JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

GROUND IMPROVEMENT OF COHESION-LESS SOIL WITH COHESION- AN EXPERIMENTAL STUDY

[1]Pulkit Pradhan, [2]Abhishek Dubey

[1]M.Tech Research Scholar, [2]Assistant Professor
[1]Department of Civil Engineering
[1]Oriental Institute of Science & Technology, Bhopal, India

Abstract: Cohesion-less soil is a loose granular soil having low bearing strength. The strength totally depends upon the angle of internal friction among the particles and is susceptible to strength loss when loads are applied. On the other hand clayey soil is a type of soil having high inter-particle attraction which binds the particles together with cohesive forces. In present study cohesive soil particularly clay is added in cohesion-less soil particularly sand in varying proportions (10%, 20%, 30%, 40%, 50%, and 60%) and an adequate percentage is found at which the ground can be improved under certain loading conditions. After replacing cohesion-less soil with cohesive soil in different proportions, soil is examined for the variation in engineering properties through Standard Proctor Test, Pycnometer test for Specific Gravity, & Falling Head Permeability Test, along with shear loads through Direct Shear test. From the study the Maximum Dry Density of the soil was found to increase with increase in cohesion at the Optimum Moisture Content. However the Specific Gravity and Permeability of soil saw a decline as the cohesion in the soil was raised. With the increase in clay content in the cohesion-less soil, the angle of internal friction reduced consistently with the gradual rise in cohesion.

Index Terms- **Cohesion, Cohesion-less, Optimum moisture, Maximum Dry Density, Shear, Permeability, Specific Gravity**

I. INTRODUCTION

Cohesion-less soil contains particles which are non sticky in nature, strength of which depends upon the internal friction among the particles. When more than 50% of the sample passes through 75 microns sieve the soil is considered to be fine grained soil. Sand and silt falls under the prescribed category.

An allowance for ground improvement is to be made using reinforcing materials (clay used here) against heavy compression and shear deformations for the dynamic cohesion-less soil, which would otherwise lead to additional costs in examining soil structure interaction.

Cohesion-less soil due to least inter-particle attraction forces it is very difficult to compact and a well defined compaction curve is not obtained. The dry density which is the important parameter for compaction is not achieved in a systematic manner on addition with moisture. As the cohesion-less soil bulks, increases void ratio and paves the way for water to flow through it from the interconnected voids, making the soil more permeable.

On the other hand Cohesive soil exhibits high plasticity and can be moulded into any shape on application of moisture. The particles of cohesive soil are strictly adhering to each other due to electrostatic attraction between them. This electrostatic forces among the particles are responsible for the particulate arrangement in cohesive soil whether flocculated structure of dispersed structure.

Cohesive soils however have a lower value of void ratio as compared to cohesion-less soils but due to the presence of active minerals responsible for high activity of clays the soil is more susceptible to expansion and shrinkage when comes in contact with the water. On addition of water to the cohesive soil, a well defined compaction curve is obtained with a definite relation of dry density and moisture content and a maximum dry density and optimum moisture content for the soil is obtained which is not possible in case of cohesion-less soils.

Due to lower values of void ratio and lesser permeability of clays, makes it denser than cohesion-less soil and a better player for ground stabilization. However the large volumetric changes in the soil seriously affect the strength of structure built over it causing uneven settlements.

The results retrieved from this study on dry densities, specific gravity, permeability and shear parameters were found on similar patterns as obtained from the works previously done in line with this topic which covered the narrow values of cohesion percentage in the cohesionless soil, however in this experimental study the vast variation of cohesion i.e. from 10% to 60% in the cohesionless soil are experimented and the results were analyzed in both compression as well as shear loads.

II. Related works

In 2022, the authors work on the physical properties of clay sand mix to assess their performance on dry density of soil at 12% moisture content, (Elsa Anglade, Jean-Emmanuel, Aubert, Alain Sellier, Aurelie Papon). The dry density at 40% clay in the sand mix was assessed about 1.92 g/cc which was found to decrease when the clay content in the sand reaches beyond 70% but the water content was raised from 12% to 21% which may prove to be the cause for decrease in dry density.

