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Shear Behavior of Compacted China Clay – Sand Mixtures

Jyothi D N[1]
Phd Scholar, NIE, Mysore, Karnataka, India

Dr. H S Prasanna[2]
Professor, NIE, Mysore, Karnataka, India

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Abstract: In geotechnical engineering practice, determining and understanding of engineering properties of fine grained soils mainly silt and clays (swelling –Montmorillonite, non-swelling –Kaolinite and combination of K-M soils) is of vital importance for all types of works. The development of the solutions to the intricate problem related to the characteristics of the clayey soils lies in understanding the nature of clay minerals, index properties, volume change and shear parameters of the clayey soil. The engineering characteristics of fine-grained soils are depending upon changes in moisture content of the soils .They are susceptible to changes in applied load, type of chemical behaviour in the pore medium, freezing and thawing conditions due to temperature.

This work is an attempt to investigate the shear parameters of Kaolinite-sand mixtures compacted at optimum moisture content (OMC) to maximum dry density (MDD). These properties were then correlated with each other.

Keywords- China clay Compaction Shear parameter

1 Introduction

Clayey soils are the naturally available materials which are containing fine sized particles and they will exhibit plasticity nature for particular water contents and becomes harder after subjected drying condition. Clay minerals are essentially hydrous aluminum silicates less than 2 microns in size. They are made up of basically two building blocks namely silica tetrahedron and alumina octahedron (Gibbsite). The degree of swelling and shrinking of a clay mineral depends on the bond between these two building blocks.

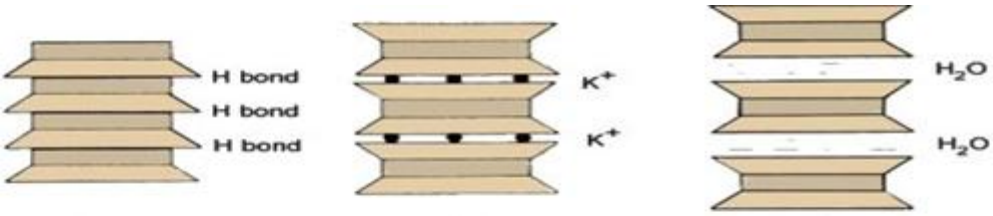

Fig 1: Types of clay minerals (Kaolinite, Montmorillonite and Illite)

The soil composition is different in all regions of the world, and it is not possible to collect all these samples as it would be a very difficult task, so to symbolically represent various types of soils, the soils with different clay mineralogical composition are mixing with sand in different proportions and properties of these samples are determined. China clay represents Kaolinite group and Bentonite represents Montmorillonite group.

1.1 Importance

Shear strength is an important property of the soil. It is the resistance offered by the soil mass against the failure surface per unit area and failure due to sliding.

Shear parameters are required to know the type of shearing resistance offered and stability analysis due to soil bearing capacity (for design of foundations), slope stability (In designing the road embankments, earthen dams etc.) and analysis of lateral earth pressure for the design of retaining walls.

2. LITERATURE SURVEY

Wasti et al., (1968) have studied on mixture of sand and clay proportions and mentioned that, how the voids to be filled with the different percentages of clay at higher value of porosity, by this effect there is a change in particle orientation of a mixture and the relationship between liquid limit(W_L) and plastic limit was a straight line. The variation of clay percentage is not valid; it is due to fact that the soil behaviour was changed for sand to clay. At W_L, It was showed that this threshold value exists about 25 % of kaolin content, for the kaolin clay involved mixture also.

Novais et al., (1971) have conducted consolidated drained (CD) box shear tests on mixtures of artificial soils with different percentages of clay, fine sand, coarse sand and clayey soil which is montmorillonitic dominant. It was found that, with increase in percentage of clay there is a tendency of decrease in shear stresses (maximum and limited).

Georgiannou V.N. (1988) has conducted the study on the characteristics of clayey sandy soils with two different types of loadings i.e constant and cyclic. It was found that the stress-strain behaviour of soil was influenced by the percentage of fines. There is a suppression of dilatant nature of soils with increasing in percentage of fines and for the 40% fine content; the response is being controlled gradually.

