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Interface Strength Parameters Analysis Between Palangkaraya Sands and Geotextile

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ABSTRACT :*Soil reinforcement using geotextile is one of geotechnical structures, involving soil-structure interaction. Recently, the problems are solved by neglecting the interface influence between soil and structure. To obtain more realistic shear-strength parameter, it is required to study the soil-structure interface. The study of behavior of soil-geotextile interaction on the shear strength parameters is discussed in this research. The used soils in this research are Palangkaraya sand. The well graded sand has relative density of 90%. The sand sample is based on the maximum dry density (MDD) value obtained from standard Vibrating table test ASTM D 4253. Determination of interface parameter on the shear strength of sand geo-textile is obtained from direct shear test ASTM 3080. The intrinsic interface shear strength parameters are friction angle of interface (δ). The used geotextile types are woven, non-woven and reinforcement. Result of the research gives review on the behavior and interface modeling of soil-geotextile. Values of friction angle of interface (δ) obtained from sand-non-woven geotextile are higher than sand- woven geotextile. The value of δ obtained from sand reinforcement is the highest. Ratio of δ/φ for non-woven geotextile ranges between 0,89~0.93. Ratio of δ/φ for woven geotextile is about 0.81~0.87. Reinforcement ratio of δ/φ is about 0.96 ~ 0.97. The value of δ/φ is relatively constant at residual strength conditions. The interface shear strength parameters are influenced by the roughness of material. Nominal mass, tensile strength and elongation is slightly given influenced concerning shear strength interface parameters. The efficiency as the portion of soil shear strength parameters that is mobilized showing trend are similar to δ and δ/φ.*

KEYWORDS:*friction angle, interface ratio Palangkaraya sands, geo-textile.*

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I. INTRODUCTION

Most of geotechnical problem in engineering project to involve interaction between soil and structure.The examples of soil reinforcement using geotextile are soil embankment, slope stability and retaining wall. All of this time most of those problems are solved by ignore influence of interface behaviors between soil and structure. Interface behaviors between soil and geotextile are needed for structure stability analysis. So that interface behavior research is needed to obtain more realistic shear stress. The most important parameter for soil stability analysis is shear stress parameter. Shear stress parameter for sand that is angle of internal friction (φ). Interface shear stress parameter which is reinforced by geotextile is mobilization of interface friction anglebetween soil and geotextile (δ). This parameter is important for modeling interface behavior of stability analysis.

Main purpose of this research is to learn interaction behavior between soil and geotextile toward shear stress parameter by direct shear test, and also learn influences the type of geotextile toward sand interface shear stress parameter. The influence variation of geotextile characteristics are also involved to learn interface shear stress parameter.

II. LITERATURE REVIEW

Geotextile has been aplicated into many engineering projectsby several function. One of thosefunction is for reinforcement. The examples of soil reinforcement using geotextile are soil embankment, slope stability and retaining wall. Interface behaviors between soil and geotextile are needed for structure stability analysis (Hardiyatmo, 2008).

Arianto (2010) compare between soil shear stress parameter value with soil and geotextile by using direct shear test (DST). The result is obtained interface friction angle correlation between soil (φ)and soil – geotextile(δ). Those correlation is $\delta = 0{,}957\ \varphi\ ^{o}$.

According to Rifa'i (2009) at the same condition of *Dr*, interface friction angle parameter between non woven geotextile with sand has higher value than woven.There is no different between wet or dry sand condition to ratio value of δ/φ.

Effendi (1995) by "interface strength of various geosyntheticsan soils from ring shear test" using Ottawa sand and non woven geotextile conclude that:

1. The ratio $t_{residual}/t_{clay}$ *for all tests* < 1
2. *the nonwoven geotxtile:* $f\ = 24° \text{ to } 27.8^{0}$

Koerner (1990) presents a friction angle and efficiency in friction angle between woven geotextile (silt film) type versus several of cohesionless soil that is concrete sand 24^{0} (77%), rounded sand 24^{0} (84%), and silty sand 23^{0} (87%). While nonwoven (needle-punched) type versus concrete sand are shown as 30^{0} (100%), rounded sand 26^{0} (92%) and silty sand 25^{0} (96%).