According to the study in 2019 on improving the geotechnical behavior of sand through cohesive admixtures (Mohie eldin Mohamed Afify Elmashad), the cohesion percentage was raised from 4% to 20%. However with the increase in cohesion the permeability of the soil falls consistently.

In the study conducted in 2018 about the influence of sand on clay content (Gunawan Wibisono, Soewignjo Agus Nugroho), the clay content to the maximum limit of 40% was added in the sand, the Maximum Dry Density of the mix was calculated and a similar pattern of continuous rise in the density was observed as the clay content raised up to 40%.

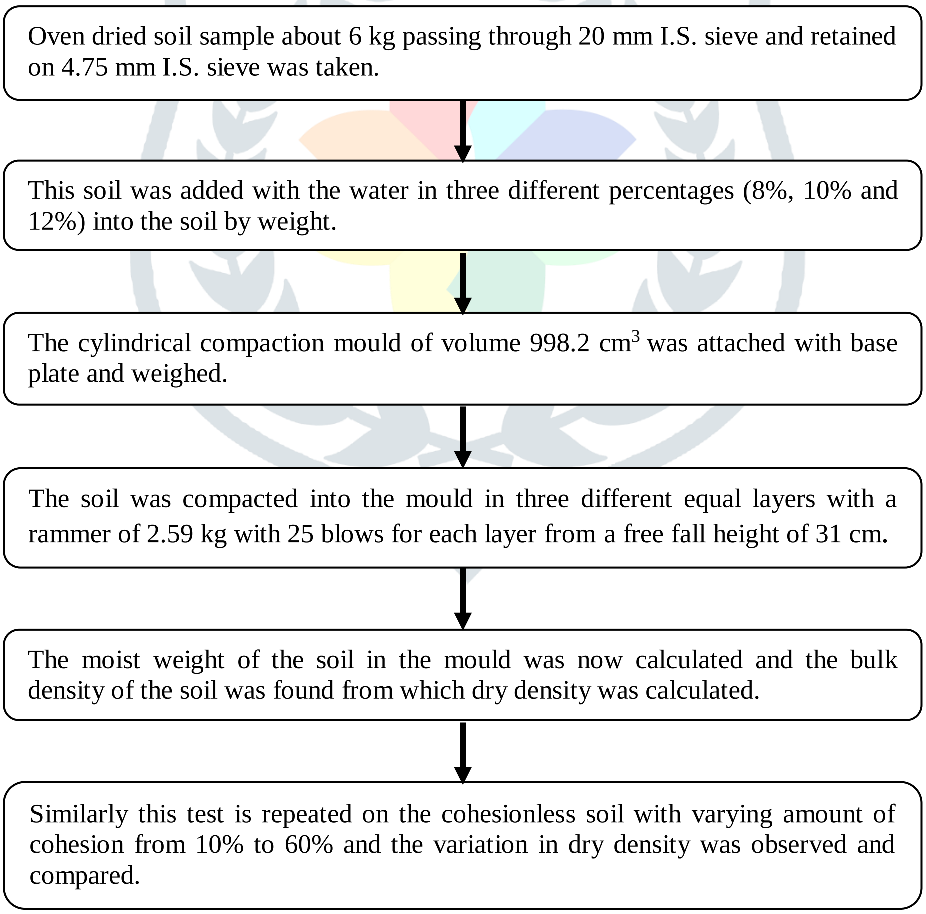
In 2017, a study based on the assessment on the effect of fine content and moisture towards shear strength (Badee Alshameri, Aziman Madun, Ismail Bakar) in which the clay content was raised from 20% to 70% and the specific gravity was found to decrease consistently with the increase in cohesion.