Georgiannou et al., (1990) have done an experimental investigation on load-deformation characteristics of anisotropically consolidated clayey sands using digitally maintained tri-axial specimens. By subjecting the ham river sand into the kaolin solution, the samples were prepared. By this, the effect of change in percentage of clay and void ration of granular sized particles were observed. The chosen method was creating a material which is having less stability, maximum void ratio in granular level, maximum brittleness character and ductility character.

Pitman et al., (1994) have studied about the effect of fines content and arrangement of soil particles on characteristics of loosely arranged sandy soils. These samples formed by changing the percentage of plastic and non-plastic fines with moist compaction procedure and consolidated by maintaining same effective stress level. These samples were subjected to constant undrained tri-axial loading and consolidated isotropically. They were mentioned that, the behaviour of undrained brittleness was decreased with the percentage of fines and increased with plastic and non-plastic fines content..

Bayoğlu, et al., (1995) have made an attempt to study the effects of the fine sized particles (particle size < 75micron) with respect to shear strength and compressibility. Different proportions of soil mixtures were considered from sand to silt-clay. The tests conducted on the soil mixtures was drained box shear and consolidated undrained tri-axial compression with different percentage of fines i.e., 5%, 15 %, 35 %, 50 %, 75 %, and 100 %. From the test results, it is concluded that, until 50% fines (optimum) the internal friction angles varied between 30-38 degrees, thereafter slight decrease in angle of internal friction with increase in percentage of fines and variation is about 10 degrees.

S. Thevanayagam (1998) has conducted the experimental investigation on large strain undrained shear strength (s_{us}) in tri-axial compression for particular host sand mixed with various percentages of non-plastic fines. The test results indicated that inter granular void ratio (e_s) was playing very crucial role on large strain undrained shear strength (s_{us}) of silty sands. Silty sand having less magnitude of large strain undrained shear strength (s_{us}) compared with host sand at same void ratio level. For less than value of maximum void ratio level of host sand ($e_{max, HS}$), the two sands are showing same s_{us} and these are independent of initial confining pressure. For the e_s (silty sand) > $e_{max,HS}$ condition, the s_{us} depends on the initial confining pressure. The value of sus was decreased with increase in e_s when the consolidation stress is very low (loose state).

Naser Al Shayea (2001) has worked on the characteristics of soil mass as small fractions having clay mineralogical dominance and the amount of clay percentage was playing an important role in finding the shear strength and compressibility. By increasing the percentage of fines, the plasticity characteristics and coefficient of secondary compression (C_R) values were increased and the angle of internal friction and hydraulic conductivity values were decreased.

Mehmat Salih Olmez (2008) has conducted three (3) different series of undrained and drained triaxial tests and box shear tests to know the shear strength characteristics of soil mixtures with effect of kaolin in sand-clay mixtures. The optimum percentage of kaolin content is 20%, for significant change in shear strength and stress-strain response.

Mohammad S.Pakbaz et al., (2012) have worked on the effect of sand particles arrangement on the behaviour of sand-clay mixtures. They conducted the box shear tests on existing over consolidated expansive clays and densified soil mixtures of sand and bentonite. The drained shear strength and angle of internal friction of the soil mixtures is decreased with increase in percentage of fines. Also, the optimum percentage of fines is 30%, for significant change in shear strength and stress-strain behaviour.

3. Materials and Methods

3.1 Preparation of Materials

Materials used:

1. River sand passing 425 micron.

2. China clay

3. Bentonite

Commercially available clay minerals (china clay) were collected from Bangalore and stored in containers. Similarly, river sand was also stored in plastic bins. For preparing the sample, they were kept in oven for a period of 24 hours for oven drying. After taking the samples out, they were kept for cooling and were mixed with different proportions of sand and following samples were prepared.

- Sand (10%) + China clay (90%)
- Sand (20%) + China clay (80%)
- Sand (30%) + China clay (70%)
- Sand (40%) + China clay (60%)
- Sand (50%) + China clay (50%)

3.2 Tests Conducted

Standard and Modified compaction test (IS: 2720- Part 7 -1980) – for obtaining the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

Tri –Axial Compression test (IS: 2720-Part 4- 1985) - to find the shear parameters i.e, cohesion (C) and friction angle (Ø).

