

AN EXPERIMENTAL BEHAVIOUR OF SAND CLAY MIXTURES

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Abstract—Soils are often mixture composed of coarse and fine particles which are intricate inhomogeneous material and occur with widely varying characteristics in nature. The main objective of this study is to investigate the effect of fine content on unconfined compression strength of clayey soils and shear resistance offered through angle of internal friction, in case of sands. Tests were conducted with varying percentage of fines (10, 20, 40, 60%) in soil samples. The individual constituents in soil composition have different mechanical and physical properties and interact differently under the influence of external and internal loads, and the relation between coarse and fine particles is difficult to differentiate. Again the fine content in coarse soil are carefully considered because they determine the composition and type of soil and affect certain soil properties such as permeability, particle friction and cohesion. In this study, laboratory tests were conducted to investigate the deformation of soil. A series of direct shear tests were carried out under same weight of sample and density with fine, reducing percentage of fine in sand with different gradation properties. A series of unconfined compressive strength tests were carried out under same weight, optimum moisture content and dry density in order to assess the effect of increasing percentage of fine in clayey soil. The angle of internal friction is found to decrease with increasing percentage of fine in sands and the unconfined compressive strength is found to increase with increasing percentage of fine particles in clayey soil.

Keywords: Atterberg's limits, Unconfined Compression test, Direct shear test, specific gravity and sieve analysis.

1. INTRODUCTION

The individual components have different mechanical and physical properties and react differently under external and internal loads, and the relation between coarse and fine particles is difficult to discern. Angle of internal friction, ϕ is one of the vital parameter taken into consideration for reconnaissance of granular soils. soil friction perspective, not like pore pressure and obvious concord, is not temporally variable and is a derivative of the dimension of soil shear power. again the fine content in coarse soil are cautiously considered due to the fact they decide the composition and kind of soil and affect certain soil homes together with permeability, particle friction and cohesion. best have also been located to affect the liquefaction capacity, compression characteristics and strain- pressure behavior of soil. the excellent content in soil additionally performs an important function in section issues inclusive of minimum and maximum void ratios and porosity. Ayodele (2008) studied The effect of fine content on the performance of soil as sub- base material for road construction and found out that the engineering properties of the studied soil sample generally reduced with increase in fines content^[18]. Internal erosion is a escaping of fine particles from soil structures. internal erosion is a complex phenomenon with

reasons essential problems to levees, dikes and embankment dam balance. about one-0.33 of the failure of modern earth dams had been attributed to inner erosion, which may be initiated by focused leak erosion, back ward erosion, soil content erosion or suffusion^[24]. (ICOLD 2012). the lack of great particles in an earth shape throughout the internal system will induce gain rearrangements and affect the content material between soil debris, main to a rough and extra permeability or maybe failure of the shape^[20]. (Wan and fell 2008 Chan and Zhang 2013).

This research studies the strength changes due to internal erosion. It is a well-established fact that the resistance due to interlocking, friction and cohesion among the soil particles is the principal cause in deriving the shear strength of soil of soil. Many natural soil deposits and artificial fills contain matrices of coarse and fine soil fractions thus imparting frictional and cohesion properties. Thus, the interplay of these contributors, like interlocking, friction is expected to affect the soil shear strength parameters C and ϕ . At smaller fine contents, the dry coarse grained soil may exhibit its usual dense or loose skeletal structure significantly. However, in case of higher amounts of fines having larger surface area, the content of the coarse soil particles may diminish thus changing the whole matrix of the soil mass thus affecting the strength parameters. Detachment and mobilization of fine particles are important considerations both in soil erosion and in transport and fate of colloidal contaminants. The phenomenon of induced fines migration is of concern of both scientific and industrial fields. It finds application in flow in porous media when severe formation damage occurs, in the migration of wastes, in the ineffective regeneration of filter beds, and in the failure of earthen dams and dykes. Internal erosion involves detachment of fine particles whose sub sequent mobilization and transport is related to the clogging occurrence when flowing through porous medium, the particles are brought in contact with retention sites, they stop there or are carried away by the stream. During the flow of the suspension through a porous medium, particle transport and capture result from several forces and mechanisms, depending on particle size. In uncracked soils, the two main phenomena of internal erosion are suffusion and backward erosion. Suffusion is the detachment and transport process of only fine particles whereas backward erosion concerns all grain. Initiation of internal erosion processes is influenced by geometric condition as grain size distribution, porosity of soil^[5]. (Kenney and Lau, 1985) and grain shape^[14]. (Li, 2008) and by loading conditions as effective stress^[14]. (LI, 2008) and hydraulic gradient^[19]. (Skempton and Brogan, 1994). Depending on the process of internal erosion, confinement stress has a complex effect on internal erosion development^[15]. (Bendahmane et al., 2008).

