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Abstract. There are several factors that affecting the shear strength and shear strength parameters (i.e. cohesion and friction angle). In this study, the effect of coarse material percentage was tested. Six different mixtures of soils (clay and sand) with different coarse material percentages (i.e. from 80 % to 30% of coarse material percentage) were tested via using direct shear test under different moisture content percentage. The results indicated that the shear strength and friction angle were decreased by the increment of the percentage of coarse materials (sand). However, the cohesion results showed unique behavior. The cohesion (at every moisture content values) increased with the increment of the percentage of coarse materials until specific point then it started to decrease with the increment of the percentage of coarse materials.

Keywords: Soft soil, ground modification.

1. Introduction

Generally, several parameters gave effect to the shear strength of soils. These parameters such as: Particle size [1-4], particle shape [5-8], moisture content, density and percentage of coarse materials. However, in this study, the effect of the percentage of coarse materials was investigated. Table 1 shows the summary of findings from previous researchers regarding the relations between the shear strength and friction angle with particle size. Meanwhile, Table 2 shows the summary of some findings by the previous researchers regarding the relations between the shear strength, friction angle with percentages of coarse materials. In addition, there are some other parameters that can affect the shear strength such as: (1) applied normal stress, Liu et al. [9] and Li et al. [10], declared that the friction angle will decrease with the increment of the applied normal stress (or confining pressure). (2) Coefficient of uniformity, Liu et al. [9] indicated that, with the increment in the coefficient of uniformity, the friction angel would decrease. Kokusho et al. [11] mentioned the same thing (for coefficient of uniformity) if the soil did not contain crushable particles. (3) The size of specimen and the oversize particles have also affect on the shear strength [12-14]. (4) Shear rate has also influenced the shear strength [10, 15].

Table 1. Relations between the shear strength and friction angle with particle size.

parameter	Soil type	Relation to increase the particle size	References
Friction angle	Mixture of silt, sand and gravel	decrease	[3]
Undrained shear strength	Mixture of clay, silt, sand and gravel	Increase when the particle diameter > 20 mm	[9]
Friction angle	Mixture of clay, silt, sand and gravel	Increase	[16]

Table 2. Relations between the shear strength and friction angle with percentages of coarse materials.

Parameters	Soil type	Relation to increase the percentage of coarse materials	References
FA	Mixture of clay, silt, sand and gravel	Increase	[4]
FA	Mixture of clay and gravel	Increase	[6]
SH	Mixture of clay and gravel	Increase	[6]
FA	Mixture of sand and gravel	Increase	[7]
USH	Mixture of clay, silt, sand and gravel	Start to increase when the percentage of fine materials is less than 75%	[9]
FA	Mixture of clay, silt, sand and gravel	Increase	[16]
FA	Mixture of sand and gravel	Increase till specific point then decrease	[17]
USH	Mixture of clay and sand	High at 90% percentage of coarse material then decrease from 70% to 50% (the lower shear strength) and then decrease from 30% to 0%	[18]
USH	Mixture of sand and gravel (gravel <50%)	Decrease	[19]
FA	Mixture of sand and gravel	Increase	[20]
SH	Mixture of sand and gravel	Increase	[20]
SH	Mixture of sand and gravel	Increase	[21]
SH	Sand	Increase	[22]
FA	Simulation of mixture of soil	Increase	[23]
SH	Mixture of sand and gravel (gravel ≤60%)	Increase	[24]
FA	Mixture of sand and gravel (gravel ≤60%)	Increase	[24]
FA	Mixture of sand and gravel (gravel ≤50%)	Increase	[25]

SH is shear strength. FA is friction angle. USH is undrained shear strength.