3.3 Measurement of Shear Strength

Triaxial Compression Test (IS: 2720-Part 4- 1985)

Triaxial Compression test is most important method for obtaining the shear strength characteristics and used for various research works.

Depends on drainage conditions, three types of shear test have been developed:

1. Unconsolidated - Undrained (UU): The tri-axial specimen is experienced by confining pressure and then the principle stress difference is applied by not allowing drainage at any stage of experiment.

2. Consolidated - Undrained (CU): The tri-axial specimen is subjected to confining pressure by allowing drainage and then the principle stress difference is applied by not permitting drainage.

3. Consolidated – drained (CD): The tri-axial specimen is experienced by confining pressure and then the principle stress difference is applied by allowing drainage at all stages of experiment.

Apparatus-

1. Triaxial test cell with base, Perspex cell and head.

2. Compression Machine.

3. Lateral pressure assembly.

4. Proving rings.

5. Rubber membranes.

6. Membrane stretches.

7. Rubber 'O' rings.

8. Split Mould.

Procedure

1. The sample is prepared by compacting at OMC to MDD.

2. The specimen is removed from the mould using the sampler tube and then extracted to the spilt mould.

3. The obtained specimen is of 38mm diameter and 85mm length.

4. On the top and bottom part of specimen is capped by covering with rubber membrane.

5. The sample is placed in position as shown in figure below and pressure head is applied to the water in the cell surrounding the specimen.

Fig 2 : Triaxial Compression test equipment

6. The applied pressure to the soil is called confining pressure and is termed as the minimum principal stress. Initially, the sample is allowed to consolidate before applying the load.

7. The deviatory load is then applied to the sample at a monotonic rate of deformation (strain).

8. The burette reading (which indicates the water draining from sample) and proving ring reading(load) corresponding to the dial gauge reading(deformation) is taken until the sample fails.

9. The procedure is repeated for different cell pressures. Cell pressure was varied in the range of 0.5 to 1.5 kg / sq cm.

Fig 3 : Failed Samples

To obtain the shear parameters

- The vertically applied stress at failure when added to the confining stress gives the maximum principal stress.
- Using the maximum & minimum principal stresses, a series of Mohr's circle is drawn.
- A common tangent is drawn for these circles which are called as the Mohr's envelope.

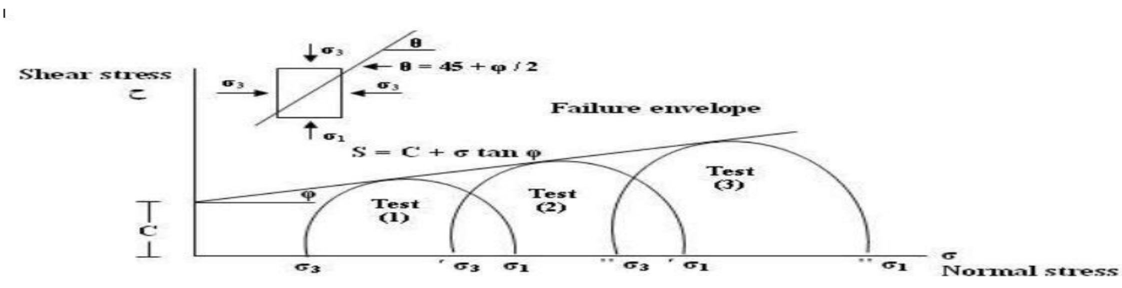

Fig 4 : Mohr's Circle for obtaining Shear parameter

4. Results and Discussions

4.1 Compaction Characteristics

Table 1 shows the compaction characteristics (OMC and MDD) of China clay – Sand mixtures.