Das (2008) recommend δ = ($1/2\varphi$-$/3\varphi$), Terzaghi& Peck (1967) δ $2/3\varphi$. Bowles (1984) recomend δ = $0{,}6$ - $0{,}8\ \varphi$.

III. THEORETICAL BASIS

Interface behavior knowledge of soil – geotextile is needed for soil reinforcement structure. Shear stress parameter is the important parameter for analyzing interaction between soil and reinforcement. Interface shear stress parameter which is reinforced by geotextile is mobilization of interface friction anglebetween sand and geotextile (δ). By using Mohr – Coulomb failure criterion, shear stress between geotextile and sand is:

$$\tau_d = \sigma_n'\ \tan\delta$$

Where: τ_d : interface shear stress betweem soil and geotextile
$\sigma n'$: effective normal stress at sliding plane

Interface shear stress can be determined by direct shear test. Advantages of direct shear test are: relatively quick test, more easier to practice, and the preparation of speciment is not difficult. Acoording to According to Bowles (1984), a variety of factors affect shear stress value are: density, void ratio, roughness, shape of soil particle, overburden pressure, mineral content and grain size distribution.

IV. RESEARCH METHODS

The specimen is sand at maximum dry density condition (γd max) and *Dr* 90%. Maksimum dry density condition is obtained by using ASTM D 4253 with vibrating table. Specimens are fine tomedium sand from Kalampangan. Direction to Kr. Bangkirai and Sebangau, Palangkaraya.Central of Borneo.Types of geotextiles are used woven, non woven and reinforcement. geotextilegeotextile Woven use HRX250 and HW91150. Non woven geotextile use TS6700 and HNW91100. Reinforcement use PEC50 (see Figure 1)

Woven geotextile characteristic is polypropelene woven sheet. This type has 150 gr/m2 mass(for HW91150), and 250 gr/m2 (for HRX250). Tensile strength for HW91150 is 20 kN/m and 38 kN/m for HRX250. Non woven geotextile is a sheet witout woven. the function are commonly as separation, filtration, protection and drainage. This type has 110 and 280 gr/m2 weight (TS700 and HNW91100). Tensile strength are 3,6kN/m (TS700) and 19,3kN/m (HNW91100). Elongation are 10% and 11% (HW91150 and HRX250), 70% and 80 % (TS700 and HNW91100).Reinforcement geotextile is made from polyethylene chloride. It is a non woven sheet with reinforcement threads.

Main equipments used in this research are; 1 set physics properties test apparatus. 1 set vibrating table, 1 set direct shear test, 1 set computer and printer. Standard refer to ASTM 1988 D 854 (specific gravity), D 422 (grain size analysis), D 4253 and D 4254 (maximum compaction test and minimum density test), also D 3080 (direct shear test). Bowles (1984) gave procedur of test, measure and evaluation according to ASTM standard test.

First step, probe grain size distribution by sieve analysis test and volumetric weight test to determine type of sand and dry density. Dry density is used to determine γdmax and γdmin. Thus volume of specimen can be obtained according relative dry density needed (Dr = 90%).Standard vibrating table compaction test purpose is to obtain average water content and maximum dry density (γdmax). It is used as reference to specimen preparation for direct shear test. Direct shear test is used to obtain interface shear stress parameter with various types of geotextile. Corelationchart between shear stress and relative horizontal movement is evaluated to get δvalue.

