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EFFECT OF PARTICLE SHAPE ON ITS OTHER GRANULAR SOIL PROPERTIES

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Abstract

Particle shape is usually determined for the coarse grained soil. It is one of the most important soil-grain properties. The other important soil grain properties are angle of shearing resistance of sands, gradation, denseness i.e. density index, uniformity of gradation etc. The mentioned factors have some inter related impacts. The strength of soil is an utmost important factor among all soil engineering parameters and is determined finding out the angle of shearing resistance. In this paper, particle shapes and particle sizes are determined minutely in the laboratory and its in-situ test such as SPT values and corresponding density indices; others are collected from the report of soil mechanics division of geotechnical research directorate of River Research Institute (RRI). In order to find out the other granular properties by determining particle shapes an attempt has been made to predict the strength of grain soils through conventional means. The study finds that SPT values as well as strength of granular soils increases with depth. It is also found that particle sizes increase with depth and their SPT also increases with depth. The shapes are found sub-rounded with medium spherecity while the depths are increased. The study result will help find out the denseness and uniformity of gradation of relevant soils in any location of Bangladesh. So, it will be an opportunity for a design engineer who may expedite the construction works by determining the particle shape of granular soil. Moreover, a design engineer may predict the granular soil strength and other grain properties through determining the particle shape of coarse grained soils. The findings of the present study are expected to help predict granular soil strength and other grain properties of any location by determining particle shape.

Introduction

Bangladesh is a developing country where lots of structures are being built on the soil. In general, Bangladesh soils contain sand, silt and clay. We know the compositions of all the ingredients make soil, but all ingredients are not in the same ratio. As a result, their classification has become different. Soils are classified according to the quantity of ingredients present in the composition and dominate the character of this particle on the soil. Indeed, soils behave in terms of loading, sewerage according to their sizes and shapes. On the other hand, particle shapes of non-cohesive soils have good linkage to its strength. Strength is an utmost important property of construction soil. Sometimes it is found that strength is difficult to determine for non-cohesive soils. As non-cohesive soils usually are collected in disturbed condition and natural density is not found out generally. Under such circumstances, this attempt has been made as such if the

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particle shapes and sizes are determined then soil strength is easily found out by knowing its SPT value.

Literature review

Garg (2008) observed that as the 'shape of the grains' is concerned; there exists no universally accepted measure of the grain shape. However, there are three general classes of grain shapes; i) Bulky grains, ii) Flaky grains & iii) Needle-shaped grains.
Bulky grains: If all the dimensions of a soil particle are about the same, as in sand and gravel, the soil grain is said to have a bulky-shape. Such soil grains are formed by the mechanical breaking of the rock masses.

i) Bulky grains: If all the dimensions of a soil particle are about the same, as in sand and gravel, the soil grain is said to have a bulky-shape. Such soil grains are formed by the mechanical breaking of the rock masses.

ii) Flaky grains: Flaky and plate like grains resemble a piece of paper, and are very thin at edges compared to their length and breadth. They have net electrical charges, on them. Sub-microscopic crystals of clay minerals usually exhibit this type of grain shape.

iii) Needle-shaped grains: Needle-like grain shape is exhibited by a special group of clay minerals, kaolinites.

When the soil formation takes place initially, these bulky grains have sharp edges and are termed angular. After a large interval of time, these edges get worn out. The effect may be considerable during transport by wind or water. Such highly smoothened particles are called well-rounded. In between these two extreme shapes of 'angular' and 'well rounded', there exist other shapes, such as sub-angular, sub-rounded, and rounded;

Beach sands and alluvial sands which are subjected to considerable activity of water, ranges from sub-angular to sub-rounded in shape; while beach gravels are rounded in shape. Wind blown sands are usually well rounded. The grain shape of coarse-grained soils can be observed under a microscope (Garg 2008).

Arora found that the angularity of particles has great influence on the behavior of coarse grained soils. The particles with a high value of angularity tend to resist the displacement, but have more tendencies for fracturing. On the other hand, the particles with low angularity (more denseness) do not crush easily under loads, but have low resistance to displacements as they have a tendency to roll. In general, the angular particles have good engineering properties, such as shear strength.