Table 1: Compaction Characteristics

Soil property	**Pure C**	**10S+90C**	**20S+80C**	**30S+50C**	**40S+60C**	**50S+50C**
OMC-SP (%)	29.6	27	25	23.6	21.7	21
Max dry density(kN/m³)	13.5	13.88	14.6	15.2	16	16.8
OMC-MP (%)	24.6	23	21.8	20.6	18.4	17
Max dry density(kN/m³)	15.2	15.6	15.96	16.46	16.8	17.3

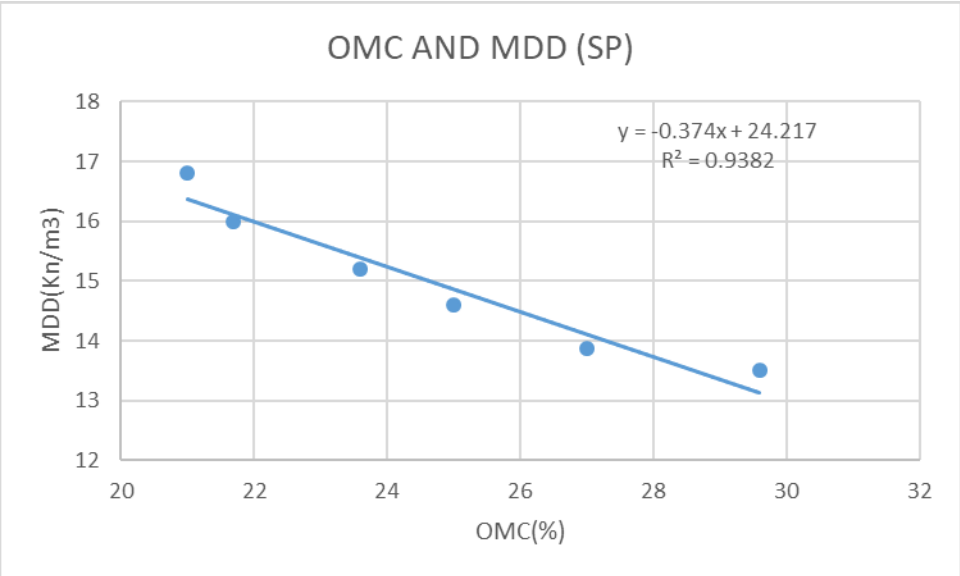

Fig 5 : correlation between OMC and MDD (SP) for China clay – Sand mixtures

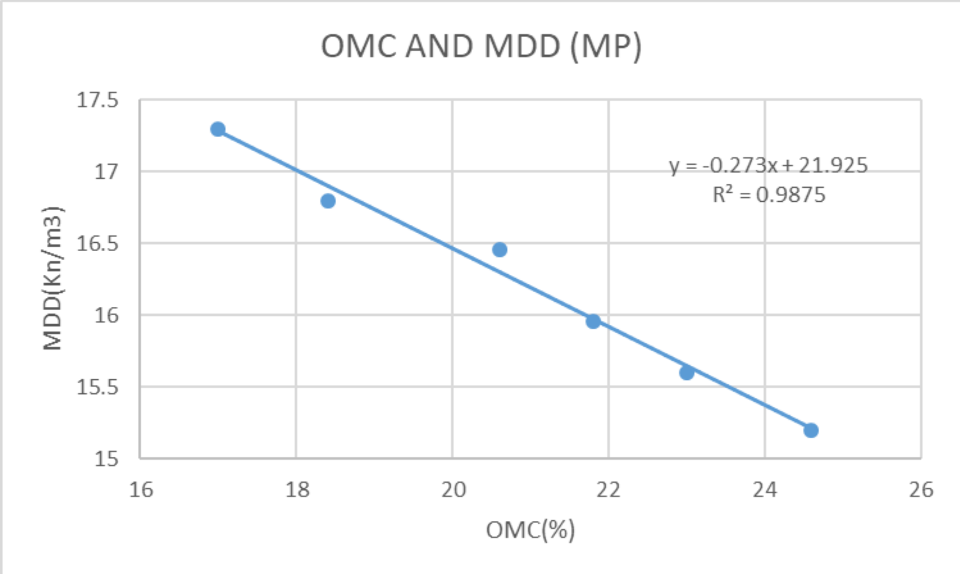

Fig 6: correlation between OMC and MDD (MP) for China clay – Sand mixtures

From figure 5 and 6 presents the relation between OMC and MDD using Standard and Modified Proctor's results.