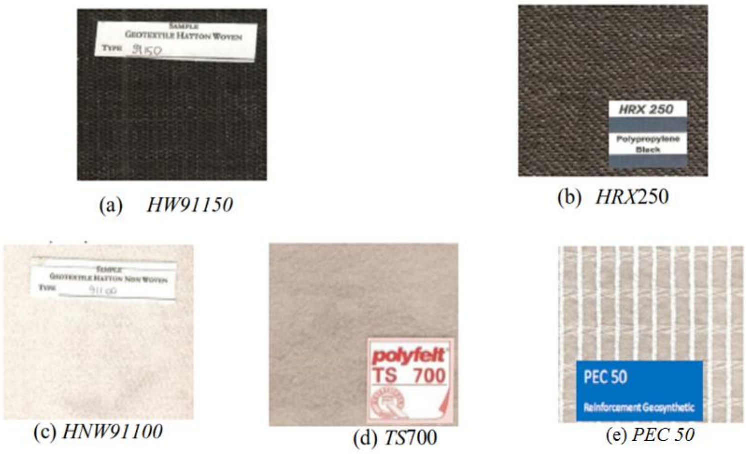

Figure 1.geotextile woven, non woven and reinforcement

V. RESULTS AND DISCUSSION

The results from soil physics properties are shown in **Error! Reference source not found.**. According to USCS (*Unified Soil Clasification System*), these sample of sand are identified as well – graded sand (SW). Direct shear test is used to obtain shear stress of sand and geotextile interface. Normal stress which is used in all of the test are 0,219 kg/cm2, 0,321 kg/cm2 and 0,422 kg/cm2.

Table 1.Summary of physic properties Palangkaraya sand

No	Parameter	Unit	Palangkaraya Sand Test Result, 2011 Kalampangan Sample	Direction to Kr.Bangkirai Sample	Direction to Sebangau Sample	PalangkarayaBinaMarga Test Result (2008)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	G	-	2.631	2.630	2.632	2.586
2	D	mm	0.082	0.085	0.076	0.159
3	D	mm	0.264	0.274	0.276	0.404
4	D	mm	0.518	0.519	0.487	0.712
5	C	-	6.31	6.11	6.42	4.47
6	C	-	1.64	1.70	2.11	1.44
7	USCSClasification	-	SW	SW	SW	SP.SW
8	$\gamma_{dmaximum}$	gr/cm^3	1.682	1.680	1.684	1.670
9	$\gamma_{dminimum}$	gr/cm^3	1.425	1.423	1.427	--
10	ω	%	17.81	17.72	17.86	17.20
11	$e_{maximum}$	-	0.85	0.85	0.84	--
12	$e_{minimum}$	-	0.56	0.57	0.56	--

Relation chart between $\sigma_n$denganτ (sand) with various geotextile interface is shown in Figure 2. The results of φ or δ with various type of interface is shown in Table 3.

Woven interface shear stress is lower than sand – sand. This is caused by its smooth surface influence shear stress value with 90% relative dry density. Sand shear stress intrinsic parameter is determined by friction angle. That is shown by the change of values from friction angle or interface (see Table 3). δ value for woven geotextile is lower than nonwoven. Whileδ value for nonwoven geotextile is higher than δ value of woven.

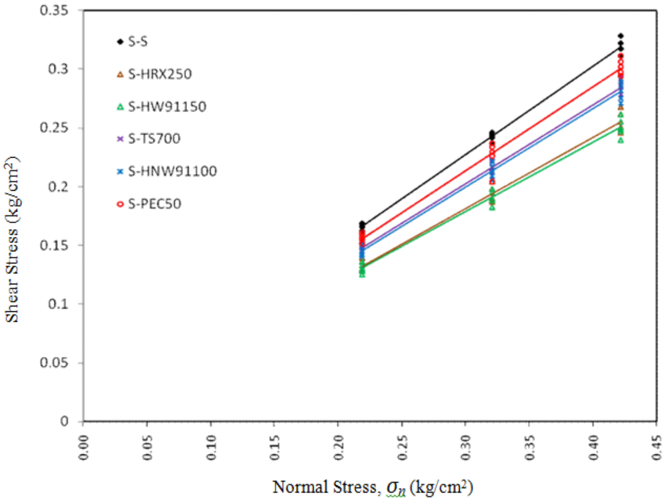

Figure 2. Relation chart between $\sigma_n$denganτ (sand) with various geotextile interface