2. Materials and test procedures

In this study, 141 compacted samples (compacted by using ASTM [26]) were tested by using direct shear test under ASTM [15] standard. The samples were classified to 6 mixtures soils (clay and sand) as the followings: (1) 80-20 (where 80 is 80% of coarse materials and 20 is 20% of fine materials < 75 µm), (2) 70-30, (3) 60-40, (4) 50-50, (5) 40-60 and (6) 30-70. Every soil mixture proportions was tested under three applied normal stresses, i.e. 10.5 kPa, 21 kPa and 31.5 kPa. However, due to the limitation of shear box size (100 × 100 mm), the maximum diameter size of coarse materials (sand) must be less than 3.35 mm. This was done to avoid soil particles to be oversized, thus to avoid overestimation in the shear strength and shear strength parameters values [22-24]. Meanwhile, the fine materials of kaolin were used due to the stable properties of kaolin compared with other clay minerals [27, 28]. Moreover, all the soil mixtures were compacted by using standard compaction test to achieve the maximum dry density. Therefore, the results on this paper included the optimum moisture content (OMC).

3. Effect of percentage of coarse materials in shear strength and shear strength parameters

The summary of shear strength results versus the percentage of coarse materials under different mixture and applied normal stress were tabulated in Table 3. The applied normal stresses in Fig. 1, 2, 3 were 10.5, 21.5 and 31.5 kPa, respectively. These plots indicate that the highest value of shear strength was at applied normal stress 31.5 kPa, while the lowest was at applied normal stress at 10.5 kPa. The mixtures 80-20, 70-30, 60-40, 50-50, 40-60 and 30-70 represent the percentages of coarse materials as 80, 70, 60, 50, 40 and 30 respectively.

Table 3. The range of shear strength for different mixtures under different applied normal stress.

	Range of shear strength in kPa					
The mixtures	80-20	70-30	60-40	50-50	40-60	30-70
Normal stress 10.5 kPa	19.3-44.2	26.9-53.4	32.6–63.2	25.6– 70.4	30.1–54.7	36.7–50.2
Normal stress 21 kPa	29.9–53.5	37.7-61.4	50.8-81.2	37.6-102	54.4-77.6	57.1-70.9
Normal stress 31.5 kPa	39.7-65.3	41.5-80.5	68.2-85.5	43.6-117	68.3-118	65.8-102

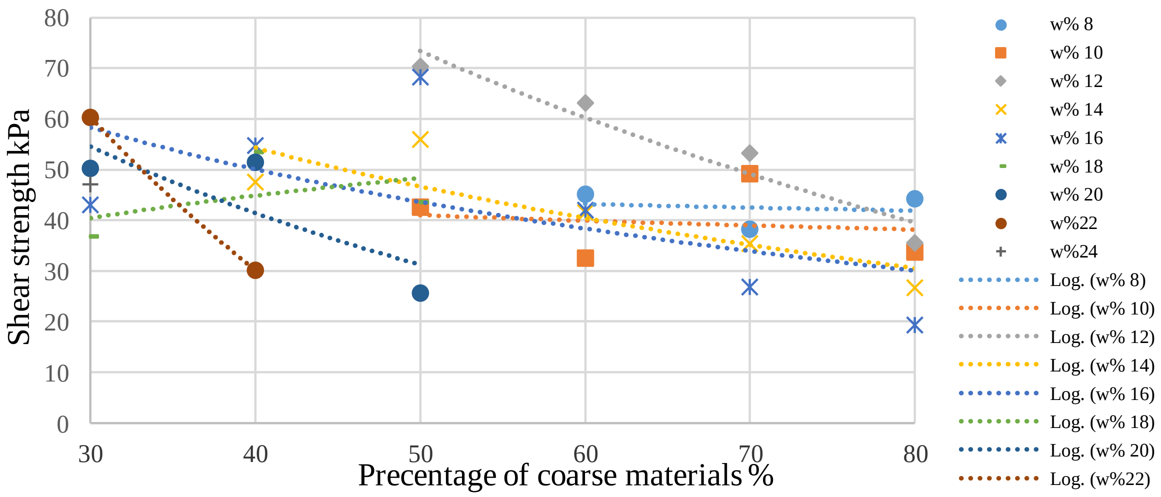

Figure 1. The plot of shear strength versus the precentage of coarse materials for applied normal stress equal to 10.5 kPa (where w% is the moisture content).