- In the light compaction test, OMC for pure china clay is 29.6% and the MDD is 13.5 kN/m^3 whereas in the modified proctor test, the OMC decreases to 24.6% and maximum dry density increases to 15.2kN/m^3.
- As the sand is added in increasing proportions to china clay, the OMC (SP) decreases to 21% for 50% sand and 50% china clay and the maximum dry density (SP) increases to 16.8kN/m^3. Similarly, in modified proctor test, the OMC and maximum dry density are 17% and 17.3kN/m^3 respectively

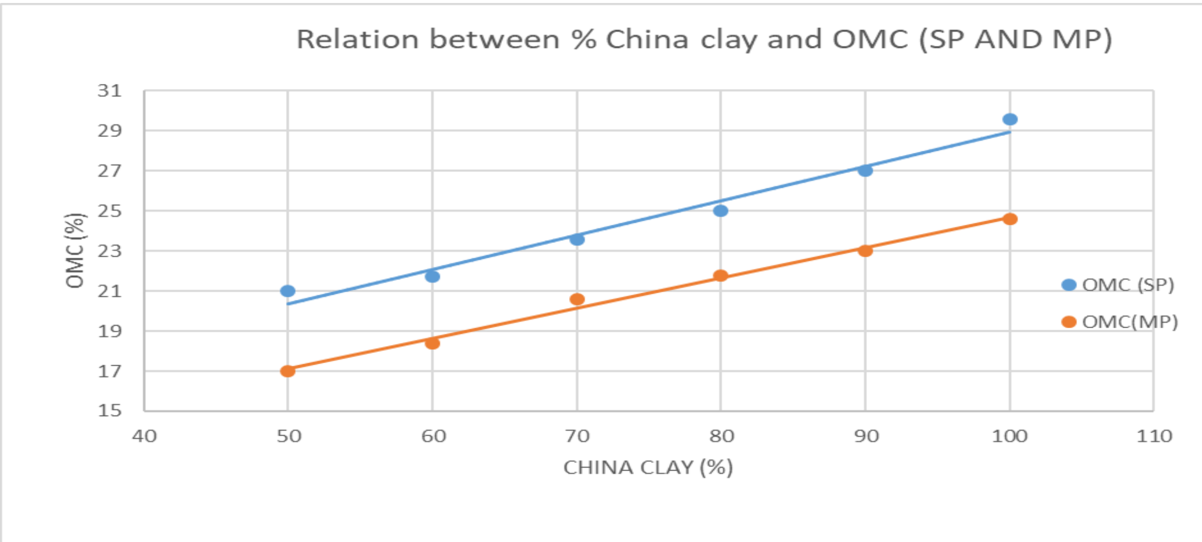

Fig 7: correlation between % China clay and OMC (SP and MP)

Fig 7 presents the variation of percentage clay and OMC with respect to standard and Modified Proctor's test, it show that with the percentage increase in china clay, the OMC also increases because of increase in fine content in the mixture , enhances the water holding capacity and percentage increase of OMC is more in Standard proctor compared to Modified proctor compaction .