Table 2. Value φ atau δ in various type of interface

No	Code	Type	Shear angleφorδ τmax(°)			Shear angleφorδ Palangkaraya Sand	
			KLP	*BKR*	*SBG*	*Range*	*Average*
1	S-S	natural	36.94	36.94	36.99	36.94-36.99	36.95
2	S-HRX250	woven(rough)	31.13	30.74	32.08	30.74-32.08	31.32
3	S-HW91150	woven(smooth)	30.61	30.02	31.32	30.02-31.32	30.65
4	S-TS700	nonwoven (rough)	33.98	33.50	34.46	33.50-34.46	33.98
5	S-HNW91100	nonwoven(smooth)	33.68	33.01	34.16	33.01-34.16	33.62
6	S-PEC50	reinforcement(rough)	35.63	35.34	35.80	35.34-35.80	35.59

Value of δ for reinforcement interface type is the highest value between all of the tests. It shows that the influence of surface texture is important. More smooth of interface surface produce lowly interface friction angle. Sand has a high shear strength and interface shear strength. Interface surface roughness influence shear stress value. Table 4 show the comparation between φ with δ. Woven geotextile ratio (δ/φ) are about 0,83 to 0,85. While non woven geotextile ratio are about 0,91 to 0,92. The higestratio of δ/φ is obtained from reinforcement geotextile, the value is 0,96 from angle of internal friction.

Table 3. Value of δ/φ and$E_\varphi$from various interface type.

Interface sand – geotextile		Shear strength parameter (τ_{max})		
Code	*Type*	*δ (°)*	*Ratio δ/φ (%)*	*E (%)*
S – S	Natural sand	36.95	1.00	100.00
HRX250	Woven (rough)	31.32	0.85	80.88
HW91150	Woven (smooth)	30.65	0.83	78.78
TS700	Nonwoven(rough)	33.98	0.92	89.59
HNW91100	Nonwoven(smooth)	33.62	0.91	88.38
PEC50	Reinforcement (rough)	35.59	0.96	95.13

The result of direct shear test which is shown in **Error! Reference source not found.**is suitable with Bowles (1984) theory.In commonly cases, failure zone willincreasuntil shear strength strong enough to end the movement (although mass of that soil will move to bottom of gap like a land slide). Shear movement will stop when in the remolded condition as a residual strength (Bowles, 1984)

Natural sand (Dr = 90%) with normal load P_1, P_2 and P_3 show brittle chart (see Figure 3). From that chart,non woven and reinforcement geotextileinterface chart tend to obtain a similar scheme (brittle chart). This condition is caused by these material have a rough surface which attach sand particle.

In Figure 3, woven geotextile (which relatively has smoothes surface than non woven geotextile) show progressif chart. Smooth geotextile surface makes loose interface to sand particle. That chart is suitable with Hardiyatmo (2006). At the dense and medium sand, shear stress increase (by movement which caused by shear δH) at the maximum value of τ_{max}. Then it decrease (approach constant) at $\tau_{residual}$.Primary characteristic of geotextile are mass, tensile strength and elongation. by several variation of geotextile in interaction between Palangkaraya sand – geotextile , the value of geotextile characteristic will also be various. Geotextile charracteristic variation will show change in behavior of sand interface shear stress parameter toward geotextile.

