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1**The Friction Coefficient of Cohesive Soils and Geotextile: An Approach Based On the Direct Shear Test Data Anas Puri**

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1**Abstract The soil reinforcement designing by using geotextile requires the friction coefficient of soil-geotextile interface, both granular and cohesive soils. For cohesive soils, this coefficient was usually defined by [⅔ tan ???? Is this approach efficient enough or conservative? This paper presents an approach to determine the friction coefficient of soil- geotextile interface based on the empirical data from some researchers. It was used direct shear test data on cohesive soil-geotextile interfaces. Result show that the friction coefficient of soil-geotextile interface higher than the value of tan ?. It was also proved by the interface friction angle ? tend to higher than the soil internal friction angle ?. Hence, the approach by [⅔ tan ???would be yield excessive safety design, which the safety factor would be added for soils and geotextiles. The new approach in determining the interface friction coefficient was conducted by using direct relationship between interface friction coefficient and soil internal friction angle.**

Keywords: cohesive soils, direct shear test, **friction coefficient,**

soil-geotextile interface, geotextiles

1. INTRODUCTION In the designing of soil reinforcement construction using a geotextile reinforcement material, in addition to known properties of the soil and geotextile materials, is also required behavior of the interaction between soil and geotextile. Interaction of soil and geotextile can be expressed by a coefficient called interface friction coefficient, ?. The problem is, not every design can be conducted the testing to determine this coefficient, so often the value of the friction coefficient of interface is taken as an approach value. Approach

2**value of the** friction **coefficient of soil-** geotextile interface **is**

often used for ? = tan ¾ ?⅔ ?, where ?

2**is the angle of** soil **internal friction.**

However, whether such approaches can be used for

10**all types of** soil, whereas **granular** soil **and cohesive**

soil having different properties. Is this approach efficient enough or conservative? Puri (Puri, 2003) has proposed a determination of the friction coefficient of sand-geotextile interface which is relatively efficient compared with the approach that is often used. How does the friction coefficient of cohesive soil- geotextile interface, will be discussed in this paper? This study aims to determine the coefficient of

7**friction between the** cohesive **soil and geotextile,** and approaches **in** determining **the**

friction coefficient of the cohesive soils-geotextile interface. 2. LITERATURE REVIEW Geometry, roughness and stiffness of reinforcement, as well as the types and soil conditions are

17**the main factors that influence the** characteristic **of** friction between **soil**

and reinforcement (Puri, 2003; Mitchell & Villet, 1987; Makiuchi & Miyamori, 1988; Puri, et al., 2003).

20**Interaction between soil and reinforcement is** generally stated as **the** apparent friction coefficient, ?*. **This**

coefficient can be calculated by using Equation 1. J. Saintis Volume 17 Nomor 01, 2017 ?* = tan ? (1) Where ??is the soil-geotextile interface friction angle. Two types of testings can be done to determine the coefficient of friction; they are

23**the direct shear tests and pull out tests.**

Therefore, if both tests are not available, then the general point of

22**friction angle between soil and geotextile** (?) is taken **the** approach **of**

assuming that ?

7**is lower than the** soil **internal friction angle**

(?), for example ? = tan-1 (⅔ tan ?) (Mitchell and Villet, 1987) or sometimes used ? = ⅔? (Mitchell and Villet, 1987; Das, 1995), for all woven and non woven geotextiles tan ? = 0,60?1,00 tan ?' (Williams and Houlihan, 1987), rough woven geotextiles tan ? = 0,80?1,00 tan ?', granular soil-solid polymer sheet tan ? ? 0,6 tan ?' (Jewell, 1996), and tan ? = ⅔?¾ tan ? which is generally taken tan ? = ⅔ tan ? for geotextile and tan ? = ¾ tan ? for geogrid (Suryolelono , 2000), so that in certain cases the value of these approach to be conservative. Puri (2003), through his research by using well rounded beach sand and non woven geotextile and data from other researchers from the direct shear test, proposed the Equation 2 to predict the apparent friction coefficient at the sand-non woven geotextile interface. ?* = 0,00004?'2 + 0,0158?' (2) Since the first term of Equation 2 does not give significant results, and then the equation can be written as ?* = 0,0158?' (3) Equation 3 shows the prediction of the friction coefficient only required soil internal friction angle, ?'. This equation can be used in case of testing on the interface is not available. Puri & Wanim (2003) compared the friction coefficient of Pekanbaru clay-geotextile interface with friction coefficient values calculated using Equation 2. Provided that the calculated coefficient closes to the friction coefficient of test results, both for the reinforcement in the form of woven and non woven geotextile. Nevertheless, the conclusion is still very limited because of soil used only one type. 3. RESEARCH METHODOLOGY The research was conducted by using

21**direct shear** test **data for the interface** of cohesive soil **and** geotextile. Data **are**

obtained from various sources that have been published, they are Williams and Houlihan (1987), Puri and Wanim (2003), Gource (1982), Garbulewski (1990), Mahmood and Zakaria (2000), and Rifa'i (2004). The type of shear test is the laboratory direct shear test. The steps undertaken in this study include: collection and sorting of data, analysis and interpretation, preparation of research reports, and publication of research results.

