

Effect Of Gradation on Shear Strength Parameters of Granular Soils

Athira S. Nair

*Assistant Professor, Department of Civil Engineering
Sarabhai Institute of Science and Technology, Thiruvananthapuram, India
doi.org/10.64643/IJIRTV12I10-204356-459*

Abstract—The shear parameters of soil are required for determining the bearing capacity of soils for all types of foundation. The equipment required for the determination of shear parameters at the accurate drainage conditions are costly and hence in most of the projects shear parameters are determined from the Standard penetration test. The correlations between the index properties of soil and its engineering properties are immensely useful since it is easier to determine index properties and is relatively difficult to determine the engineering properties. It is easy to determine the particle size distribution since the equipment required is cheap and easily available. Twenty granular soil samples of varying gradation parameters like uniformity coefficient and coefficient of curvature were prepared by mixing gravel and sand in various proportions. The shear parameters are determined from large scale direct shear test carried out in a shear box of size 300 mm x 300 mm x 200 mm. Thus, correlations are developed between angle of shearing resistance and gradation parameters like coefficient of curvature and uniformity coefficient. It is observed from the results that angle of shearing resistance is inversely proportional to the uniformity coefficient.

Index Terms—Gradation, Laboratory scale plate load test, Shear parameters, Uniformity Coefficient.

I. INTRODUCTION

In Transportation Geotechnics, various mixes of soil are studied to frame sub-mix for the construction of airport and highway pavements to form their sub-base course. For this the sub-base course is formed from the mixture of granular soils. It would be advantageous if the shear strength of these sub-base courses can be determined from the Particle Size Distribution without any further testing such as the expensive large scale direct shear test. [12] Studied the effects of particle shape on angles of repose and bulk densities of a

granular solid and found that the angle of repose increased with increasing departure from spherical shape.

Several shear tests are carried out with a direct shear apparatus modified in order to apply matric suctions greater than 101 kPa to the soil specimen ([4]). They reported that the failure envelope for an unsaturated soil is somewhat nonlinear with respect to the matric suction axis. As the soil became unsaturated at higher matric suctions, the angle of internal friction appears to decrease to a relatively constant value. It is also noticed that the non-linearity in the failure envelope became noticeable when the soil is tested over a wide range of matric suctions.

Undrained shear strength of granular soils with different particle gradations were determined by [16]. It is reported that the undrained monotonic loading strength corresponding to larger axial strain showed a drastic increase with increasing C_u for the same relative density. It is also noticed that the post-liquefaction undrained strength for larger strain is not uniquely determined by relative density but largely dependent on particle gradations. Mainly soils with larger C_u and larger absolute density tend to show considerably larger undrained strength. Some performed experiments to study the effect of particle size on the shear strength behavior of sands and found that maximum shear strength as well as angle of internal friction increases with an increase of particle size and gradation ([2]). It is also reported that the normal load plays an important role in this. Tests were carried out to examine the influence of particle size and particle orientation on the shear strength parameters of unbound slate slag by collecting soil rich in slate slag obtained from mining activities ([11]). It is reported that the particle size plays an important role in the angle of shearing resistance. When the particles

are stacked perpendicular to the shear box, the angle of internal friction becomes much steeper. A study is also made for finding the effects of particle shape and size distribution on the shear strength behaviour of composite soils ([8]). It is reported that on increasing the coarse fraction the constant volume friction angle increases.

An experimental study is carried out on the fines content and angle of shearing resistance of lateritic soil and is found that the angle of internal friction generally decreases with increase in fines content ([1]). Some studies are carried out to examine the effects of particle size distribution on shear strength of accumulation soil which is non-homogeneous and has the characteristics of both rock and soil ([5]). It is reported that the angle of shearing resistance increases with an increase in the median particle diameter or the gravel content and decreases with an increase of the coefficient of uniformity.

