road contruction, from site study observation shows the stages of damages from construction time to maintenance period. From some previous studies (Orense et al., 2013), the damages and collapses are more correlated with a lack of accuracy in calculation and assessment of stability values of soil foundation.

Based on these problems, it is necessary to find an optimal solution, so that an analysis of slope stability is required. This analysis was performed using the PLAXIS software since this tools makes convenience to find a construction model.

Figure 1. Study Site, Tangerang Regency, Banten Province, Indonesia (PUPR, 2017)

Analysis can be performed easily and quickly and produces output that provides more information on slope stability. One of the options presented in this study is a selection of soil improvement model to be implemented at study site as a solution method in determining construction method and increasing the slope safety factor (SF).

METHODS

From geological data, almost the entire study site was composed by alluvium layer due to the weathering process from claystone, especially for Cisoka area (Figure 2). Rock layers at study area consist of the massive claystone, sandy claystone and lignite. Generally, cohesive soil structured by alluvial layers and has high potential for swelling.

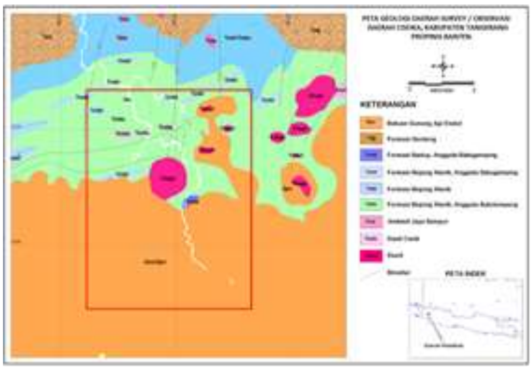

Figure 2. Geology Map at Survey and Observation Area (Source: Sujatmika & Santosa, 1992)

Swelling potential of expansive clay can be estimated by 2 (two) point of views, such as from laboratory test results and, or field (in-situ) conditions during survey and observation.

In laboratory work during soil investigation, the swelling potential can be measured by some factors such as clay mineral content (e.g. montmorillonite), initial density, drying and wetting time, soil sample thickness, saturation level, initial moisture content and pressure due to external loads. In expansive soil, the first from four factors is the important parameters to increase the swelling potential. Otherwise, the last three factors tends to decrease.

In field condition, swelling process on soil foundation of road body structure is much more complex. Swelling and shrinking potential are the important issues because these problems often create some damages to the upper structural layers of the road body structure at study area.

A number of other additional factors which are greatly influence to the swelling process included: (1) Some effects of climate changes, such as: precipitation, evaporation and transpiration in the study area, as well as the alternating soil moisture content. Climate changes greatly affects the physical properties of the expansive clay soil; (2) Soil thickness and layer position in the soil profile will greatly influence the swelling process in certain local position; (3) Fluctuation and flow pattern of groundwater movement will greatly affect the swelling process. But, the swelling potential will not influence affect for the expansive soil layer below the area of groundwater fluctuation; and (4) Seepage process due to leak of irrigation or drainage system and absorption process from some vegetables. Both of these problems can lead the extreme swelling and shrinking process in local position in the soil layers.

Expansive soil identification

According to Coduto (1994), identification of expansive soil can be identified from clay content of CL or CH particles (sometimes ML, MH and SC) and the soil symbols according to USCS *(Unified Soil Classification System)* (Bowles, 1991). In dry conditions, expansive soil induces cracks or slits on the surface and very hard, but, in wet conditions leaves a residue when squeezed by hand (visually).

It is very important to assess a soil deposit is expansive soil or not with considering the amount of material and time losses generated due to the properties of expansive soil. Identification must be carried out at preliminary design stage, so that possible damage to the road body structure can be anticipated. In this study, identification of expansive soil can be performed in various ways based on the theoretical base approach, such as:

a. Visual identification

Some natural indications were used to identify expansive soil, such as:
(a) characteristics of soil sample, these are: very hard when drying, slippery when cut with a scraper or shovel, has a certain crack pattern, soft and sticky when wetting and leaves a residue when squeezed by hand as shown in Figure 3;
(b) field characteristics, those are: some movements on the slope, deep cracks due to shrinkage at a constant distance, subgrade and foundation soil layers suffers erosion very quickly and created some hollow spaces under the road road body at study area as shown in Figure 3.