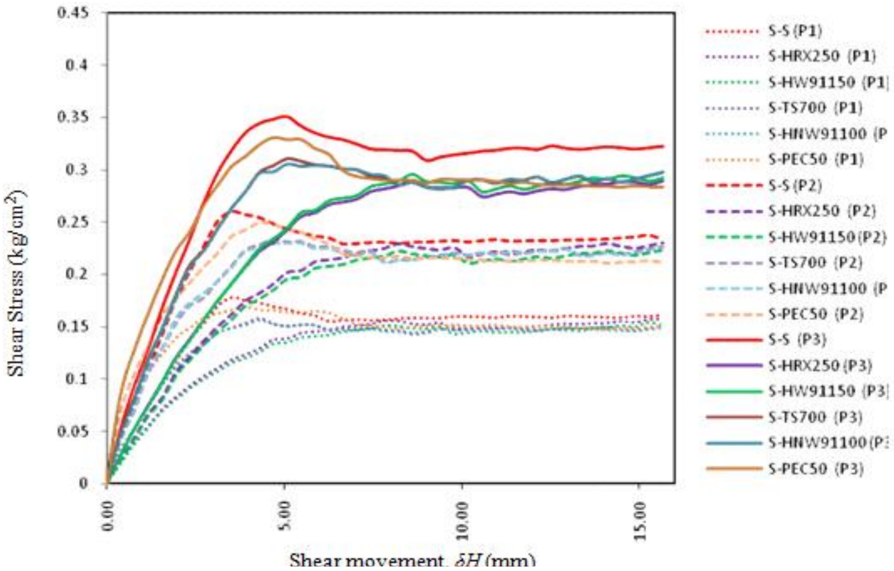

Figure 3. Relation chart between shear movement (δH) and shear stress (τ)

Table 4show correlation between main characteristic of geotextile with interface shear stress parameter.Correlation between mass of geotextile with interface shear stress parameter is shown at

Table 4a andFigure 4. According to variation of geotextile mass, (δ) value increase linearly from 33,62˚ to 35,59 ˚.δ/φ ratio also increase linearly from 90,97 % to 96,31%. Similarly for $E\varphi$ value increase linearly from 88,34% to 95,13%.Alteration scale of interface shear stress parameter is relatively more slight if it compare with scale of geotextile mass. So that, the influence of geotextile mass to interface shear stress parameter is relatively slight.

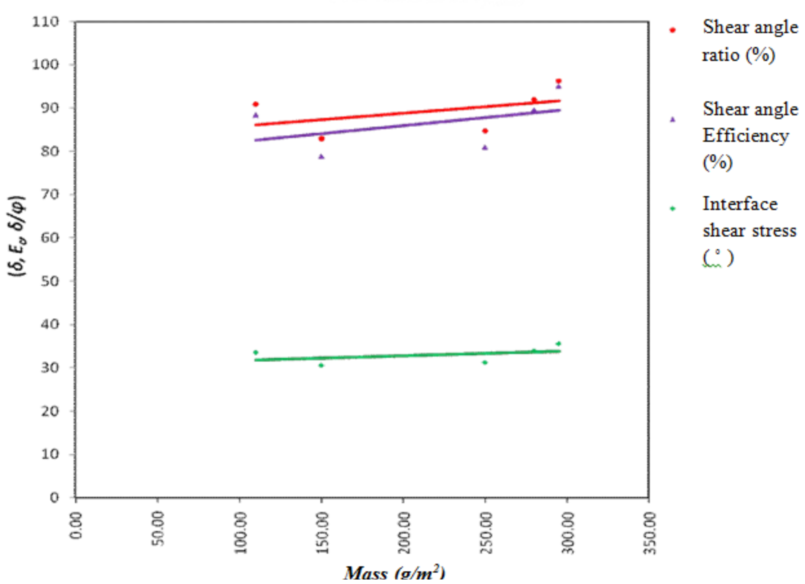

Figure 4. Correlation between mass of geotextile and interface shear stress parameter

Correlation between tensile strength of geotextile with interface shear stress parameter is shown at

Table 4b and Figure 5. According to variation of geotextile tensile strength, (*δ*) value increase linearly from 33,62˚ to 35,59 ˚.δ/φ ratio also tend to increase linearly from 90,97 % to 96,31%. Similarly for *Eφ* value increase linearly from 88,34% to 95,13%.Alteration scale of interface shear stress parameter is relatively more slight if it compare with scale of geotextile tensile strength. So that, the influence of geotextile tensile strength to interface shear stress parameter is relatively slight.