2.LITERATURE REVIEW

Donghwi Kim,Boo Hyun Nam and Heejung Youn(2018) studies the "Effect of Clay Content on the shear strength of clay-sand mixture. To measure the shear strength of clay sand mixtures. direct shear and angle of repose test were carried out. They concluded that for pure sand the angle of friction was 35.7° and by the addition of 10% of clay content, it increased to peak value 38.7° . and for clay content of 30%, it decreased to 34.0° . for pure sand the angle of repose was 34.5° and by the addition of 25% of clay content, it increased to peak value 40.8° and for clay content of 30%, it decreased to (40.3°)

Orabi Al Rawi et al(2018) studied the "effect of sand additives on the engineering properties of fine grained soils" Atterberg limits, coefficient permeability, unconfined compressive and direct shear tests were performed for this study they concluded that by addition of 20% of sand material with cohesive soil decreases the value of liquid limit (47-33%), increases the value of plastic limit (20-24%) and increases the value of plasticity index (20-24%) they also concluded that by addition of 20% of sand with soil increases the value of coefficient of permeability (1-12.5%) and in direct shear test, by considering the shear strength parameters, cohesion value decreased (1.50-0.15%) and angle of internal friction value increased (13-30%).

Boufer et.al(2018) conducted research on "influence of fines on the resistance to liquefaction of clayey sand" trial apparatus on sand-clay mixtures and on soil sample undrained compression tests together with cycle liquefaction test were carried out in this study they found that the resistance to liquefaction of sand-clay mixtures reduced (R_c) (0.2-0.16) with the increase in fines content (f_c) (0-15%).

H.B.Nagaraj(2016) studied the "Influence of gradation on proportions of sand on stress-strain behaviour of clay-sand mixtures". In this study, undrained test were carried out for this study. (kaolinite, bentonite) clay mixed with three grades of sand varying from 10 to 80%. red earth and Bc soil are later mixed with different grades of sand. the results showed that, in kaolinite medium sand series, there is increase in unconfined compression strength (160-400 kpa) with increase in sand content upto (50%). in Bentonite medium sand series at 50% unconfined compression strength (480-1100 kpa) in red sand medium sand series, unconfined compression strength (410-780. kpa) in BC -medium sand series, unconfined compression strength (900-1500). kpa.

Meraj Ahmad Khan et.al (2016) studied the effects of fines on liquefaction resistance on fine sand and silty sand. In soils containing less than 10% fines are most susceptible to liquefaction. The fines with plasticity index greater than 10% and clay content above 10%. Possessive the relative density beyond 75% shows the liquefaction of soils. The results shows that increasing the percentage of fines increase the resistance to liquefaction also increases.