Some tests are performed to study the influence of coefficient of curvature on the shear strength parameters of reinforced soil ([6], [7]). It is reported that the coefficient of curvature and proportion of 0.5mm particle size has a considerable influence on the shear parameters of reinforced soil.

Investigations are carried out for determining the influence of gradation on the shear parameters of reinforced soil and found that the shear strength in sand – geogrid interface mobilized under direct shear mode is related to the particle size ([7], [8]). It is also noticed that the angle of friction decreased with the decrease of particle size and reached almost 10 degrees. The ratio of internal friction of sand obtained from direct shear test and the interface friction angle is proportional to the ratio of coefficient of uniformity and coefficient of curvature of the soil.

The porosity and particle size for hydraulic conductivity of binary mixed soils containing two different-sized silica particles are studied and reported that the coefficient of permeability of the three tested mixed materials decreases with an increase in the volume fraction of fine particles ([3]).

The purpose of this paper is to study the influence of uniformity coefficient (C_u) and coefficient of curvature (C_c) on the angle of shearing resistance for granular soil by carrying out sieve analysis and large-scale direct shear tests.

II. LARGE SCALE DIRECT SHEAR TESTS

The shear parameters are obtained from large scale direct shear tests which are carried out for each mix proportions of sand, 6 mm aggregates and 12 mm aggregates.



Fig.1 Large scale direct shear test set-up

The soil mixes of required mix proportions are made and are taken for the direct shear tests. The shear box is of dimensions 300 mm x 300 mm x 200 mm has a 10 kN proving ring for applying the horizontal load and a dial gauge of 0.01 mm sensitivity for measuring the deformation. The shear box is made up of MS plates which are having a thickness of 4 mm. The whole test set-up is mounted on a MS testing bench with facilities for applying the vertical and the horizontal loads. Fig.1 shows the large-scale direct shear test set-up.

A. MATERIALS USED

In this paper, the samples are prepared by mixing sand, 6 mm aggregates and 12 mm aggregates which are taken at various proportions. They are taken in the ratio of sand: 6 mm aggregates: 12 mm aggregates. The various proportions in which samples are prepared are given in Table I. The samples are well mixed and the required tests are being conducted.

III. RESULTS AND DISCUSSIONS

Grain Size Analysis is carried out for each mix proportions of sand, 6 mm aggregates and 12 mm aggregates. The soil samples of required mix proportions are made and grain size analysis is carried out. The angle of shearing resistance obtained from large scale direct shear tests are presented in Table I.

Table I

Sample	Uniformity Coefficient, C_u	Coefficient of Curvature, C_c	Angle of Shearing Resistance, ϕ ($^\circ$)
1:1:1	10.77	1.37	6
1:1.5:1	3.67	0.70	19
1.5:1.5:1	12.4	1.65	5.8
1.5:1.5:2	5.20	0.62	12.2
1:1:1.5	6.27	1.69	10
1:1.5:1.5	5.80	0.80	10.5
0.5:1:0.2	4	0.69	13.5
1:1:0.1	8	1.125	6.5
3:0.5:0.1	5.7	0.514	12
3:1.5:0.1	6.26	1	9
5:3:1	4.4	1.31	12.5
4:4:1	5.71	1.43	11.5
4:3:2	6.25	1	7
2:4:3	5.72	1.42	11
1:1:3	1.241	2.78	20
1:3:1	3.8	2.368	15
2:5:1	3.75	1.956	18
3:2:1	3.913	2.367	14.5
2:2:5	3.78	2.941	15.5
1:2:3	4.286	2.593	13

Fig.2 shows the variation of angle of shearing resistance with uniformity coefficient of the mixes. It is observed that the angle of shearing resistance reduces with an increase in uniformity coefficient. The equation of the curve is also presented in the figure.