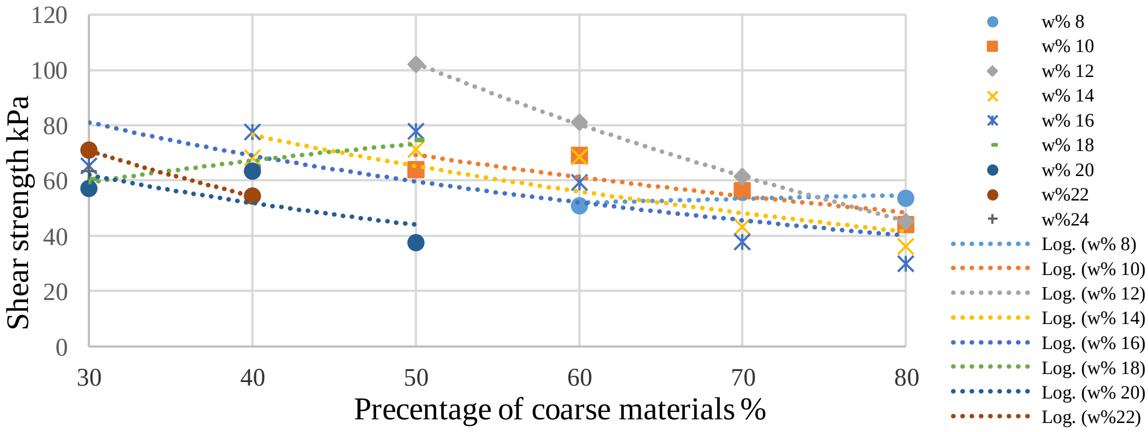

Figure 2. The plot of shear strength versus the precentage of coarse materials for applied normal stress equal to 21 kPa (where w% is the moisture content).

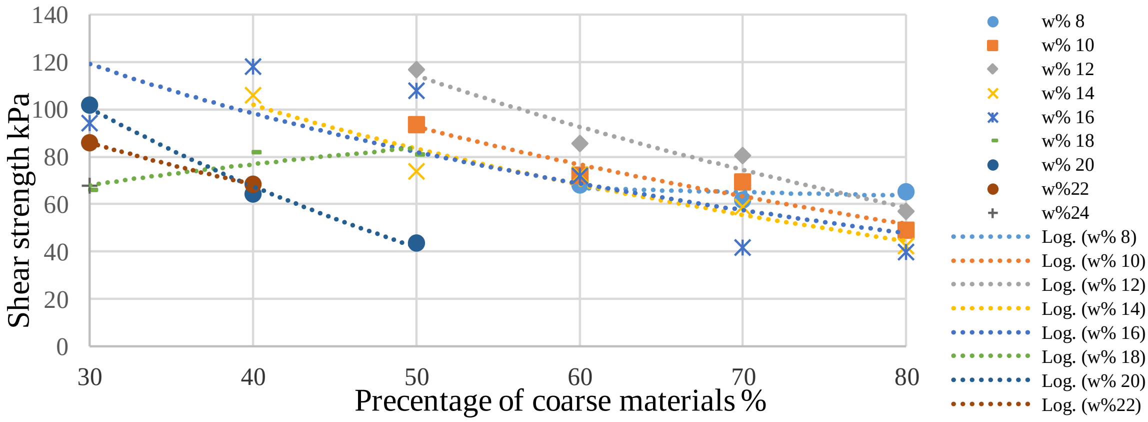

Figure 3. The plot of shear strength versus the precentage of coarse materials for applied normal stress equal to 31.5 kPa (where w% is the moisture content).