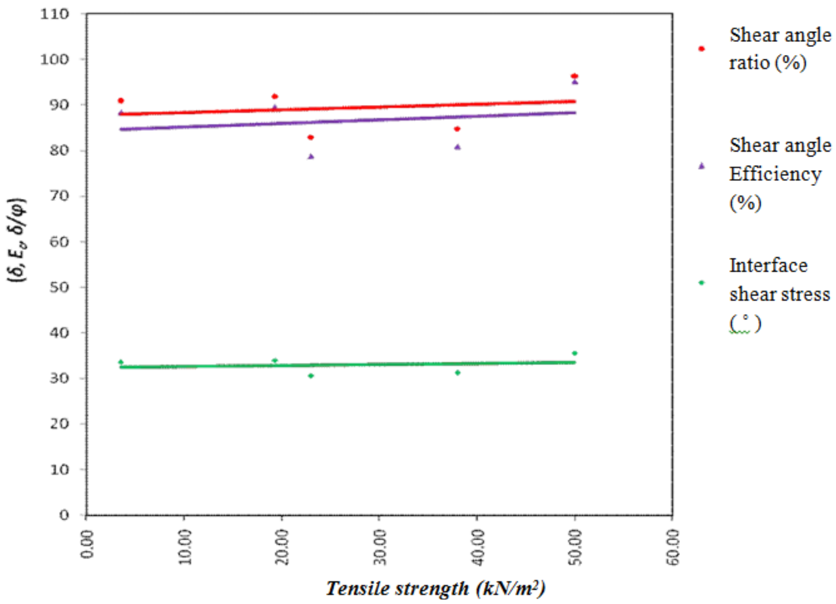

Figure 5. Correlation between tensile strength of geotextile and interface shear stress parameter

Correlation between elongation of geotextile with interface shear stress parameter is shown at

Table 4c and Figure 6. According to variation of geotextile elongation, (*δ*) value decrease linearly from 35,59˚ to 33,98 ˚. Alteration scale of interface shear stress parameter is relatively more slight if it compare with scale of geotextile elongation variety. δ/φ ratio tend to decrease linearly from 96,31 % to 91,95%. Similarly for Eφ value decrease linearly from 95,13% to 89,59%. So that, the influence of geotextile elongation to interface shear stress parameter is relatively slight.

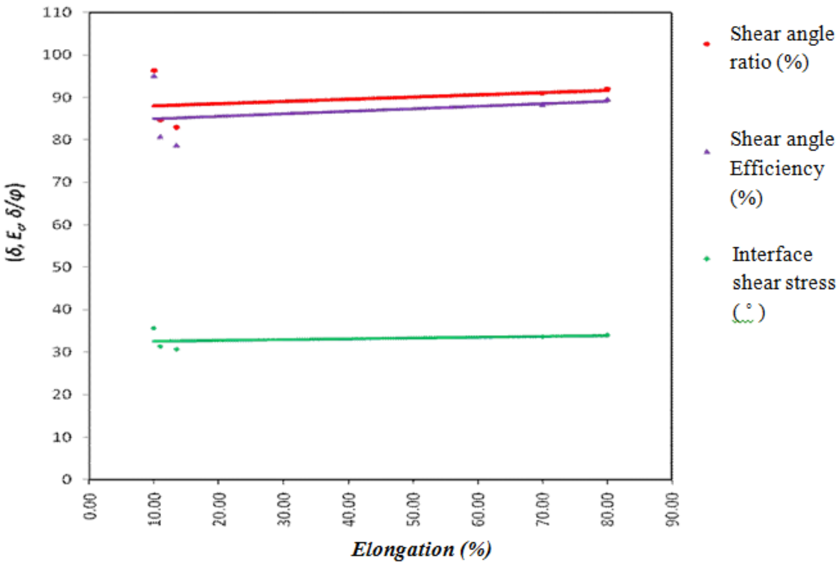

Figure 6. Correlation between elongation of geotextile and interface shear stress parameter