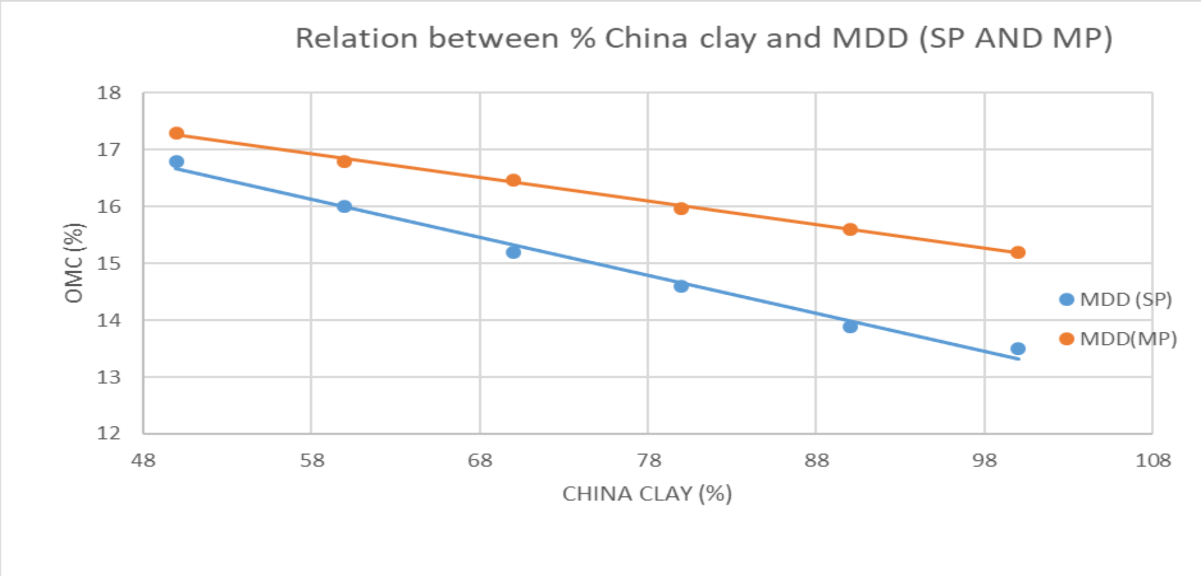

Fig 8: correlation between % China clay and MDD (SP and MP)

Figure 8 presents the variation of China clay and MDD, with the percentage increase of fines in the mixture OMC increases and MDD decreases, from fig it clearly shows that MDD is decreases with increase of fine content in the mixture and it is more in standard proctor's test compared to Modified Proctor's test .

4.2 SHEAR PARAMETERS

Table 2 and 3 shows the Shear parameters for China clay- Sand Mixtures SP/ OMC/MDD/Drained condition and MP/ OMC/MDD/Drained condition (C- China clay S-Sand)

Table 2: Shear parameters for China clay- Sand Mixtures SP/ OMC/MDD/Drained condition

Shear parameters	Pure C	10S +90C	20S+ 80C	30S +70C	40S+ 60C	50S +50C
Cohesion(N/mm^2)	0.14	0.11	0.10	0.078	0.064	0.05
Ø	9.72	12.26	18.43	19.79	20.22	22.25

Table 3 Shear parameters for China clay- Sand Mixtures MP/ OMC/MDD/Drained condition

Shear parameters	Pure C	10S +90C	20S+ 80C	30S +70C	40S+ 60C	50S+50C
Cohesion(N/mm^2)	0.202	0.17	0.14	0.12	0.115	0.091
Ø	2.86	6.34	9.09	10.12	11.04	15.64

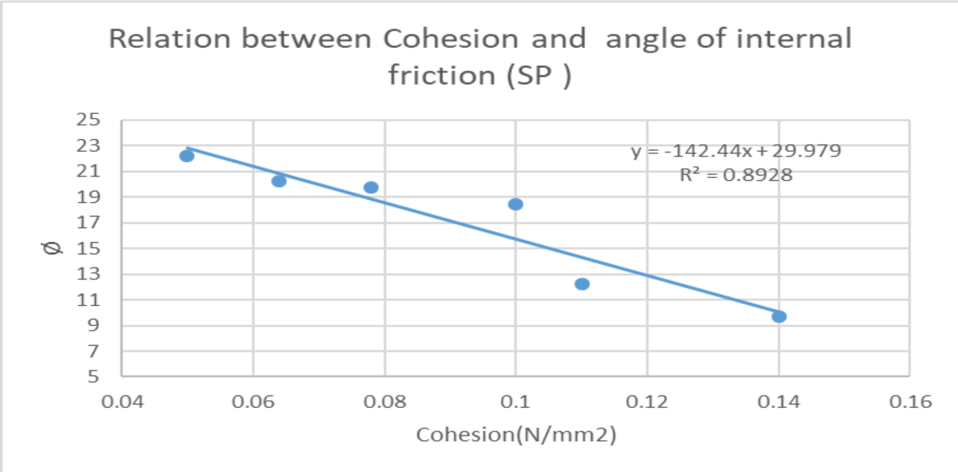

Fig 9: correlation between cohesion and friction angle (SP)