Moreover, Fig. 4 and 5 show the results of shear strength parameters (i.e. cohesion (c) and friction angle (∅)) versus the percentage of coarse materials. Fig. 4 shows the results of cohesion versus the percentage of coarse materials. The results indicate that the cohesion tends to provide the concave down quadratic curve relation with percentage of coarse materials with most of moisture content points. On the other side, Fig. 5 shows the results of friction angle versus the percentage of coarse materials. The results indicate that the friction angle tends to provide linear relation with the percentage of coarse materials.

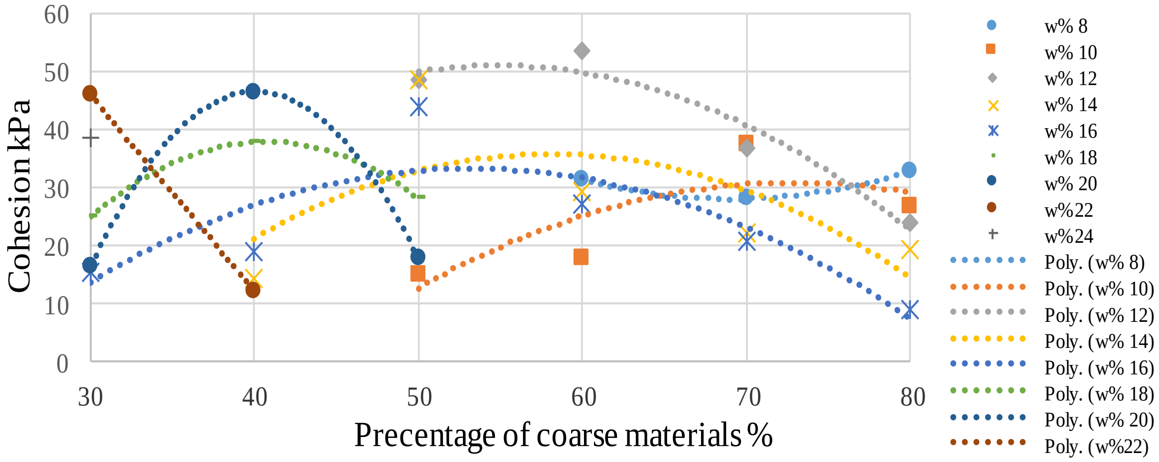

Figure 4. The plot of cohesion versus the precentage of coarse materials (where w% is the moisture content).

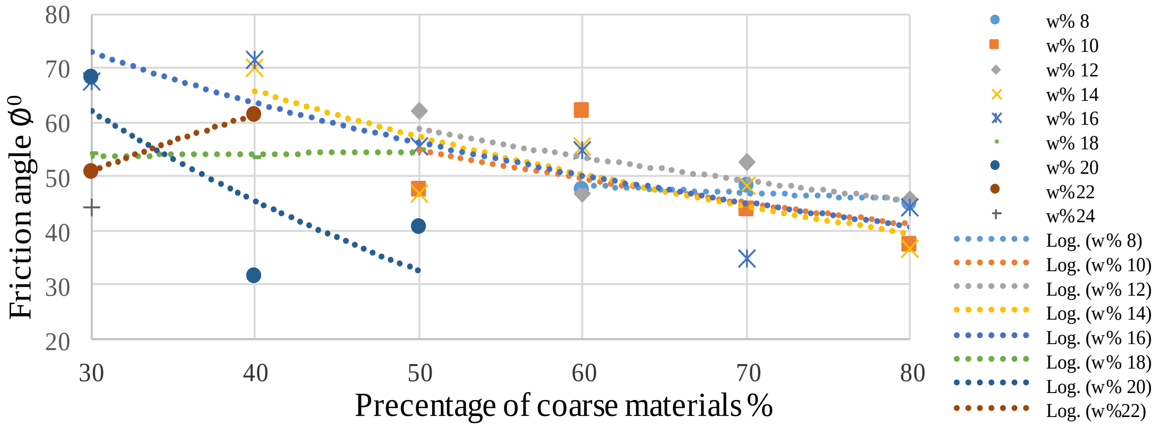

Figure 5. The plot of friction angle versus the precentage of coarse materials (where w% is the moisture content).