1**Soil internal friction angle** data and **soil- geotextile interface friction**

angle depicted in graphic form and in the same way for

10**the angle of** soil **internal friction** and friction coefficient **of soil-**

geotextile interface. Tabulation of data and drawing graphs was using Microsoft Office Excel. Statistical tests performed included the t test, correlation test and regression test, using SPSS 12 application program. 4. RESULTS AND DISCUSSIONS Soil Types and the Interface Based on data from various researchers, it can be resumed that the soil types are clay, silt, sandy clay, silty clay, and kaolinite. Woven and non woven geotextiles manufactured from various companies was used. Direct shear box size used by all

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(Anas Puri) researchers are also vary from the smallest 100 mm ? 100 mm up to the largest size of 3000 mm ? 300 mm. Summaries of soil types and soil-geotextile interfaces are given in Appendix A. Relationship of

1**Interface Friction** Angle **and Soil Internal Friction Angle** Recapitulation of **interface friction**

angle is presented in Appendix B. Relationship of soil-geotextile

3**interface friction angle ? and the soil** internal **friction angle**

? is given in Figure 1.

1**Interface friction angle ? tend to** be **higher than the soil internal friction angle**

?, as well as to the value of ⅔ ?. ? This suggests that the frictional resistance at the interface is greater than the soil one. Approach value [tan ? = ⅔ tan ?] which is commonly used will always be smaller than the real resistance. Figure 2 shows that the ratio ?/? tend to be higher than 1.0. The lowest, the largest and the average value of ratio ?/? are 0.87; 6.97 and 1.67 respectively. Figure 1. Relationship of

3**interface friction angle ? and the soil** internal **friction angle**

? Figure 2. Rasio ?/? vs.

2**the soil internal friction angle** ? Relationship of Interface **Friction**

Figure 3 shows the relationship of interface Coefficient and Soil Internal Friction friction coefficient ? with

2**soil internal** Angle **friction angle** ?. Seen that **the** interface **friction**

coefficients tend to be above [⅔ tan 35 J. Saintis Volume 17 Nomor 01, 2017 ??? and increase with increasing soil internal friction angle. Interface friction coefficient values range from 0.045 to 1.00. From the statistical tests, the soil internal friction angle has standard deviation of 14.87? with a mean of 16.08? and the average standard < 0.05. error 3.04?. The coefficient of friction has a standard deviation of 0.35 with a mean of 0.40 and the average standard error 0.07. The t test results for one-sided test and two- sided test was qualified, where t calculation > t table. The probability of sig. is 0.000 Figure 3.

1**Interface friction coefficient** ? vs. the **soil internal friction angle** ? Correlation of **interface**

friction coefficient and

2**the soil internal friction angle** is significant at **the**

level of confidence 99%. It is based on Product moment correlation test (Pearson), Spearman rank and Kendall tau. Furthermore, the relationship of ? vs. ? is obtained as Equation 4. ? = 0,034?0,869 (4) The Equation 4 has a

12**correlation coefficient R = 0.** 858. It **means the**

?-? relationship is 85.8%.

12**The coefficient of determination R2 = 0.**

838 (or R2 = 0.839 from MS Excel analysis), which means 83.8% of the variation that occurs is caused by soil internal friction angle or soil frictional resistance, while the remaining 16.2% due to something else. Based on the F test (Anova) was obtained F calculation > F table and the probability of sig. < 0.05. It is also found the satisfying the t test and significance < 0.05. Regression models are not susceptible to heteroskedastisity interference and multicollinearity (not random), but having otocorrelation. So in general the Equation 4 is acceptable to model the relationship ? vs. ?. Interface Cohesion Figure 4 shows the relationship of cohesive soil-geotextile interface cohesion (adhesion) ca with soil cohesion c. Seen that the interface cohesion tends to decrease with increasing soil cohesion, so that the adhesion factor will be decrease, too. The curve for approache ca = ⅔ c which is often taken in the desiging is also shown. It turns out that there is trend data contrary to the approach. Presumably the failure that occurred was not on the interface of soil-geotextile but rather in the soil near the interface.