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Figure 3. Expansive Soil Sample After Slope Sliding

b. Micro analysis for identification

According to Gromko (1974), the content of an expansive soil type can be determined using an electron and optical microscope, X-ray diffraction, thermal difference analysis, infrared ray analysis, etc in a micro laboratory. This study used X-ray diffraction method, and the result shows in Figure 4.

Montmorillonite (MMT) is a phyllosilicate mineral and belongs to the smectite family of clays and it has 2:1 layer structure (Mitchel & Soga, 2015). Its layered structure consists of stacked layers, and each layer is composed of two O-Si-O tetrahedral sheets sandwiching one O-Al or Mg-O octahedral sheet. Due to the isomorphous substitution, the layer is positively charged and cations are existed in the interlayered space of MMT. Neighboring layers are held together primarily by van der Waals force and electrostatic force to form the primary particles of MMT.

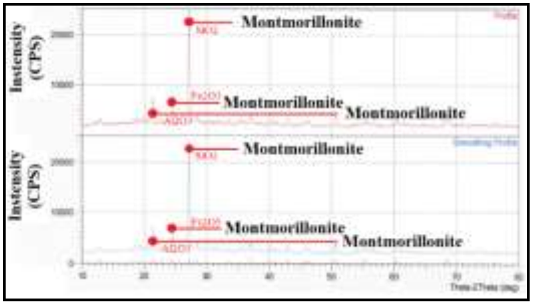

Figure 4. Chemical Bonds of Clay Mineral on Expansive Soil at Study Site *(montmorillonite fraction)*

c. Macro analysis for identification

Direct tests can be carried out using a modified Terzaghi Oedometer (Doran et al,, 2006), however, this method is costly because it requires a complex procedure and a large number of samples for this test. This method was not applied for this study.

Several criteria according to evaluate the swelling potential have been widely studied by researcher, such as: Van der Merwe (1964), Driscoll (1983), Seed et al., (1963), Delage & Lefebrve (1984), Holtz and Gibbs (1956). BRE (1996) NAVFAC DM-7.1 in following of Figure 5 and Table 1. Seed, Woodward & Lundgreen (1963), Chen (1988) and Coduto (1994) stated that there is a relationship between the activity (A) value of a clay and the percentage of clay fraction with grain size smaller than 0.002 mm from laboratory hydrometer test, amd this relationship is expressed by Figure 6 and 7. Classification of swelling potential is divided by 3 (three) levels, such as: low, medium and high. PUPR Dept. (Indonesia) (SNI 6425:2015) was also adopted the qualitative method from Coduto (1994).

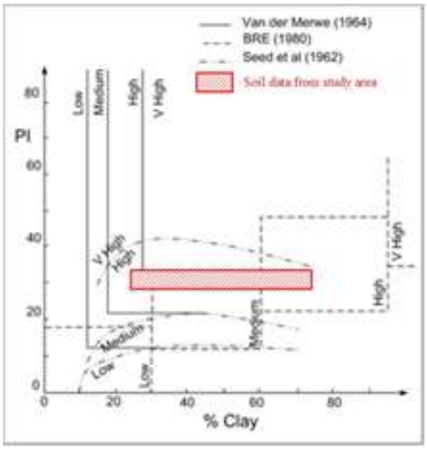

Figure 5. Identification of Swelling Potential (Van Der Merwe, 1964)

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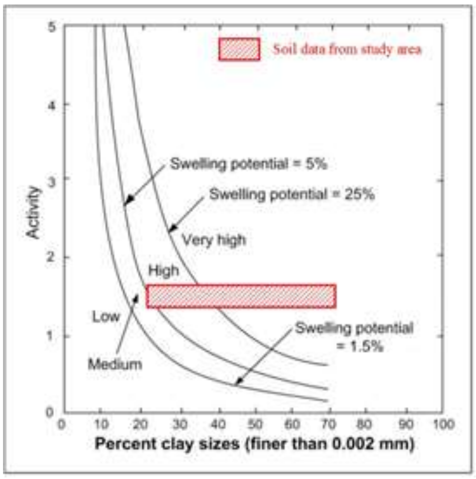
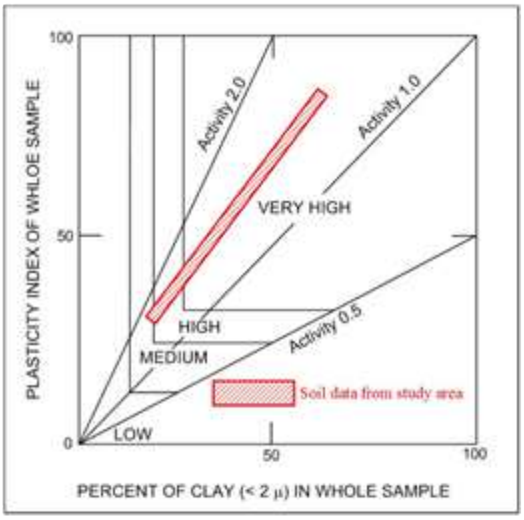
Table 1. Swelling Potential (Chen, 1988; Coduto, 1994; BRE, 1996; NAVFAC DM-7.1)