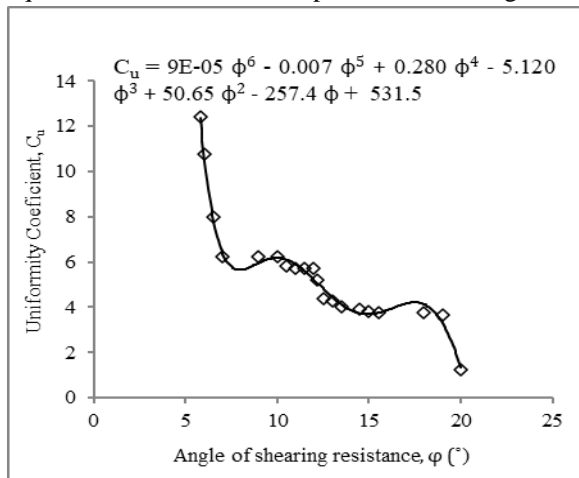


Fig.2 Variation of angle of shearing resistance with uniformity coefficient

Fig.3 presents the variation of angle of shearing resistance with coefficient of curvature. It is observed that as the coefficient of curvature increases, the angle of shearing resistance decreases.

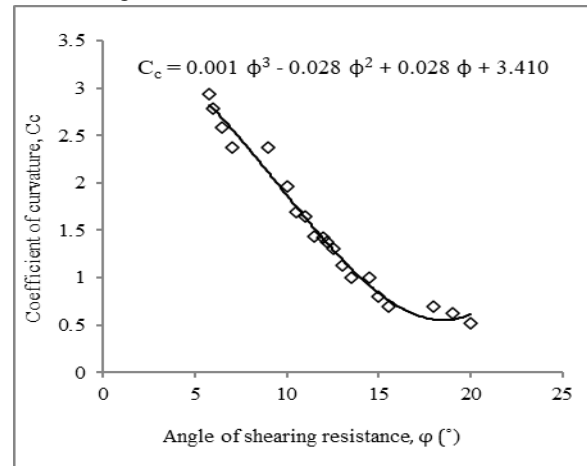


Fig.3 Variation of angle of shearing resistance with coefficient of curvature

Fig.4 presents the relation between coefficient of curvature with uniformity coefficient. It is seen that as the coefficient of curvature increases, the uniformity coefficient also increases.

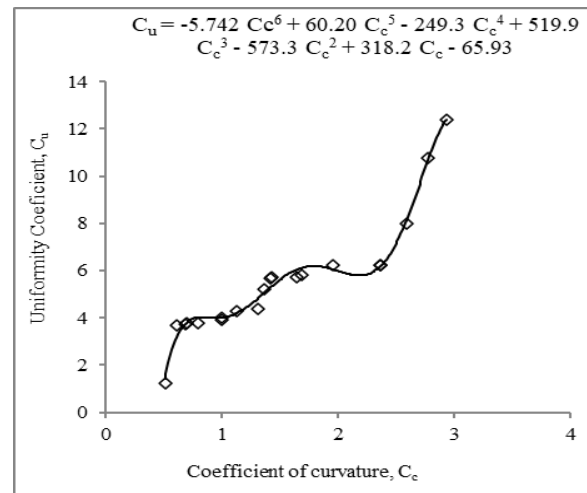


Fig.4 Variation of coefficient of curvature with uniformity coefficient

Based on the results obtained, the following correlations between gradation parameters and angle of shearing resistance of granular soils are made.

- $C_u = 9E-05\phi^6 - 0.007\phi^5 + 0.280\phi^4 - 5.120\phi^3 + 50.65\phi^2 - 257.4\phi + 531.5$
- $C_c = 0.001\phi^3 - 0.028\phi^2 + 0.028\phi + 3.410$
- $C_u = -5.742 C_c^6 + 60.20 C_c^5 - 249.3 C_c^4 + 519.9 C_c^3 - 573.3 C_c^2 + 318.2 C_c - 65.93$

IV. CONCLUSIONS

Based on the results obtained, the following conclusions are made from this study:

- Coefficient of curvature and uniformity coefficient have a considerable influence on the shear parameters of soil.
- Angle of shearing resistance decreases with an increase of the coefficient of curvature and uniformity coefficient.
- Angle of shearing resistance generally decreased with increase in fines content.