The effect of clay & moisture content was worked upon in 2013 (Muawia A. Dafalla), the sand preparing the clay sand mixtures for obtaining the cohesion and angle of friction at different clay contents. In the study, standard proctor test at 15% moisture content was performed from 5% to 20% clay content. The dry density of the mix was found to increase continuously with the increase in clay content. Also the cohesion value in the soil was raised with increase in clay content.

III. Research Methodology

3.1 Compaction

The compaction properties of the soil specimen for the dry densities at various moisture contents which are 08%, 10% and 12% for different soil samples of cohesionless soil imparted with cohesion in different proportions from 10%, 20%, 30%, 40%, 50%, and 60% are found. Here the I.S. Light Compaction test or Standard Proctor Test was performed to determine the Maximum Dry Density of the soil specimen at which it can be compacted for minimum void ratio and maximum strength. Methodology adopted for compaction as per the I.S. Code 2720-1980 (Part VII) is described in the below flow chart.



3.2 Specific Gravity

Specific Gravity of soil is the ratio of density of soil with respect to the density of standard liquid (usually water). The specific gravity of soil determines how porous the soil is. The aim is to examine the variations in specific gravity of soil when the cohesionless soil is added with cohesive soil at different percentages from 10%, 20%, 30%, 40%, 50%, and 60%. Methodology adopted to examine the specific gravity of soil as per the I.S. Code 2720- 1980 (Part III) is provide in the flow chart.

A clean air dried Pycnometer of capacity 900 ml was used and weighed (W_1).

↓

Oven dried soil approximately 200 grams passing through 4.75 mm I.S. sieve was used and weighed along with Pycnometer (W_2) with the cohesion added in desired percentage.

↓

The water was added to the soil in the Pycnometer completely full and the entrapped air was removed with vacuum pump and then weighed (W_3).

↓

The soil from the Pycnometer was removed and filled completely with water up to the screw and weighed (W_4).

↓

The following relation is used in this test to determine the specific gravity of soil.

$$G= [(W_2-W_1) / (W_2-W_1) - (W_3-W_4)]$$

↓

The above steps were repeated for three consecutive samples for same cohesion percentage from 10% to 60% and the variation in specific gravity was compared.

3.3 Permeability

The permeability of the cohesionless soil infused with cohesion in varying proportions from 10% to 60% was examined using the Falling Head Permeability test. The variation in permeability was found. The aim to perform this test was to observe the effect of cohesion on the coefficient of permeability for cohesionless soil which is initially highly permeable. The Falling Head test for the given soil was performed as per the methodology adopted in I.S. Code 2720 (Part 17) – 1986

The empty permeameter mould was weighed and was attached to base plate with extension collar.

↓

Soil was mixed with cohesion in desired percentage and passed through 9.5 mm I.S. sieve.

↓

An optimum moisture content of 10% was added to the soil and compacted statically.

↓

After compaction, excess soil was trimmed off and the top of the soil specimen in the mould was connected to the stand pipe and bottom outlet of the mould was kept open.

↓

The time interval required for the water in the stand pipe to flow from known initial head to known final head was noted.

↓

The stand pipe was refilled and the three successive readings were recorded for same cohesion values.

↓

The permeability values on different proportion of cohesion were observed and compared.

3.4 Shear

To determine the shear strength of soil sample granular cohesionless soil (sand) when supplemented in the adequate proportions by weight i.e. 10%, 20%, 30%, 40%, 50%, and 60% with cohesive soil (clay). Here, the clay- sand mix is assessed using Direct Shear Test on the soil specimens in the Unconsolidated Undrained (U-U) condition. The aim to perform the test was to examine shear strength of the cohesionless soil generally with varying percentage of cohesion governed by two shear parameters, namely, 'Cohesion' (C) & 'Angle of Internal Friction' (ϕ).The methodology adopted to perform the Direct Shear test as per the I.S. Code 2720 (Part 13) – 1986 is described in the flow chart

Cohesionless soil was infused with cohesion in desired percentage by weight with the maximum particle size of 4.75 mm and moisture content 10% was added.