Arora also found that the angle of shearing resistance of sands in the field can be determined indirectly by conducting in-situ tests, such as the standard penetration test (SPT). The factors that affect the shear strength of cohesionless soils are; shape of particles, gradation, deneseness etc.

The shearing strength of sands with angular particles having sharp edges is greater than that with rounded particles. A well graded sand exhibits greater shear strength than a uniform sand. The degree of interlocking increases with a increase in density. Consequently, the greater the deneseness, the greater the strength.

Table 1. Representative values of shearing angle of sands

Soil	Shearing Angle in degree
Sand, round grains, uniform	27^0 to 34^0
Sand, angular, well-graded	33^0 to 45^0
Sandy gravels	35^0 to 50^0
Silty sand	27^0 to 34^0

It is noticeable that smaller values are for loose conditions and larger values for dense conditions (Arora 2010).

Using natural sands Dodds (2003) found that strength increases with particle size and may decrease with increasing sphericity.

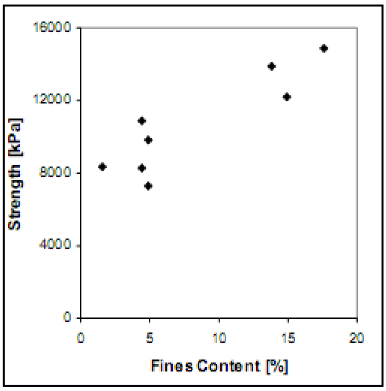


Figure 1. Strength vs. Fines content

The shape of Georgia crushed granites is size dependent. Larger grains exhibit uneven surface texture and comparatively rounded corners. Smaller grains have planar sides and angular corners.

The shape of natural sands varies markedly, from very round and spherical to angular and non-spherical. The maximum void ratio depends on the coefficient of uniformity and particle shape. Lower roundness values in crushed sands lead to higher maximum void ratios, higher critical state friction angles, lower small strain stiffness values, and increased mortar strength. Increased fines content leads to increased workability and strength in the tested sands and conditions. The value of flow is correlated with mortar strength for the sands and conditions tested. The strength of a sand exhibiting a given flow value is higher for crushed sands than for natural sands (Dodds 2003).

Rodriguez and Edeskär (2013) found that the particle shape is affected by the size of the aggregates. Aggregates in small fractions are more elongated and less rounded i. e. more angular, compared to larger fractions. Furthermore, the Aspect Ratio and Circularity seems to be the most suitable quantities to describe the tailings behavior in relation with the empirical model. The accuracy in predicting the friction angle of the tailings by previously published relations based on uniformly graded sand material is low. But the systematic underestimation of the friction angle indicates that it would be possible to establish such empirical relations based on tailings material (Rodriguez and Edeskär 2013).

Methodology

Administratically, Payra is a river of Galachipa Upazilla of Patuakhali district in South-Western Bangladesh. This is the main entrance for the beach of Kuakata. It is watered by the Bay of Bengal (Wikipedia 2015).