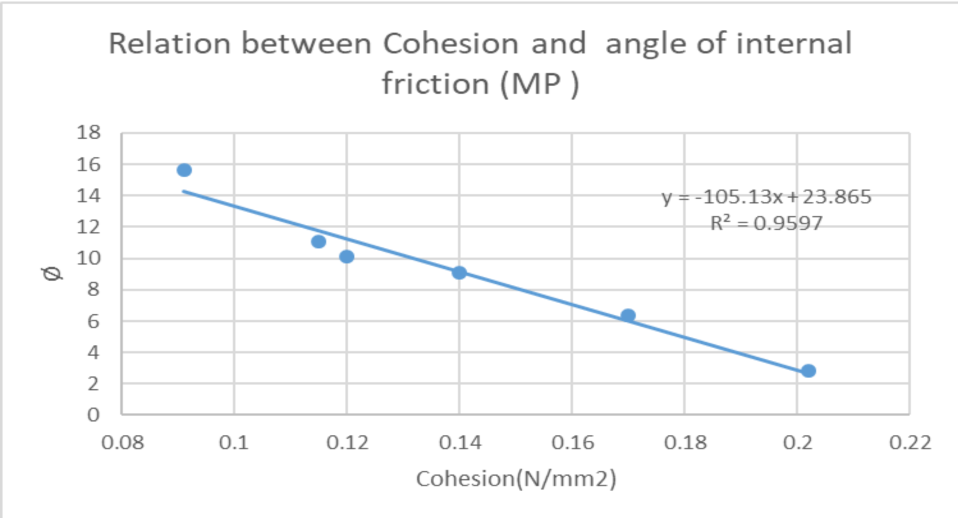

Fig 10: correlation between cohesion and friction angle (MP)

Figure 9 and 10 shows a strong correlation between the friction angle and cohesion for different proportions of clay-sand mixtures. From these graphs, it is evident that pure-clay have maximum cohesion and with the addition of sand in increasing proportions, the value of cohesion decreases gradually since sand is a cohesion less soil. Whereas the angle of internal friction is less for pure-clay and increases as the percentage of sand increases because the sand gets filled in gaps of voids and the friction between them increases.

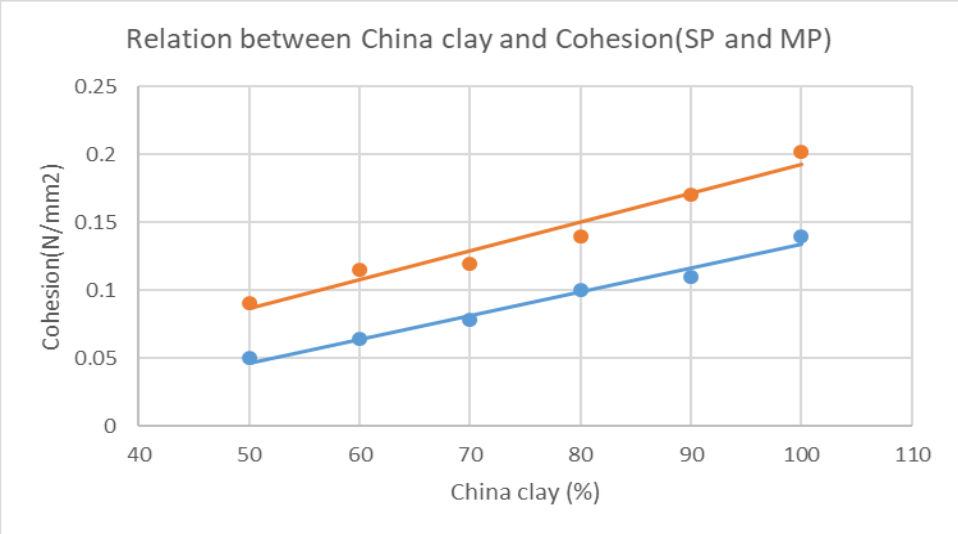

Fig 11: Relation between China clay and Cohesion(SP and MP)

Fig 11 shows that the samples prepared by compacting at OMC to maximum dry density(modified proctor test) shows higher cohesion as compared to those obtained from standard proctor test. This is because in MPT, as the compactive energy and density is higher, the voids are less and shear strength is more.