Interface shear stress ratio comparison between this research with similar research ago are shown in

Table 5 and Figure 7. From those figure and table, it obtain the lowest ratio (δ / φ) that is Ottawa sand with non woven geotextiles. The value is 0,69 (Effendi, 1995). Woven geotextile constantly has a lowest*δ/φ* ratio value. While the highest one is non woven geotextile (reinforcement geotextile are included non woven type). Smooth surface texture of woven geotextile deliver lower δ/φ ratio value than rough surface (nonwoven). So the conclution is the geotextile surface texture very important to determine interface shear angle value.

Table 4.Geotextile charracteristic and interface shear stress parameter

a. According geotextile mass

Geotextile charracteristic					Interface shear strength parameter					
					Paramaterat τ_{max}			Paramaterat $\tau_{residual}$		
Code	Type	**Mass (g/m²)**	Tensile strength (kN/m')	Elongation (%)	δ (°)	δ/φ (%)	E (%)	δ (°)	δ/φ (%)	E (%)
S-HNW91100	nonwoven(smooth)	**110**	3.58	70.00	33.62	90.97	88.34	28.81	94.00	92.81
S-HW91150	woven(smooth)	**150**	22.50	13.50	30.65	82.94	78.78	28.09	91.62	90.05
S-HRX250	woven(rough)	**250**	38.00	11.00	31.32	84.74	80.58	28.81	93.97	92.79
S-TS700	nonwoven(rough)	**280**	19.30	80.00	33.98	91.95	89.59	29.36	95.10	94.94
S-PEC50	reinforcement(rough)	**295**	50.00	10.00	35.59	96.31	95.13	29.76	97.09	96.49

b. According geotextile tensile strength

Geotextile charracteristic					Interface shear strength parameter					
					Paramaterat τ_{max}			Paramaterat $\tau_{residual}$		
Code	Type	Mass (g/m²)	**Tensile strength (kN/m')**	Elongation (%)	δ (°)	δ/φ (%)	E (%)	δ (°)	δ/φ (%)	E (%)
S-HNW91100	nonwoven(smooth)	110	**3.58**	70.00	33.62	90.97	88.34	28.81	94.00	92.81
S-TS700	nonwoven(rough)	280	**19.30**	80.00	33.98	91.95	89.59	29.36	95.10	94.94
S-HW91150	woven(smooth)	150	**22.50**	13.50	30.65	82.94	78.78	28.09	91.62	90.05
S-HRX250	woven(rough)	250	**38.00**	11.00	31.32	84.74	80.58	28.81	93.97	92.79
S-PEC50	reinforcement(rough)	295	**50.00**	10.00	35.59	96.31	95.13	29.76	97.09	96.49

c. According geotextile elongation

Geotextile charracteristic	Interface shear strength parameter

Code	Type	Mass	Tensile strength	**Elongation**	Paramaterat τ_{max}			Paramaterat $\tau_{residual}$		
		(g/m²)	(kN/m')	**(%)**	δ (°)	δ/φ (%)	E (%)	δ (°)	δ/φ (%)	E (%)
S-PEC50	reinforcement(rough)	295	50.00	**10.00**	35.59	96.31	95.13	29.76	97.09	96.49
S-HRX250	woven(rough)	250	38.00	**11.00**	31.32	84.74	80.58	28.81	93.97	92.79
S-HW91150	woven(smooth)	150	22.50	**13.50**	30.65	82.94	78.78	28.09	91.62	90.05
S-HNW91100	nonwoven(smooth)	110	3.58	**70.00**	33.62	90.97	88.34	28.81	94.00	92.81
S-TS700	nonwoven(rough)	280	19.30	**80.00**	33.98	91.95	89.59	29.36	95.10	94.94