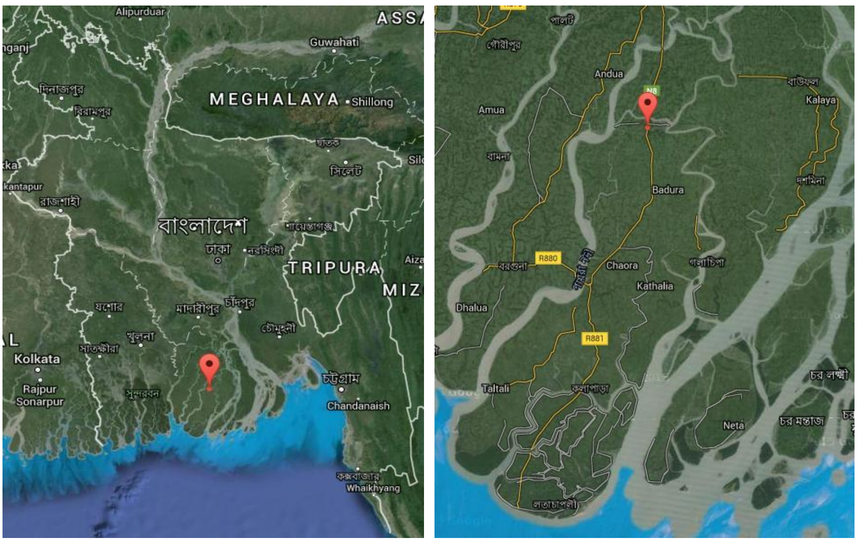


Figure 2. Map of the study area

We know that the soil is called coarse grain whose sizes are 0.02 mm to 0.42 mm. In this context, some coarse grained soil's particle shape and their simultaneous Standard Penetration Resistance for Test (SPT-values i.e. N values) are collected and grain sizes are collected from the Payra Port Project's report of soil mechanics division of Geotechnical Research Directorate of River Research Institute (RRI). Accordingly, other relevant data such as granular soil properties, SPT values, grain sizes, the image of grain shape, relative density have been collected from the same report (Soil Report 2015).

Mentioned tests are conducted through laboratory conventional method and the particle shapes are analyzed as per delivered instructions of the Payra Port Project authority, such as examining the grains under a microscope or magnifying lens and comparing them to a set standard BS14688-1which are shown below the table and figure.

Table 2. Terms for the designation of particle shape

Parameter	**Particle shape**
Angularity/roundness	Very angular Angular Sub angular Sub-rounded Rounded Well rounded
Form	Cubic Flat Elongate
Surface texture	Rough Smooth

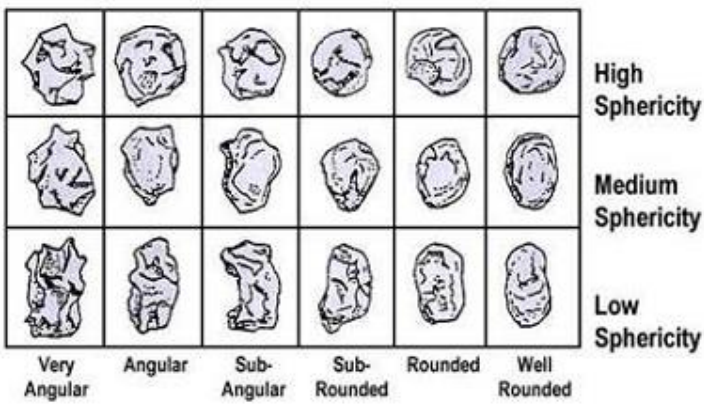
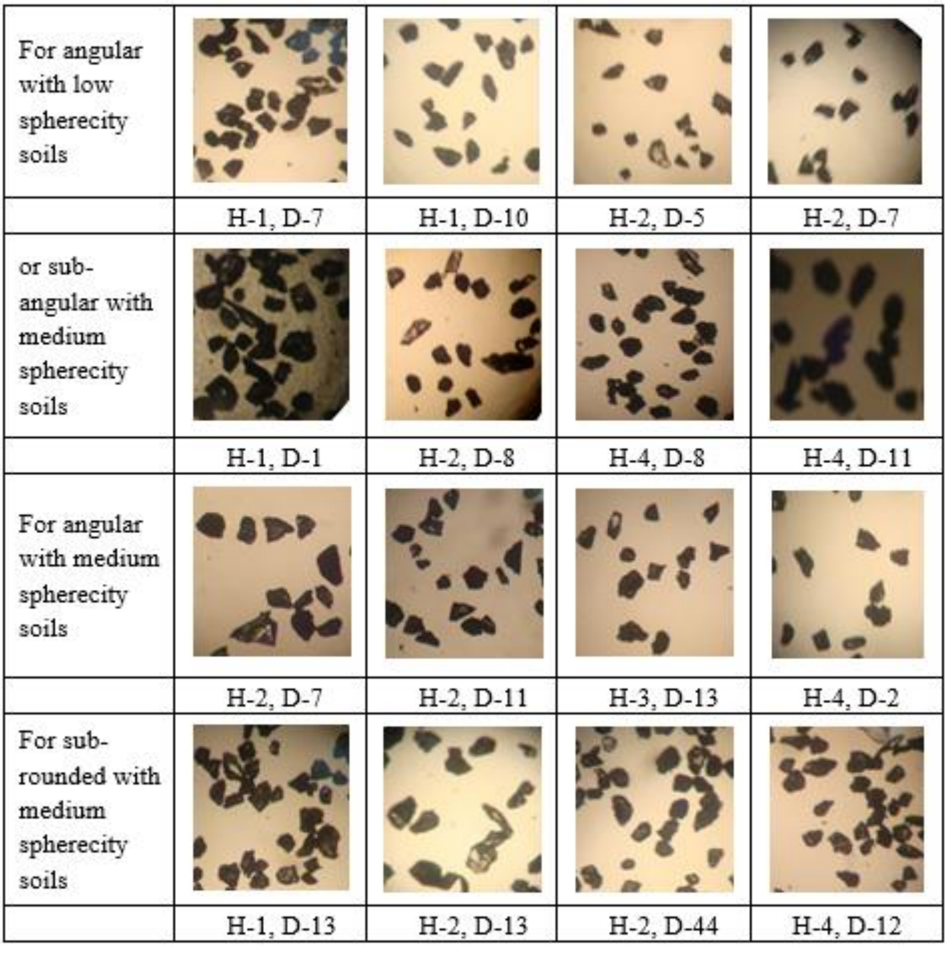