↓

Sample of dimensions 60 mm and thickness 25 mm is compacted into the sample trimmer and the sample are obtained into the shear box.

↓

The two halves of the shear box were connected with the connecting pins and the two base plates are placed on either side of the shear plates.

↓

The serrations of both the two shearing plates placed in the shear box on either side of the sample were perpendicular to the line of shearing force to be applied.

↓

The whole arrangement was placed in the loading frame of Shear Testing machine consisting of a proving ring of capacity 2.5 kN and vertical load was applied.

↓

The connector pins were removed from the shear box and the minimum seating load was applied and the dial gauges were set to zero.

↓

The test was repeated to determine the shear strength on same cohesion values at 0.5, 1.0 and 1.5 kg/cm^2 normal stress for cohesion values upto 60% and shear parameters were computed.

IV. Results & Discussions

4.1 Compaction

I.S. Light Compaction test was performed on the cohesionless soil when mixed with cohesion at 10%, 20%, 30%, 40%, 50%, and 60% to examine the relation between dry density and moisture contents of 8%, 10% & 12% from which 10% moisture content was found to be the Optimum Moisture Content. Here, a curve is plotted considering Cohesion percentage at abscissa and Maximum Dry Density at ordinate, since Cohesion is the governing parameter for variations in the Dry Density of the soil. The rising curve is obtained for the Maximum Dry Density as the Cohesion percentage is raised in the soil. The curve rises steeply from 10% to 20% after which there is a little rise and the curve is almost flat between 20% and 30% cohesion. However the curve rises steeply as the cohesion is raised above 30% up to 50% and then becomes flat after 50% up to 60% cohesion. As the curve rises till 50% cohesion consistently without any decline as no appreciable rise in the curve on further addition of cohesion after 50% is observed (Fig. 1).

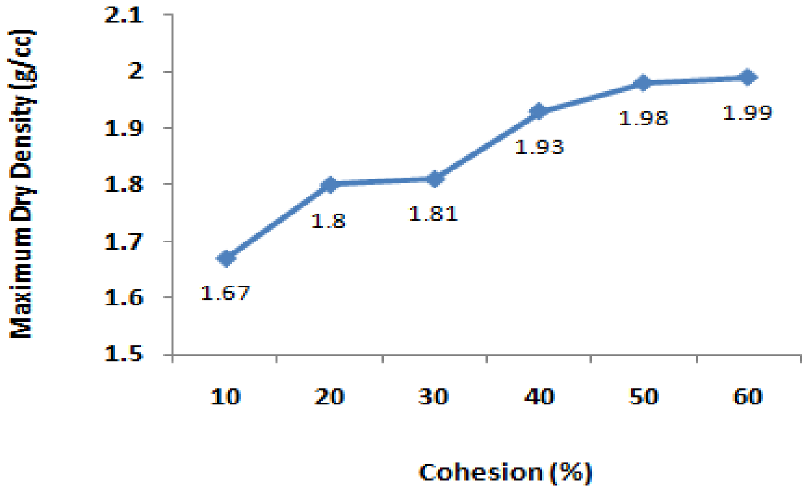


Figure 1 displays the variation of Maximum Dry Density with respect to Cohesion (%)

4.2 Specific Gravity

The specific gravity of the cohesionless soil sample infused with clay material was found using the Pycnometer test. Specific gravity witnesses a consistent decline when the infusion in clay was raised upto 60%. The sand particles on addition with water bulks creating larger voids. Similarly on addition of water clay particles expands creating larger voids. Hence these factors make the soil more porous with addition of cohesion in the cohesionless soil thus reducing the specific gravity of soil mix. The Specific Gravity of cohesionless soil declines consistently as the cohesion value rises. As the values of specific gravity are plotted, it falls from 2.74 at 10% Cohesion to 2.18 at 60% cohesion which can be observed in (Fig. 2).