Table 5. Resume of interface shear angle ratio

No	Reference	Interface	δ/φ
1	Research,2011	Sand– Woven geotextile (Palangkaraya sand)	0.81-0.87
		Sand– Nonwoven geotextile (Palangkaraya sand)	0.89-0.93
		Sand– Reinforcement geotextile(Palangkaraya sand)	0.96-0.97
2	Ariyanto,2010	Sand – Geotextile	0.96
3	Rifa'i,2009	Sand– Woven geotextile (Parangtritis sand)	0.83-0.86
		Sand– Nonwoven geotextile (Parangtritis sand)	0.91-1.05
4	Effendi,1995	Sand– Nonwoven geotextile (Ottawa sand)	0.69-0.79
5	Koerner,1990	Sand – Woven geotextile (Roundly sand)	0.86
		Sand – Nonwoven geotextile(Roundly sand)	0.93
		Sand – Woven geotextile(Silty sand)	0.88
		Sand – Nonwoven geotextile(Silty sand)	0.96

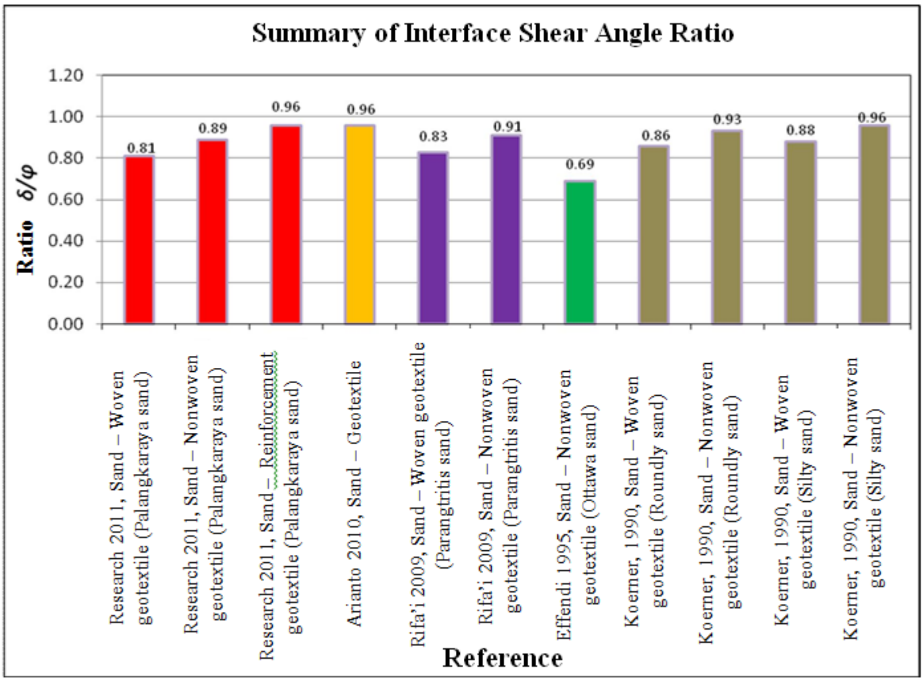

Figure 7. Interface shear angle ratio comparison

VI. CONCLUTION

From this labolatory test and discussion, it can be concluded that :

1. Palangkaraya sands are identified as well – graded sand (SW).
2. The lowest ratio (*δ/φ*) of interface shear angle between Palangkaraya sand with geotextile is 0.81. The ratio is higher than recommended value of Das, 2008 (*δ/φ*= 0.5-0.67), Terzaghi& Peck, 1967 (*δ/φ*=0.67) and Bowles, 1984 (*δ/φ*=0.6-0.8).
3. The surface texture of the geotextile (smooth and rough) also affects the shear strength value of the sand-geotextile interface
4. Geotextile characteristics have little effect on changes in interface shear strength parameters.

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