4. Discussion

The study indicates that the shear strength decreased with the increment of the percentage of coarse materials. This result has good agreement with previous researchers who studied on the mixture of clay and sand [12], and sand and gravel [13]. However, these outcomes disagree with other researchers who studied on the mixture of clay and gravel [6] and sand only [16]. The disagreement is due to the different shear rate, where a faster shear rate causes the pore water pressure to develop fast, and thus gives a low friction between the coarse particles. Thus, the decrement in the shear strength can be explained by the decrement of the friction angle with the increment of the percentage of coarse materials as shown in Fig. 5. Meanwhile, the cohesion shows different values at the same moisture content for all different mixtures proportions. Fig. 4 shows that the increment in the percentage of coarse materials led to the increment of the cohesion until it reaches maximum point. Then, with the increment in the percentage of coarse materials, the cohesion started to decrease, produced the concave down quadratic curve relation. On the other hand, with the increment of the applied normal stress, the shear strength increased. These results show an agreement with the findings by Liu et al. [9] and Yazdanjou et al. [20].

Conclusion

A series of tests were conducted by using direct shear box test to study the effect of the percentage of coarse materials in the shear strength and shear strength parameters. The results are as the followings:

- With the increment of the percentage of coarse materials, the shear strength and friction angle decreased.
- The cohesion trends increases with the increment of the percentage of coarse materials until maximum points, then it decreased with the increment of the percentage of coarse materials.
- With the increment of the applied normal stress, the shear strength increased.

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References

[1] Seminsky, L. 2013. The Shear Strength of Granular Materials with Dispersed and Non-Dispersed Oversized Particles (*Doctoral dissertation, University of Pittsburgh*).

[2] Hsieh, Chiwan Wayne, Gee Ham Chen, and Jeng-Han Wu. 2011. The shear behavior obtained from the direct shear and pullout tests for different poor graded soil-geosynthetic systems. *Journal of GeoEngineering* **6**, no. **1**: 15-26.

[3] Kim, Daehyeon, and Sungwoo Ha. 2014. Effects of Particle Size on the Shear Behavior of Coarse Grained Soils Reinforced with Geogrid. Materials **7**, no. **2** : 963-979.

[4] Li, Yanrong. 2013. Effects of particle shape and size distribution on the shear strength behavior of composite soils. *Bulletin of Engineering Geology and the Environment* **72**, no. **3-4**: 371-381.

[5] Cho, Gye-Chun, Jake Dodds, and J. Carlos Santamarina. 2006. Particle shape effects on packing density, stiffness, and strength: natural and crushed sands. *Journal of Geotechnical and Geoenvironmental Engineering* **132**, no. **5**: 591-602.

[6] Li, Y., Huang, R., Chan, L. S., and Chen, J. 2013. Effects of particle shape on shear strength of clay-gravel mixture. KSCE Journal of Civil Engineering. **17(4)**, 712-717.

[7] Yagiz, Saffet. 2001. Brief note on the influence of shape and percentage of gravel on the shear strength of sand and gravel mixtures. *Bulletin of Engineering Geology and the Environment* **60**, no. **4**: 321-323.

[8] Azéma, Emilien, Nicolas Estrada, and Farhang Radjai. 2012. Nonlinear effects of particle shape angularity in sheared granular media. *Physical Review* E **86**, no. 4: 041301.

[9] Liu, X. L., H. Loo, H. Min, J. H. Deng, L. G. Tham, and C. F. Lee. 2006. Shear strength of slip soils containing coarse particles of Xietan landslide. *Geotechnical Special Publication* **151**: 142-149.

[10] Li, Yanrong, Lung S. Chan, Albert T. Yeung, and Xiqiong Xiang. 2012. Effects of test conditions on shear behaviour of composite soil. *Proceedings of the ICE-Geotechnical Engineering* **166**, no. **3**: 310-320.