G.O.Adunoye(2014) studied the "An Experimental Study on Fines content and angle of internal friction of a lateritic soil. Tri axial tests were carried out for this study to determine the shear strength parameters i.e., cohesion and angle of internal friction. Three samples of red soils (S1, S2, S3) were taken. The results showed that for sample S1, for 10% fines angle of friction (Φ) value is 42° , Cohesion value (C) is 8 KN/m² and for 100% fines Φ value is 0° , C value is 63 KN/m². This represents that for 100% fines, there was a decrease in Φ value (42°) and for 687.5% fines, there was increase in C value 55 KN/m². for sample S2, for 10% fines angle of friction (Φ) value is 41° , Cohesion value (C) is 5 KN/m² and for 100% fines Φ value

is 0° , C value is 67 KN/m². This represents that for 100% fines, there was a decrease in Φ value (41°) and for 1240% fines, there was increase in C value 62 KN/m². For sample S3, for 10% fines angle of friction (Φ) value is 36° , Cohesion value (C) is 10 KN/m² and for 100% fines Φ value is 0° , C value is 66 KN/m². This represents that for 100% fines, there was a decrease in Φ value (36°) and for 560% fines, there was increase in C value 56 KN/m². Hence it was concluded that, with increase in fines content, angle of friction (Φ) decreased and Cohesion (C) decreased.

Muawia A.Dafla(2013) studied the "Effects of clay and moisture content on Direct Shear Tests for Clay-Sand Mixtures. Cohesion and angle of internal friction were obtained by using direct shear test. The results showed that there was increase in shear strength (2.4-3.6 Kg/Cm²) for the increase of clay content for all normal stresses tested (0.5, 1.0 and 1.5 g/cc) and there was increase in moisture content of clay caused the cohesion drop for 5% (0.15- 0.08 KN/m²) and 10% (0.5-0.05 KN/m²) of clay sand mixtures and at 20% showed a very steep drop (0.05-0.03 KN/m²) and increase in clay increases cohesion for 5% (0.08-0.14 KN/m²) and 10% (0.3-0.28 KN/m²) of clay. for 10% clay content, the angle of friction ($40.3-39.7^{\circ}$) and for clay-sand mixture of 20% moisture content angle of friction is less than 38° . Hence it was concluded that with the increase of clay content, the cohesion increased and there was a drop in cohesion and angle of internal friction with the increase in water content.

Benjamin et.al(2010) conducted research on "Index and strength properties of clay-gravel mixtures" and studied plasticity of mixture of fine sand coarse grained soil. They use fall-cone, Quasi-static cone penetration on mixture of gravel and high plastic clay. The plastic limit used in this study is corresponding to hundred fold increase in the liquid limit undrained strength and is denoted by PL100. The Quasi-static penetration test is used to determine PL of coarse and fine grained soil mixtures. The plasticity of mixtures of highly plastic clays and fine gravel appears to be linearly dependent on gravel fraction content of 50%.

Ali Firat Cabalar(2000), studied the "Effect of fines content on the behaviour of mixed samples of sand" In this study, the uses of SEM to demonstrate linkage between particle size and particle shape. They found that coarse particles are round and fine particles are platy and angular. They investigate the fines content with its effect on tri axial behaviour of coarse sand. They carried out tri axial test on two types of fine grained sands and coarse sand. The results shown that high compressibility and mixed with clay particles because of particle characteristic i.e., size and shape.

Kajun and E.Rugenga(1986) studied the "Relationship between the angle of repose and angle of internal friction for agricultural granular materials". The parameters angle of repose and internal friction determine the flow characteristics of agricultural granular materials such as rice, maize and wheat. Triaxial compression machine was used for this study. At four moisture content levels 10, 15, 20 and 25% angle of internal friction, angle of repose were determined. The results showed that angle of friction, angle of repose increased with increase in moisture content. Above 15% angle of friction ($23-30^{\circ}$) sensitive to water content, below 15% angle of friction ($20-23^{\circ}$) increased. At 10 to 25% of moisture content, angle of repose ($30-45^{\circ}$) sensitive to water content. At 50% water content it increased to 70° . The angle of friction was large for maize ($25-32^{\circ}$), followed by rice ($17-26^{\circ}$) and wheat ($23-31^{\circ}$). Hence, it was concluded that angle of repose greater than angle of friction and

angle of internal friction highest for maize followed by rice,wheat.