REFERENCES

- [1] G. O. Adunoye, "Fines content and angle of shearing resistance of a lateritic soil: An experimental study," *American Journal of Engineering Research (AJER)*, vol. 3, no. 3, pp. 16–21, 2014.
- [2] A. Asad, M. N. Islam, B. Hossain, A. Rahman, and A. Siddika, "Effect of particle size on the shear strength behavior of sands," *Australian Geomechanics*, vol. 46, no. 3, 2011.
- [3] H. L. Choo and S. E. Burns, "Estimating porosity and particle size for hydraulic conductivity of binary mixed soils containing two different-sized silica particles," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 144, 2018.
- [4] J. K. Gan, D. G. Fredlund, and H. Rahardjo, "Determination of the shear strength parameters of an unsaturated soil using the direct shear test," *Canadian Geotechnical Journal*, vol. 25, 1988.
- [5] M. Ghazavi, M. Hosseini, and M. Mollanouri, "A comparison between angle of repose and friction angle of sand," in *Proc. 12th Int. Conf. International Association for Computer Methods and Advances in Geomechanics (IACMAG)*, 2008, pp. 1272–1275.
- [6] J. J. Wang, H. P. Zhang, S. C. Tang, and Y. L. Xu, "Effects of particle size distribution on shear strength of accumulation soil," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 141, 2008.
- [7] A. Latheef, J. Jayamohan, and V. I. Beena, "Influence of coefficient of curvature on the shear strength parameters of reinforced soil," in *Proc. National Conf. Geotechnical Engineering and Modelling*, 2016.
- [8] A. Latheef, J. Jayamohan, and V. I. Beena, "Influence of gradation on the shear parameters of reinforced soil," in *Proc. National Conf. Geotechnical Engineering and Modelling*, 2017.
- [9] Y. Li, "Effects of particle shape and size distribution on the shear strength behavior of composite soils," *Bulletin of Engineering Geology and the Environment*, vol. 24, 2012.
- [10] A. Manne and D. N. Satyam, "Effect of particle size on the shear modulus of granular soil," in *Proc. Indian Geotechnical Conf. (IGC)*, 2014.
- [11] S. P. Narayanan and S. P. Jeyapriya, "Numerical modeling and development of empirical correlations for prediction of plane strain properties of cohesionless soils," *Electronic Journal of Geotechnical Engineering (EJGE)*, vol. 20, no. 14, 2015.
- [12] T. Nishimura and S. K. Vanapalli, "Volume change and shear strength behavior of an unsaturated soil with high soil suction," in *Proc. 16th Int. Conf. Soil Mechanics and Geotechnical Engineering*, 2006, no. 28.
- [13] V. Prashanth and M. L. Gali, "Influence of particle size on the friction and interfacial shear strength of sands of similar morphology," *International Journal of Geosynthetics and Ground Engineering*, 2015.
- [14] G. S. Riley and G. R. Mann, "Effects of particle shape on angles of repose and bulk densities of a granular solid," *Powder Technology*, vol. 7, no. 2, 1972.
- [15] K. Seth, F. S. Adam, B. R. Brad, and J. B. John, "Influence of particle size and particle orientation on the shear strength parameters of unbound slate slag," in *Proc. Int. Conf. Geotechnical Engineering*, 2011.
- [16] T. Takeji, T. H. Tadashi, and R. H., "Undrained shear strength of granular soils with different particle gradations," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 130, 2004.
- [17] C. Zhou, X. X. Min, and Y. P. C., "Effect of particle size distribution on the correlation between liquefaction resistance and shear wave velocity of granular soils," *EPJ Web of Conferences*, vol. 140, 2017.