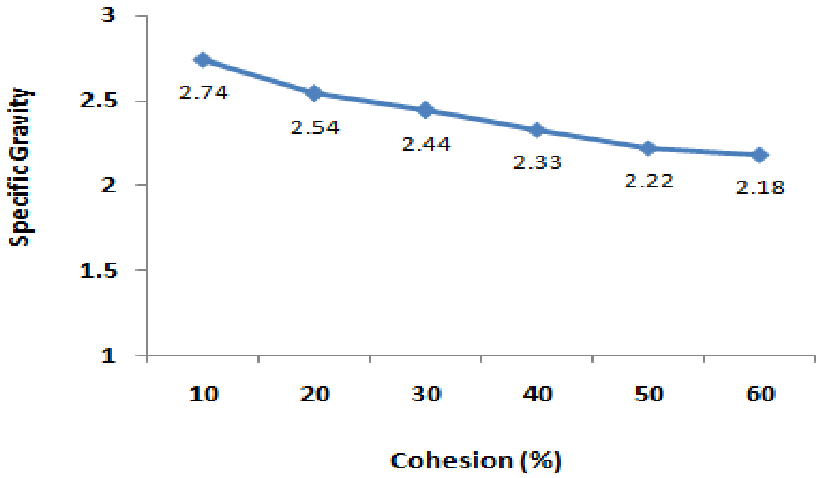


Figure 2 exhibits the variation in Specific Gravity of Cohesionless soil with increasing proportion of Clay

4.3 Permeability

For Vertical Permeability in soil the Falling Head test was performed. The permeability value from the 10% - 60% cohesion ranges from 0.0525 cm/s to 0.0067 cm/s (Fig. 3). This reduction in interconnectivity of voids reduces the permeability values of soil; however the porosity of soil increases with addition of cohesion in the soil mix (Fig. 2) creating more voids as the cohesionless soil bulks. However the finer clay particles fill in the majority of voids created by cohesionless soil. Although the clay soil also expands on addition with water but obstructs the flow of water through the voids thereby reducing the interconnectivity. This seepage in the soil reduces, creating lesser pore pressure and increase in the effective stress of soil. The load bearing capacity of the soil thus increases with these effects. A continuous decline in the values of vertical permeability is observed with addition of cohesion upto 60% in the cohesionless soil. A sharp reduction was observed between the cohesion values ranging from 10%- 20% and a consistent decline is seen till 50% cohesion. The curve falls gradually as the cohesion values increases beyond 50%.

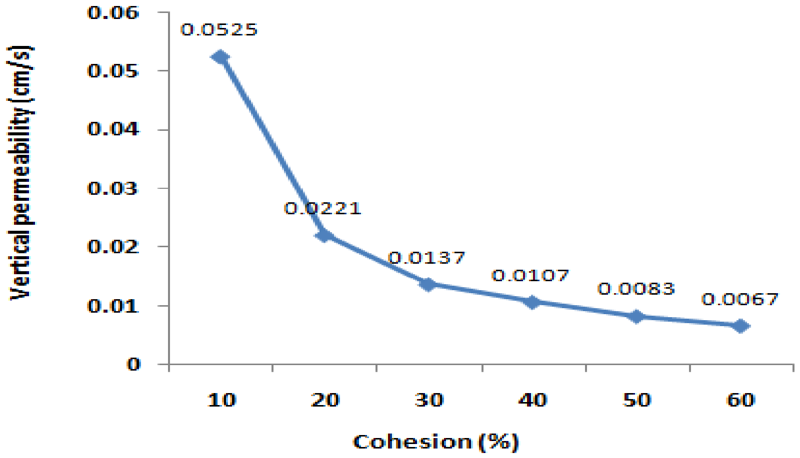


Figure 3 displays the reduction in Vertical Permeability in soil with altering proportions of Cohesion.