Figure 3. Particle shapes of grannular soils

The study area has been located in the map in Figure 2. For ease and notable classification particle shapes are identified according to the Table 2 and Figure 3 respectively

Results and discussion

Analysis of particle shapes of granular soils of Payra Port area have been shown in Figure 4 and a table of depth, SPT values, angle of shearing resistance ¢, density index, grain size and relative density have been presented the tabular form in Table 3.



[N.B. H-1, H-2 etc. means-Hole number and D-1, D-2 means-Sample number in disturbed condition]

Figure 4. Particle shapes of granular soils of Payra River

Table 3. Testing parameters of granular soil of Payra port area

Location	Hole No.	Sample No.	Depth in m	SPT values	Angle of shearing resistance, φ in degree	Density Index	Grain shape	Grain size in mm	Relative Density
Payra River, Galachipa, Patuakhali	1	D-1	2.1336	4	30	very loose	Sub-angular, Medium Spherecity	0.08-0.25	2.654
	1	D-7	11.2776	8	33	loose	Angular, Low Spherecity	0.074-0.25	2.657
	1	D-10	16.4592	12	35	medium dense	Angular, Low Spherecity	0.074-0.25	2.657
	1	D-13	20.4216	27	33	medium dense	Sub-Rounded, Medium Sphericity	0.08-0.25	2.656
	2	D-5	8.2296	10	34	loose	Angular, Low Spherecity	0.08-0.42	2.657
	2	D-7	11.2776	5	33	loose	Angular, Medium Spherecity	0.08-0.42	2.657
	2	D-8	12.8016	12	32	medium dense	Sub-Angular, Medium Spherecity	0.08-0.42	2.659
	2	D-11	17.3736	10	34	loose	Angular, Medium Spherecity	0.08-0.25	2.657
	2	D-13	20.4216	25	32	medium dense	Sub-rounded, Medium Spherecity	0.08-0.42	2.655
	3	D-7	11.2776	8	34	loose	Angular, Low Spherecity	0.074-0.25	2.666
	3	D-9	14.3256	13	36	medium dense	Angular, Low Spherecity	0.074-0.25	2.661
	3	D-13	20.4216	23	38	medium dense	Angular, Low Spherecity	0.074-0.25	2.658
	4	D-2	2.1336	3	33	very loose	Angular, Medium Spherecity	0.074-0.25	2.664
	4	D-3	3.6576	4	27	very loose	Sub-rounded, low Spherecity	0.08-0.25	2.656
	4	D-8	12.8016	10	30	loose	Sub-Angular, Medium Spherecity	0.074-0.25	2.661
	4	D-11	17.3736	18	35	medium dense	Sub-Angular, Medium Spherecity	0.074-0.25	2.661
	4	D-12	18.8976	22	30	medium dense	Sub-Rounded, Medium Spherecity	0.074-0.25	2.665
	5	D-2	3.6576	3	30	very loose	Sub-Angular, Low Spherecity	0.074-0.25	2.661
	5	D-5	8.2296	9	34	loose	Angular, Medium Spherecity	0.074-0.25	2.657
	6	D-11	17.3736	18	36	medium dense	Angular, Medium Spherecity	0.074-0.25	2.659