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(Anas Puri) Figure 4. Relationship of ca vs. c ? Plastisity Index Effects to Interface Figure 6 shows

25**the relationship** of **interface Shear Strength** Parameters cohesion **and**

PI. It appears

18**that the Shear strength parameters of the soil**

interface cohesion tends to increase with interface are the interface cohesion ca and increasing PI. This means that cohesion in interface friction angle ?. The relationship cohesive soil is an important part to the of interface friction angle ? with plasticity formation of bond resistance in the index PI of cohesive soil is shown in interface. It is also concluded by Mahmood Figure 5. The interface friction angle tends & Zakaria (2000). Therefore, interface to decrease with increasing PI. This is due cohesion should be taken into account in to soil with a higher PI resulted in soil reinforcement design. Relationship ca decreasing of friction between soil vs. PI in the cohesive soil-geotextile particles; here the role of cohesion tends to interface can be expressed as be more dominant. This phenomenon can lead to the failure tends to occur in the soil ca = 0,2316PI + 0,5773 (5) near the interface. Figure 5. Relationship of interface friction angle ? with plasticity index PI 37 J. Saintis Volume 17 Nomor 1, 2017 Figure 6. Relationship of cohesion of cohesive soil-geotextile interface and PI 5. CONCLUSIONS The research results the value of the friction coefficient of cohesive soil-geotextile interface ranged from 0.045 to 1.00. Coefficient of interface friction ? tends to be higher than tan ?. This is also evidenced by the value of

1**interface friction angle** ? tends **to** be **higher than the soil internal friction angle** ?. Therefore, determination **the**

interface friction coefficient with the commonly approach of ? = ⅔ tan ?, will produce a very safe design (conservative), considering the safety factor is also given on the parameters of the soil, and geotextile tensile strength. Equation 4 can be used to estimate the friction coefficient of cohesive soil- geotextile interface in case there is no available testing of the interface. The proposed approach in determining the friction coefficient of cohesive soil- geotextile interface should be tested with numerical analysis in a case of soil reinforcement structure using geotextile. ACKNOWLEDGEMENT The manuscript is part of the research has been funded by the Research Institute of the Islamic University of Riau, Pekanbaru. REFERENCES

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Appandix A. Recapitulation of Cohesive Soil-Geotextile Interfaces No. Researchers Description of Interface Area and Others Type of Geotextile ? (o)? a c (kPa) Soil Descriptions ? (o)? c (kPa) 1 Williams & Houlihan (1987)

19**Area 30,5 cm x 30,5 cm.**

Soil two sides, Typar 3401 Trevira 1155 Nicolon 900-M Typar 3401 Trevira 1155 Nicolon 900-M 38 45 43 33 37 35 1,3 1,8 2,0 0,4 0,5 2,5 Gulf Coast clay (CL), LL= 42%, PL=28%, PI=14%, wopt=15,5%. Silt Glacial till (ML), LL=47% PL=17%, wopt=7,5%. 20 38 57 31 2* Saxene & Budiman Area 25 cm x 25 cm. Soil two sides, depth 1,27-7,6 cm displacement rate 0,75 mm/min normal stress 72-288 kPa. Celenese 800X Monsanto C-34 14 15 14 22 45%DS, 5% bentonite, 50% kaolonite, saturated 12,8 12,8 7,8 3* Degoute & Mathleu Area 3 x 0,3 m, soil depth 15cm, normal stress 200- 1200 kPa, soil one side Geotextile 39 Sandy clay, PL= 13% 34 50 4 Puri & Wanim (2003) Area 10 cm x 10 cm soil thickness 1,0 cm, soil one side. Displacement rate 0,25 mm/menit Non woven:

15**Polyfelt TS** 30 **Polyfelt TS 50 Polyfelt TS 60 Polyfelt TS**

70 Woven: Hate Reinfox HT385-130XT HT385-185XT HT385-250XT 3,5 3,22 3 3,03 2,71 2,56 2,62 5,73 5,54 6,47 8,88 1,69 5,43 6,16 Pekanbaru clay,CH LL= 68,56%; PL= 45,56%; PI= 23%, Gs = 2,66. coloid (particle <2?m) 75% very fine particles (<0,001 mm) 35% 2,46 8,52 5 Gourc (1982) Area 40 cm x 25 cm. Normal stress 2-30 kPa. Soil two sides, depth 2x10 cm BD 340 BD 340 41,8 39,9 6,46 2,09 saturated clay (undrained) 39 39 30 10 40 J. Saintis Volume 17 Nomor 1, 2017 Appandix A. Continued Area 100mm x 100mm, soil one side, rate 0,1 mm/min conventional 6 Garbulewski (1990) Road geotextile-1000 (needle punched poly- propylene) Filtration geotextile J/Sm 5214 (polypropy- lene & polyamid) ? =? 0,47 (25,2) ? =? 0,4 (21,8) 10,2 12,5 Mud (organic mud), classified as silty clay with 2% of sand 77% silt, 21% clay.13% organic matter, wn=54%, LL=90%, PL=33,7%, PI=56,3%, su=12 kPa, ?=15 kN/m3 24,2 12,4 7 Mahmood & Zakaria (2000) Area 10 cm x 10 cm soil one side. Displacement rate 1,27 mm/menit. Non woven needle

punched: TS550 TS600 TS700 TS750 5,6 8,6 14,98 3,5 12,5 11,6 9,66 12,0 Organic clay, ? = 1,356 g/cm3 wn=115,41%; organic content 14,70%. PI = 35,4%; Undrained Gs = 2,54 2,15 9,44 8 Rifa'i (2004) Standard direct shear Soaked condition: Non-woven TS600 Non-woven R206 Woven BW250 Unsoaked condition: Non-woven TS600 Non-woven R206 Woven BW250 27,5 31,6 23,0 34,3 22,2 20,7 2,24 0 0,53 1,85 15,0 3,69 Wonosari clay, CH ? = 1,775 g/cm3, Gs=2,673 LL= 72,01%; PL= 35,65%; PI= 36,36%. OMC=37,64; MDD=1,292; fine grain 81,36% 20,2 26,6 29,6 39,1 * see William & Houlihan (1987) 41

Internal Friction Angle and Interface Parameters No. Researchers Type of Interface Frcition Soil internal, ?' (o) angle Inter- face, ? (o) Friction coefficient, ? 1 Williams & Houlihan (1987) Gulf Coast clay-Typar 3401 20 38 0,781 Gulf Coast clay-Trevira 1155 20 45 1,000 Gulf Coast clay-Nicolon 900-M 20 43 0,933 Silt Glacial till-Typar 3401 38 33 0,649 Silt Glacial till-Trevira 1155 38 37 0,754 Silt Glacial till-Nicolon 900-M 38 35 0,700 2* Saxene & Budiman Kaolinite-Celenese 800X 12,8 14 0,249 Kaolinite-Monsanto C-34 12,8 15 0,268 3* Degoute & Mathleu Sandy clay-Geotextile 34 39 0,810 4 Puri & Wanim (2003) Pekanbaru clay-Polyfelt TS 30 2,46 3,5 0,061 Pekanbaru clay-Polyfelt TS 50 2,46 3,22 0,056 Pekanbaru clay-Polyfelt TS 60 2,46 3 0,052 Pekanbaru clay-Polyfelt TS 70 2,46 3,03 0,053 Pekanbaru clay-Hate Reinfox HT385- 130XT 2,46 2,71 0,047 Pekanbaru clay-Hate Reinfox HT385- 185XT 2,46 2,56 0,045 Pekanbaru clay-Hate Reinfox HT385- 250XT 2,46 2,62 0,046 5 Gourc (1982) Clay-BD 340 39 41,8 0,894 Clay-BD 340 39 39,9 0,836 6 Garbulewski (1990) Silty clay-Road geotextile-1000 24,2 25,2 0,471 Silty clay-Filtration geotextile J/Sm 5214 24,2 21,8 0,400 7 Mahmood & Zakaria (2000) Organic clay-Non woven TS550 2,15 5,6 0,098 Organic clay-Non woven TS600 2,15 8,6 0,151 Organic clay-Non woven TS700 2,15 14,98 0,268 Organic clay-Non woven TS750 2,15 3,5 0,061 8 Rifa'i (2004) Wonosari CH clay-Non woven TS600 20,20 27,52 0,521 Wonosari CH clay-Non woven R206 20,20 31,6 0,615 Wonosari CH clay-Woven BW250 20,20 23,04 0,425 Wonosari CH clay-Non woven TS600 26,59 34,34 0,683 Wonosari CH clay-Non woven R206 26,59 22,23 0,409 Wonosari CH clay-Woven BW250 26,59 20,66 0,377 * See William & Houlihan (1987) 34 36 38 42