3.MATERIAL INVESTIGATION & IT'S PROPERTIES

The soil and sand samples are used in this study and collected from Thadakanapalli (Kurnool) and Chandragiri (Thirupathi). For these samples the engineering and index properties are determined and are tabulated in table 1 and table 2. The soil sample collected as representative soil sample were collected from trial Pits at a depth of about 3.0m from ground level. The soil collected from the site was pulverized with wooden mallet to break lumps and then air-dried. Subsequently it was sieved through 4.75mm sieve and then dried in an oven at 105°C for 24 hours. The soil are classified as I.S Classification system (IS 1498-1970).

Table 1: Properties of sandy soil

| Description | Sand A | Sand B |
|--|---------------|---------------|
| D ₆₀ | 0.93 | 0.96 |
| D ₃₀ | 0.59 | 0.43 |
| D ₁₀ | 0.39 | 0.2 |
| Specific gravity | 2.56 | 2.42 |
| Density index | 52.57 | 46 |
| Coefficient of uniform (c _u) | 2.389 | 4.739 |
| Coefficient of curvature (c _c) | 0.960 | 0.98 |
| Classification of sand | Poorly graded | Poorly graded |

Note: sand A collected from Thadakanapalli (Kurnool) sand B collected from Chandragiri (Thirupathi).

Table 2: Properties of clayey soils

| Description | SOIL A | SOIL B |
|------------------------------|--------|--------|
| %Gravel | 5.56 | ----- |
| %sand | 46.12 | 7.8 |
| %Silt + clay | 48.32 | 92.2 |
| Liquid limit | 56 | 57 |
| Plastic limit | 22 | 22 |
| Plasticity index | 34 | 35 |
| Free swell index | 90 | 140 |
| Specific gravity | 2.64 | 5.54 |
| Maximum dry density (g/cc) | 18.4 | 17.3 |
| Optimum moisture Content (%) | 14.53 | 18.64 |
| Classification of soil | (SC) | (CH) |

Note: Soil A collected from Thadakanapalli (Kurnool) Soil B collected from Chandragiri (Thirupathi).



Fig 1: Mixture of soil with sand

From Table 2 the soil sample classified as SC (clayey sand) and soil sample B can be classified as CH (clay with high compressibility). From these soil samples the sand is mixed in

different proportions like 100% soil (S1), 90% soil + 10% sand (S2), 80% soil + 20% sand (S3), 60% soil + 40% sand (S4), 40% soil + 60% sand (S5), and the strength were determined and are discussed.

4. EXPERIMENTAL PROGRAMME & DISCUSSION

The unconfined compression and direct shear tests are conducted on samples and the test results as follows.

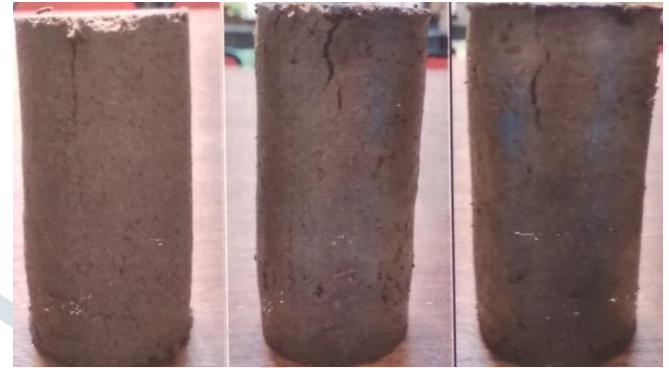


Fig 2: Unconfined compression test samples

Fines content added at 10, 20, 40 and 60% by weight of soil. The quantity of fines computed corresponding to the above percentage is directly mixed to the soil before water adding to it, in order to obtain even distribution of the fines.