A number of graphs have been presented below such as Depth vs. SPT graph, particle shape vs. SPT graph, particle shape vs. relative density graph and SPT vs. angle of internal friction, ¢ graph etc. have been plotted in Figure 5, Figure 6, Figure 7 and Figure 8 respectively.

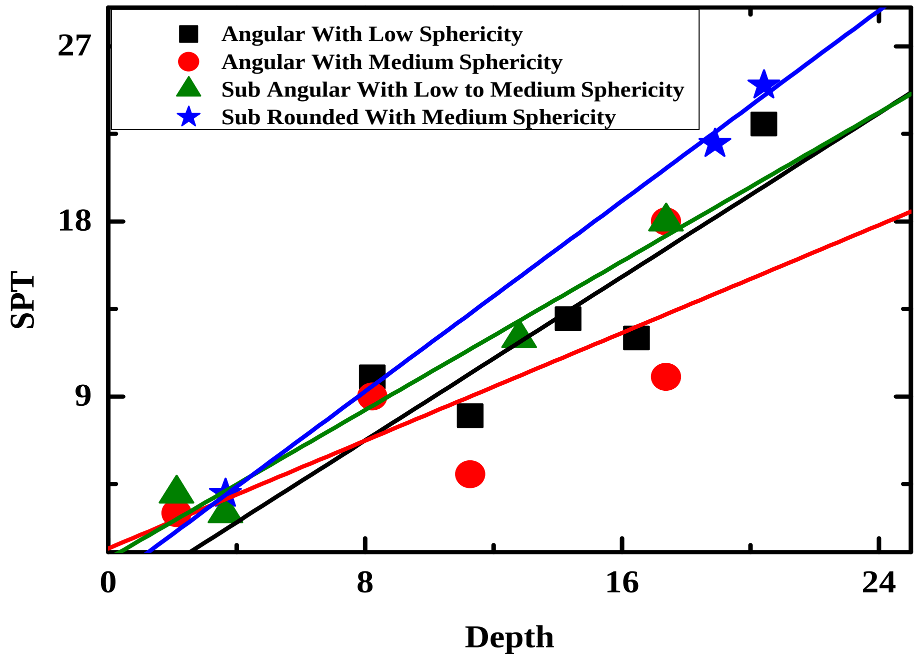


Figure 5. Depth vs SPT value curve for different shapes of granular soil

From the depth vs. SPT graph in Figure 5 it has been found that SPT values have been increases with the increases of depth. Though, the increasing trends have been observed as seen as all types of granular soils even it is found especially in case of sub-rounded with medium spherecity soil. That means the strength is more than that of other granular soils with shapes.