[11] Kokusho, Takeji, Tadashi Hara, and Ryousuke Hiraoka. 2004. Undrained shear strength of granular soils with different particle gradations. *Journal of Geotechnical and Geoenvironmental Engineering* **130**, no. **6**: 621-629.

[12] Wu, Po-Kai, Kenichi Matsushima, and Fumio Tatsuoka. 2008. Effects of specimen size and some other factors on the strength and deformation of granular soil in direct shear tests. *Geotechnical Testing Journal* **31**, no. **1**: 473.

[13] Cerato, Amy B., and Alan J. Lutenegger. 2006. Specimen size and scale effects of direct shear box tests of sands. *Geotechnical Testing Journal* **29**, no. **6**: 507.

[14] Fakhimi, Ali, and Hooman Hosseinpour. 2011. Experimental and numerical study of the effect of an oversize particle on the shear strength of mined-rock pile material. *ASTM geotechnical testing journal* 34, no. **2**: 131-138.
[15] ASTM D 3080. 2011. Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions. West Conshohocken, PA: Am. Soc. Test. Mater. USA
[16] Wang, Jun-Jie, Hui-Ping Zhang, Sheng-Chuan Tang, and Yue Liang. 2013. Effects of particle size distribution on shear strength of accumulation soil. *Journal of Geotechnical and Geoenvironmental Engineering* **139**, no. **11**: 1994-1997.
[17] Simoni, Alessandro, and Guy T. Houlsby. 2006. The direct shear strength and dilatancy of sand–gravel mixtures. *Geotechnical and Geological Engineering* **24**, no. **3**: 523-549.
[18] Prakasha, K. S., and V. S. Chandrasekaran. 2005. Behavior of marine sand-clay mixtures under static and cyclic triaxial shear. *Journal of geotechnical and geoenvironmental engineering*. **131**: 213-222.
[19] Naeini, S. A. 2006. The ultimate shear behavior of loose gravelly sandy soils. *The Geological Society of London*. IAEG2006: 526
[20] Yazdanjou, V., N. Salimi, and A. Hamidi. 2008. Effect of gravel content on the shear behavior of sandy soils. *In Proc. of 4th National Congress on Civil Engrg*., Tehran University, Iran.
[21] Vallejo, Luis E., Sebastián Lobo-Guerrero, and Leanna F. Seminsky. 2014. Shear Strength of Sand-Gravel Mixtures: Laboratory and Theoretical Analysis. *In Geo-Congress 2014 Technical Papers@ Geo-characterization and Modeling for Sustainability*, pp. 74-83.ASCE.
[22] Shin, H., and J. C. Santamarina. 2012. Role of particle angularity on the mechanical behavior of granular mixtures. *Journal of Geotechnical and Geoenvironmental Engineering*. **139**: 353-355.
[23] Ueda, Takao, Takashi Matsushima, and Yasuo Yamada. 2011. Effect of particle size ratio and volume fraction on shear strength of binary granular mixture. *Granular Matter* **13**, no. **6**: 731-742.
[24] Hamidi, A., M. Alizadeh, and S. M. Soleimani. 2009. Effect of particle crushing on shear strength and dilation characteristics of sand-gravel mixtures. *International Journal of Civil Engineering* **7**, no. **1**: 61-72.
[25] Yagiz, Saffet. 2001. Brief note on the influence of shape and percentage of gravel on the shear strength of sand and gravel mixtures. *Bulletin of Engineering Geology and the Environment* **60**, no. **4**: 321-323.
[26] ASTM D 698. 2012. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12400 ft-lbf/ft3 (600 kN-m/m3)). *ASTM International*, West Conshohocken, PA, USA.
[27] Das, B., 2007. *Fundamentals of Geotechnical Engineering*. Cengage Learning. pp 622
[28] Murthy, V. N. S. 2002. *Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering*. CRC Press. pp 1029