PI	**SL**	**LL**	**Swelling Potential**
< 18	< 15	< 39	Low
15 – 28	10 – 16	39 – 50	Medium (*)
25 – 41	7 – 12	50 – 63	High (*)
> 35	> 11	> 63	Very high (*)
Note: (*) Laboratory test result based undisturbed samples for study area *(medium to very high)*.			



Gambar 6. Relationship Between Activity (A) Values and Swelling Potential (Chen, 1988)



Gambar 7. Relationship Between Plasticity Index (PI) Values and Swelling Potential (Chen, 1988)

PLAXIS model analysis

PLAXIS software was only used to calculate during dry and rainy season in back analysis. Typical of safety factor (SF) values on slope stability analysis could be estimated as shown in Figure 8 during dry season. From PLAXIS analysis was obtained maximum SF = 1,07 during dry season. Based on some observation at the field, during rainy season, SF values started to decrase as long as increasing the water content (w) of soil layer indicated by Table 2.

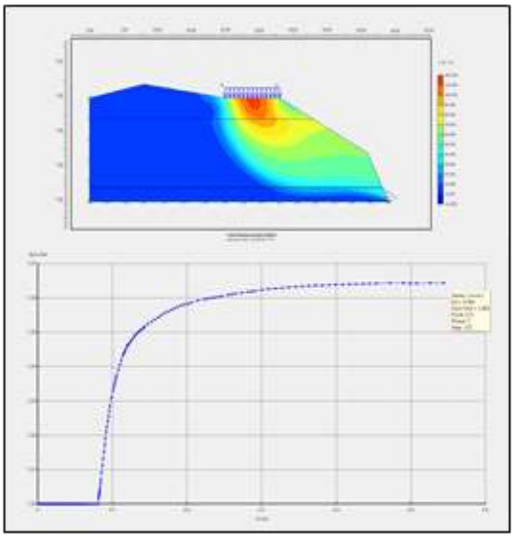


Figure 8. Maximum Safety Factor (SF) using PLAXIS Software During Dry Season *(confirmatory data)*

Table 2. Alternation of Safety Factor (SF) Values Based on the Change of Water Content (w)

Water content (w) [%] (confimatory data)		**Safety factor (SF) using PLAXIS**	
Initial	**Collapse**	**Initial**	**Collapse**
21.5	37.5	1.07	0.81
25.9	39.8	1.04	0.79
26.7	42.3	1.15	0.92

From several model analyzed by PLAXIS software, each analysis produces the different failure patterns. The analysis shows some collapse models, such as: rotational; translational; and block or wedge, and material flowing slides. Based on this analysis, mechanisms of slope collapse can be estimated, these are: all processes started by groundwater seepage, then followed by some cracks, and finally causes collapse. These analysis with using PLAXIS also

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demonstrated the failure and defect of cohesion (c) parameter caused by the alternation of water content (w) at study area.

RESULTS AND DISCUSSION

From this research, it is well known that the expansive soil layer is very susceptible to alteration of the soil water content (w). Clay mineral of *Montmorillonite (MMT)* was detected by micro and macro testing. Confirmatory data also shows the value of Plasticity Index (PI) ≥ 30% and indicates a swelling potential of expansive clay soil. The clay soil is very dependent on cohesion (c) parameter to resist the loads from upper structure in order to remain stable. However, the swelling potential caused by MMT has reduced the (c) parameter and produced the collapse.

From micro analysis for soil identification to MMT contained in expansive soil and macro analysis for observation at laboratory and field studies, it can be indicated that the subgrade of embankment and or soil foundation have the swelling potential layers (medium to very high) at a depth of < 10.0 m. One improvement method is not sufficient to deal with road damages caused by failure and defect of cohesion (c) parameter, but must be carried out by a combination ground improvement method, such as:

1. A combination of geosynthetic materials and sheet pile system.
2. A combination of stabilization and aquifer materials.
3. A soil replacement and gabion structure systems

CONCLUSION

In general, the expansive soil layer at study site is soft, fine grained soil and containing the Montmorillonite (MMT) to the depth larger than 10.0 m. Expansive Swelling potential tends to reacts (medium to very high) rapidly with water and air in the rainy season. Safety factor (SF) is less than 1.25.