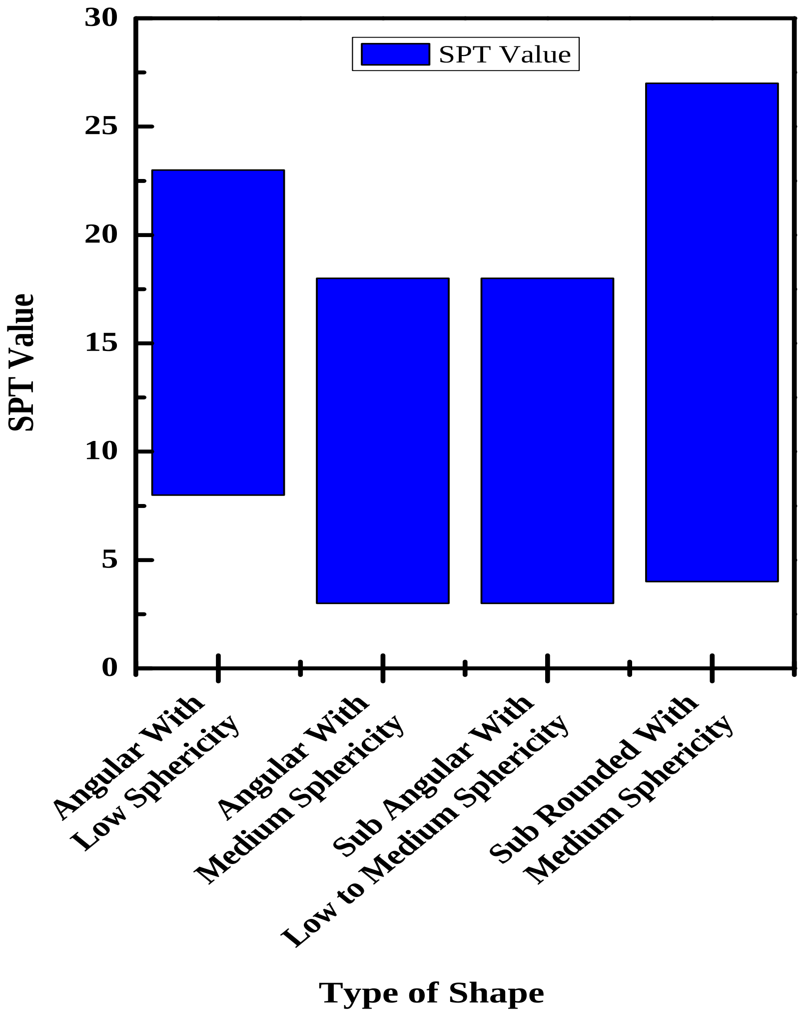


Figure 6. Range of SPT value for different shapes of granular soil.

Figure 6 is a comparison graph of SPT values of different types of granular soil. Here it is found that SPT values have been varied from 8 to 23 for angular with low spherecity soil, from 3 to 18 for angular with medium spherecity soil, from 3 to 18 for sub-angular with low to medium sphericity soil and from 4 to 27 for sub-rounded with medium spherecity soil. From the comparison graph, it is observed that SPT values of sub-rounded with medium spherecity soils are more than that of other granular soils. The increasing value of SPT indicates that its strength increases i,e. the strength of this soils is higher than that of other granular soil.