4.1 TEST REGARDING ON SANDY SAMPLE:

In sands with increasing percentage of loss of fine particles the angle of internal friction should be increased, because generally shear resistance is a result of angle of internal friction, content between particles and interlocking between particles. The fines increasing in sands the surface gets smooth and coarse particles have highly interlocking compare to fines, so increasing fine particles decrease the angle of internal friction. In sandy soil content of fines affect initiation and rate of suffusion. The soil A and B are well graded soil this are resist more shear strength compare to poorly graded soil. The coarse sand (4.75mm to 2mm) show higher value of angle of internal friction compare to other ones. In Table 3 shows the relationship between shear stress and normal stress obtained by direct shear test for different sand proportion. The graph shows linearly variation between normal stress to shear stress

The phenomena may be because of the fact that, at smaller fine contents, fines could hardly occupy the full volume of void in between the coarse particles. Thus it had a very little effect on the strength contributors like interlocking, friction or cohesion. At higher percentage of fines the voids would have been filled with finer particles. If the fine were sample, they might have surround the coarser particles.



Fig 3: Direct shear test apparatus

Table3: Varion of angle of internal friction with increasing of %fines

| DESCRIPTION | Angle of internal friction(deg) | |
|---------------|---------------------------------|--------|
| | Sand A | Sand B |
| Without fines | 32.12 | 34.59 |
| 20% fines | 28.48 | 32.00 |
| 40% fines | 26.33 | 27.42 |
| 60% fines | 24.13 | 24.12 |
| Fine sand | 26.33 | 27.48 |
| Medium sand | 36.52 | 34.59 |
| Coarse sand | 42.59 | 41.59 |

Table 4: Variation of cohesion with increasing percentage of fines in sandy soils

| Disruption | Cohesion (kg/cm ²) | |
|---------------|--------------------------------|-------------|
| | SP (Sand A) | SP (Sand B) |
| Without fines | | |
| 20% fines | 0.08 | 0.084 |
| 40% fines | 0.18 | 0.18 |
| 60% fines | 0.25 | 0.25 |