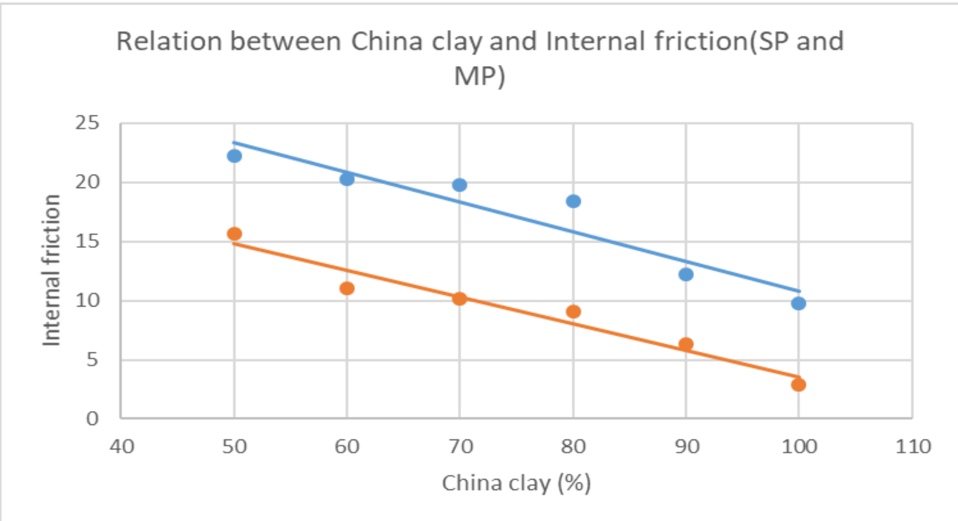

Fig 12: Relation between China clay and Internal friction(SP and MP)

From Figure 12 represents the relation between China clay and angle of internal friction, with the increase of fine content in the mixture the angle of internal friction is reduces because of the fact that with the increase of cohesion angle of internal friction decreases.

5. Conclusions

- From figures 5 and 6, It can be concluded that, in the standard proctor test, the Optimum Moisture Content (OMC) for pure china clay is 29.6% and the maximum dry density is 13.5 kN/m^3 whereas in the modified proctor test, the OMC decreases to 24.6% and maximum dry density increases to 15.2kN/m^3. It concludes that MDD is increases in Modified Proctor's test due to the increase in Compactive energy as compared to standard proctor's test.
- From fig 7, inclusion of fine content in the sand, the water holding capacity increases hence OMC is increases with increase of china clay content in the mixture.
- Fig 9 and 10 shows a strong correlation between the angle of internal friction and cohesion for different proportions of clay-sand mixtures. From these graphs, it is evident that pure-clay have maximum cohesion and with the addition of sand in increasing proportions, the value of cohesion decreases gradually since sand is a cohesion less soil. Whereas the angle of internal friction is less for pure-clay and increases as the percentage of sand increases because the voids in the clay gets occupied by sand and friction between them increases.
- The samples prepared by compacting at OMC to maximum dry density(modified proctor test) shows higher cohesion as compared to those obtained from standard proctor test. This is because in MPT, as the compactive energy and density is higher, the voids are less and shear strength is more.
- The obtained values of cohesion (SP) for china clay–sand mixtures ranges from 0.14N/mm^2 (pure china clay) to 0.05N/mm^2(50%china clay+50% sand) whereas the angle of shearing resistance increases from 9.75 to 22.25 for pure to 50% china clay respectively. Similarly in case of MP, the cohesion decreases from 0.202N/mm^2 to 0.091N/mm^2 and angle of internal friction increases from 2.86 to 15.64

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