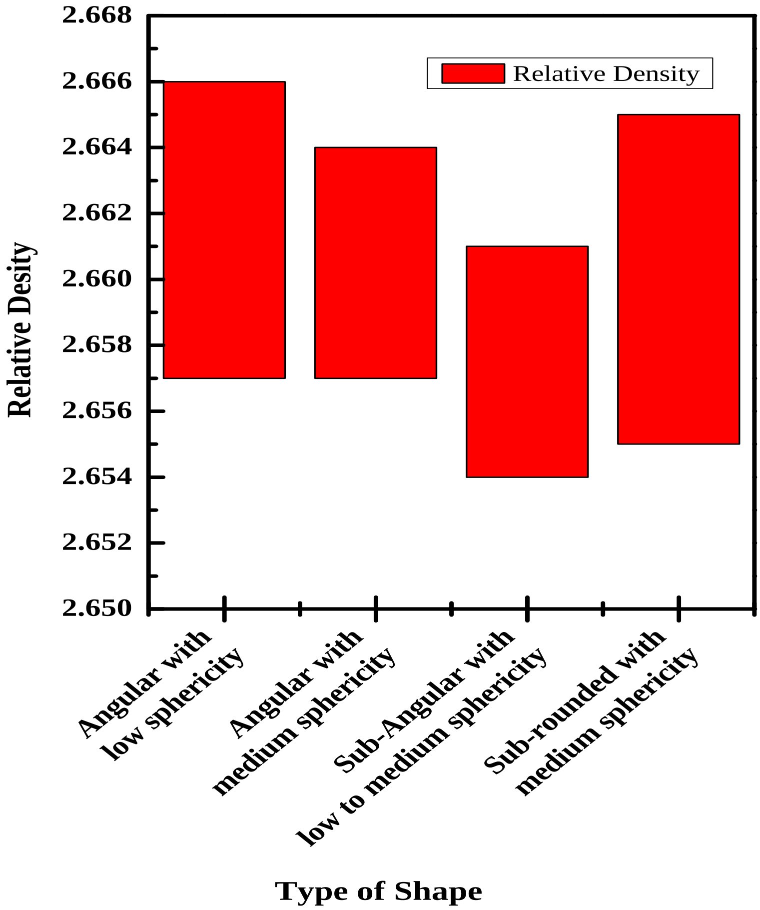


Figure 7. Range of Relative density for different shapes of granular soil

Figure 7 is a comparison graph of relative density of different type's granular soil. Here it is found that relative densities have been varied from 2.657 to 2.666 for angular with low spherecity soil, from 2.657 to 2.664 for angular with medium spherecity soil, from 2.654 to 2.661 for sub-angular with low to medium sphericity soil and from 2.655 to 2.665 for sub-rounded with medium spherecity soil. From the comparison graph, it is observed that relative densities of sub-rounded with medium spherecity soils are more than that of other granular soils which indicates their sizes are large than that of other soil. As a result, the predicted strength of these soils is higher than that of other granular soil.

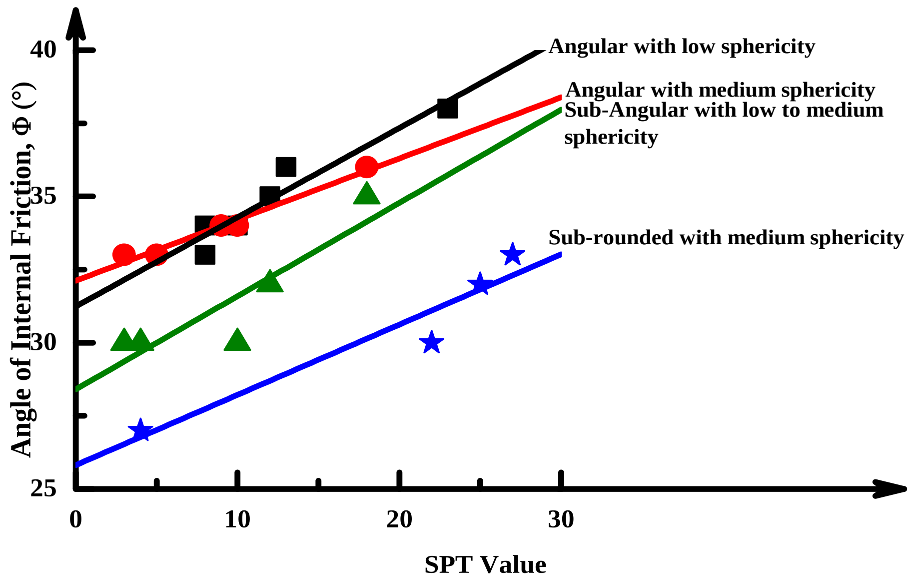


Figure 8. SPT value vs. ¢ graph for different shapes of granular soils

From the SPT vs. ¢ graph in Figure 5, it is found that angle of internal friction ¢ increases with the increase of SPT values in all types of granular soils. The increasing value of ¢ signify the increases of strength.

Conclusions

It is concluded from the present study that standard penetration resistance increases with the increase of depth in all type of granular soils. The maximum SPT value is observed 27 which indicate that the soil is in medium dense condition as well as its corresponding strength. This SPT value is noticed especially in case of sub-rounded with medium spherecity soil at depth 20.4216 m. The comparison graph also points towards the more strength for sub-rounded with medium spherecity soil as SPT values of these soils are more than that of other granular soils. The particle sizes of this soil vary from 0.08 mm to 0.25 mm and relative density varies from 2.655 to 2.665. They are the maximum values obtaining from observation in comparison with other granular soils. In the same order, the angle of shearing resistance increases for granular soils. This study may help the design engineers to know the sizes and corresponding strength according to the shape and their corresponding SPT values. In this study, a few number of granular soils have been considered for grain shape analysis and for this reason, some difficulties have been arisen to analyse the results. So, authors recommend that a further study may be needed on good number of soil samples to get good results with more accuracy.

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