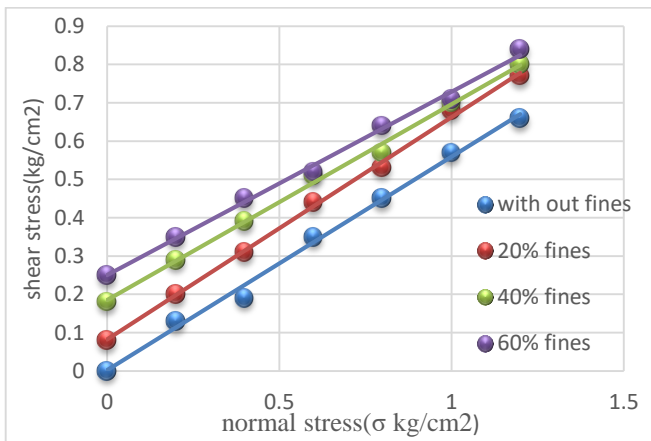


Fig 4: Normal stress- shear stress curve for sample A with increasing % of fines

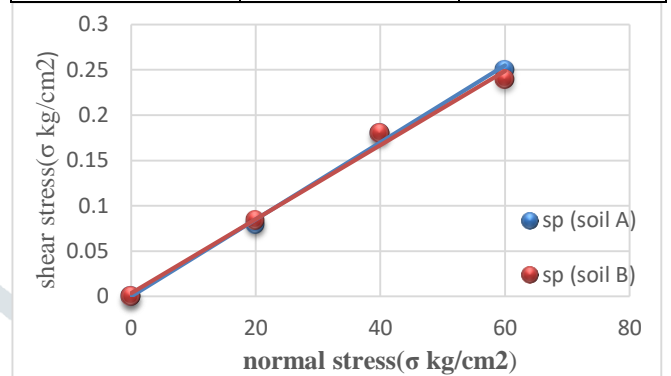


Fig 6: Variation of cohesion with increasing % fines in sands
When increasing percentage of fines in sands the cohesion will be increases because the fines are attached each other and also amount of cohesion less particles (sand) will be decreased. So find out the angle of internal friction will be reduced when increasing percentage fines at same time cohesion will be increases. So the angle of internal friction will be inversely proportional to cohesion. In table 4.3 show the how to change cohesion with increasing percentage of fines in sands. The SP soil (A) with 60% fines having higher valve of cohesion is (0.25 kg/cm²) compare to other B (0.25 kg/cm²) and (0.3 kg/cm²). Figure 4.63 shows how to vary cohesion with increasing fine content in soil in sand. Finally cohesion is found to increase with increases fine content in sands.

From the analysis above fig.5 increasing fines cohesion will be increased

4.2 TEST REGARDING ON CLAY SOILS

The fines and coarse particles taking from oven after 24 hours, the coarse and fine particles are mixed with require propeortion. In UCC test amount of coarse particles should be decreased with increasing fine particles at 20% addition.



Fig 7: Mechanical operating of UCC testing machine

After a certain amount of fine particles was lost, a significant change in the soil microstructure occurred. In clay increasing

From the analysis above fig.3 show the graph coming from direct shear test of sample A. The coarse sand of sample A having higher angle of internal friction is 42.59° compare to same soil with 20% (28.48°), 40% (26.33°), and 60% (24.13°) fines. When increasing fines in sand also increases the angle of internal friction and decreases the cohesion sand

From the analysis above fig.4 show the sample B of coarse sand having a high angle of internal friction (41.59°) Compare to medium sand (34.59°) and fine sand (27.48°). The sand without fines having higher angle of internal friction compare to increasing percentage of fines in sand.

The maximum and minimum of angle of internal friction is more than compared with sand sample B due to the fines .

percentage of fine particles the bonding between coarse particles should be increased then it resist the more compressive load compare to soil having a less fine particles. The percentage of fine particles increased from 10% to 60%. The graphs are show the increasing stress with increasing strain up to certain limit after reaching maximum stress its decreases with increasing strain

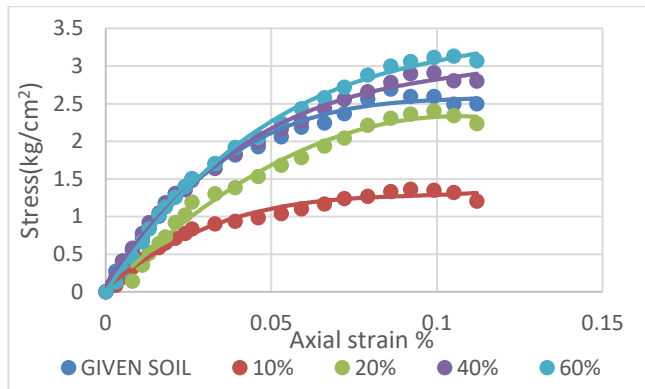


Fig8: Stress-Strain behavior in uni-axial compression for SC soil with increasing % of fines

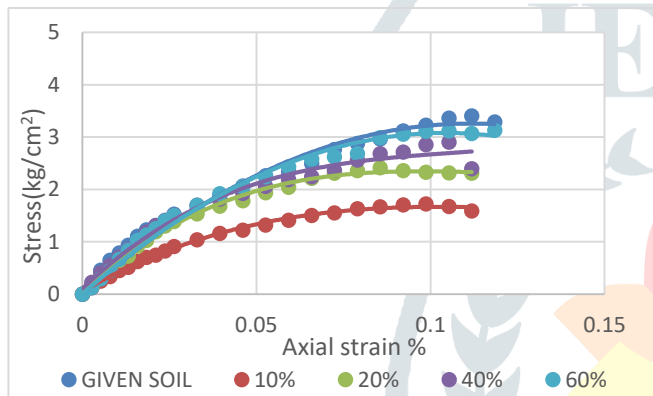


Fig9: Stress-Strain behavior in uni-axial compression for CH(soil) with increasing % of fines

From the analysis of above graph sample A having a more stress than sample B. in sample a 60% fines gives more stress due to increases of fine content.