From design process to field implementation, it is necessary to pay attention to the comfort factor, environmental safety and other factors in supporting detail engineering design. Collapse of road body structure is caused by surface runoff; seepage flow on the phreatic line; and underneath flow. All types of water flow should be provided with media and without disturbance to the subgrade of embankment and soil foundation. Construction works was not discussed in detail in this study, however, some methods in field implementation can be developed to cut or reduce the construction cost.

Natural water content conditions of expansive soil should be maintained from disturbance water and air to avoid the failure and defect of cohesion (c) parameter. Thus, soil strength to resist external driving forces is still constant or stable and produces SF larger than 1.25. These soil improvement of road access is believed to be very useful in accelerating the mobilization of people, goods and services from one to another places.

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REFERENCES

BRE. (1996). *Desiccation in clay soils*. BRE Digest, *412*(12). CRC, London.

Bowles, L. E. (1996). *Foundation analysis and design*. McGraw-hill.

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Chen, F. H. (1988). *Foundations on expansive soils*. Elsevier, Amsterdam, the Netherlands.

Driscoll, R. (1983). The influence of vegetation on the swelling and shrinking of clay soils in Britain. *Geotechnique*, *33*(2), 93-105.

Delage, P., & Lefebvre, G. (1984). Study of the structure of a sensitive Champlain clay and of its evolution during consolidation. *Canadian Geotechnical Journal*, *21*(1), 21-35.

Coduto, D.P. Kitch,. W.A., Yeung, M.C.R. (1994). *Foundation Design: Principles and Practices (3rd Edition)*. Prentice Hall. p. 984.

Doran, I. G., McKinley, J. D., Day, R. A., & Morris, P. H. (2006). Discussion: Determination of the coefficient of consolidation using a least squares method. *Géotechnique*, *56*(1), 73-76.

Gromko, G. J. (1974). Review of expansive soils. *Journal of the Geotechnical Engineering Division*, *100*(6), 667-687.

Hasan, M. F. R., Swastika, T. W., Martina, N., & Wulandari, L. S. (2019). Identification of Groundwater Distribution Using Self Potential Method. *Applied Research on Civil Engineering and Environment (ARCEE)*, *1*(01), 16-23.

Holtz, W. G., & Gibbs, H. J. (1956). Engineering properties of expansive clays. *Transactions of the American Society of Civil Engineers*, *121*(1), 641-663.

Orense, R., Mirjafari, Y., & Suemasa, N. (2013). Geotechnical site characterisation using Screw Driving Sounding method.

Peta Infrastruktur Kabupaten Tangerang. 2017. Kementrian Pekerjaan Umum dan Perumahan Rakyat (PUPR).

Sujatmika & Santosa, S. (1992). *Geological Map of The Leuwidamar Quadrangle, Jawa*. Bandung: Geological Research and Development Centre.

Peraturan Menteri Perumahan Rakyat Republik Indonesia Nomor 10 Tahun 2014 *Tentang Pedoman Mitigasi Bencana Alam Bidang Perumahan dan Kawasan Permukiman*.

Seed, H. B., Woodward, R. J., & Lundgren, R. (1963). Prediction of swelling potential for compacted clays. *Transactions of the American Society of Civil Engineers*, *128*(1), 1443-1477.

Seed, H. B., Woodward, R. J., & Lundgren, R. (1963). Prediction of swelling potential for compacted clays. *Transactions of the American Society of Civil Engineers*, *128*(1), 1443-1477.

SNI 6425:2015. *Metode uji indeks ekspansi tanah Standard test method for expansion index of soils* (ASTM D 482908a, IDT). ICS. 93. 020. Pusat Litbang SDA.

Undang-Undang Republik Indonesia Nomor 24 Tahun 2007 *Tentang Penanggulangan Bencana*, Lembaran Negara Republik Indonesia Tahun 2007 Nomor 66, Tambahan Lembaran Negara Republik Indonesia Nomor 4723.

Van der Merwe, D. H. (1964). The prediction of heave from the plasticity index and percentage clay fraction of soils. *Civil Engineering= Siviele Ingenieurswese*, *1964*(6), 103-107.

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