Table 5: Unconfined Compressive strength of clay with Increasing Fine Content

| Description | Unconfined compressive strength (kg/cm ²) | |
|-------------|---|-------------|
| | SC(Soil A) | CH (Soil B) |
| Given soil | 2.6 | 3.2 |
| 10% fines | 1.4 | 1.9 |
| 20% fines | 2.4 | 2.6 |
| 40% fines | 3.0 | 2.8 |
| 60% fines | 3.4 | 3.3 |

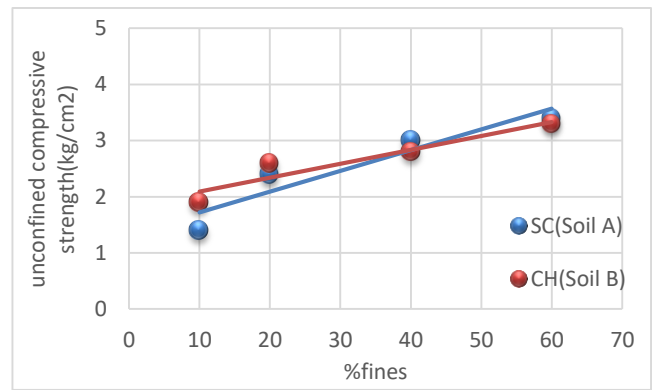


Fig 10: Variation of unconfined compressive strength with increasing % fine in sample A & B

Above fig.8 shows a variation of unconfined compressive strength with increasing percentage of fines in clayey sample and the unconfined compressive strength will be increasing when increasing fine content in clays. The unconfined compressive strength will be varying linearly with increasing fine content in clayey samples.

From the analysis of above table, the sample (SC) having more unconfined compressive strength than (CH). at 60% fine gives more unconfined strength due to increases of fine content.

5. CONCLUSIONS

An attempt has been made to conduct series of experiments involving different composition in soil such as sand with varying fine content of 0-60%, gradation of sands and in clays with fine content varying from 10-60%. A detailed analysis of test results leads to the following concluding remarks.

- With the increasing percentage of fine particles in sand, the angle of internal friction will be decreased and cohesion increased.
- The coarse sand in sample A shows maximum angle of internal friction to a magnitude of 42.59° compared to other sandy soil, considered in the present study.
- Sand sample A, B show greater shear resistance with 20% of fine (28.48°, 32.00°) as compared to 60% fines (24.13°, 24.13°)
- Sand sample, A, B show greater cohesion with 60% of fines (0.25 kg/cm², 0.24 kg/cm²) as compared to 20% fines (0.08 kg/cm², 0.084 kg/cm²).
- Angle of internal friction is found to have inverse relation to cohesion.
- Sand sample A, B show maximum variation of angle of internal friction between coarse to medium sands (6.07°, 7.00°) as compared to medium to fine sands (10.17°, 7.11°)
- With increasing percentage of fine particles in clayey soil, the compressive strength is increased due to bonding between coarse particles increases, leading to greater resistance to compressive load.
- The clayey sand (A), clay with high compressibility (B) and clay with high compressibility with 60% of fines having more compressive strength of the order of 3.4 kg/cm², 3.3 kg/cm² to soil having 20% (2.4 kg/cm², 2. kg/cm²) and 40% (3.0 kg/cm², 2.8 kg/cm²) of fines.
- with increasing percentage of fines from (40% to 60%) for Soil sample A, the unconfined compressive strength, increases by 0.5 kg/cm². Soil sample B (0.5 kg/cm²) show maximum variation of unconfined compressive strength compare to other sample A (0.4 kg/cm²) and B (0.3 kg/cm²).

ACKNOWLEDGEMENT

The author acknowledges the support of Director, Principal and all the Civil Engineering Staff of KSRM College of Engineering, Kadapa.

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