4.4 Shear

This test was performed on the cohesionless soil sample mixed with cohesion in the range varying from 10% to 60% with 10% moisture content in Unconsolidated Undrained condition on the remolded soil specimens, to test its stability against shear force. As the percentage of cohesive soil (clay) is increased in the cohesionless soil (sand) with every successive sample to be tested, the cohesion in the soil is likely to increase which can be observed (Fig. 4). The cohesion value of the soil ranges from 0.336 kg/cm^2 to 1.458 kg/cm^2 with an appreciable rise of almost 334% corresponding to cohesion percentage in the soil from 10% to 60%. This rise in cohesion in the sand – clay mix is the governing shear parameter to resist the shear loads in extreme situations of slope stabilities and retaining walls.

The gradual rise in the cohesion curve can be observed when 10%- 20% cohesive soil is added. However the curve rises rapidly when the percentage of cohesive soil in the cohesionless soil goes beyond 30% and continues to rise at the same rate up to 50%. The curve attains flatness when the infused cohesive soil percentage reaches 60%. Therefore as far as Cohesion is concerned the most appropriate mix of the cohesive soil in the cohesionless soil ranges from 30% to 50%, an average figure of 40% can be adopted. The ϕ-value is the governing factor to resist shear forces in case of cohesionless soils. Soil having larger ϕ-value offers greater resistance, but as in the case as seen in (Fig. 4), the ϕ-value witnesses a considerable decline from 26.6^0 to 14.1^0.

The two reasons can be cited for the fall of the ϕ-value curve. Firstly as the cohesion percentage in the soil is increased successively from 10% to 60% correspondingly the proportion of cohesionless soil is reduced and as discussed ϕ-value is the primary shear parameter responsible for governing shear strength in the soil which in result faces a sharp decline Secondly as the test performed is Unconsolidated Undrained test (U-U type), in this case after the application of shear and normal loads, the pore pressure in the soil increases. Since there is no drainage for the dissipation of pore pressure, which in the above case resulted in reduced internal friction among the granular particles of cohesionless soil, thus, reducing the ϕ-value of the soil. However as per the ϕ-value curve (Fig. 4), the curve falls sharply until the cohesion percentage in the soil rises up to 20%, beyond which the curve falls gradually.

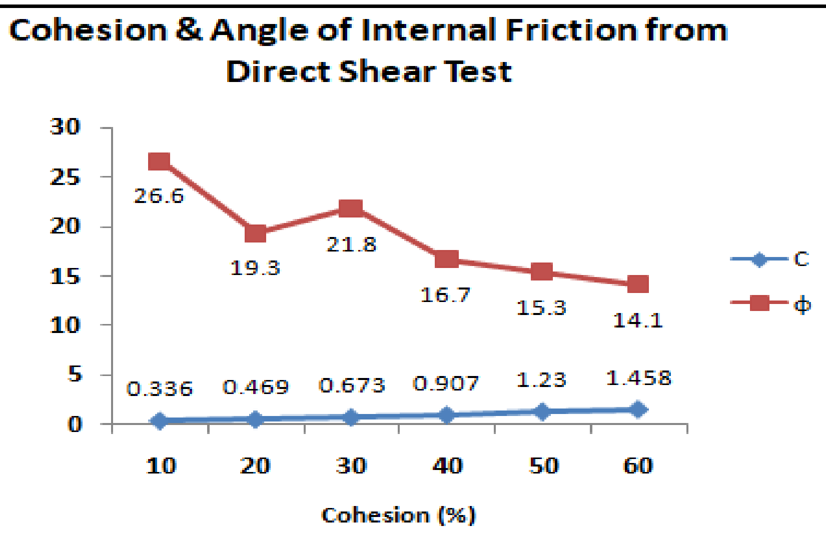


Figure 4 depicts the variation in Cohesion with Internal friction angle at different proportion of cohesion percentage in cohesionless soil.

V. CONCLUSION SUMMARY

In this study, the cohesionless soil was studied under the effect of cohesion varying in different percentages 10%, 20%, 30%, 40%, 50%, and 60%. The sand – clay mix was assessed on different strength parameters namely, compaction, specific gravity, permeability & shear.

From the I.S. Light Compaction test, The Maximum Dry Density required for maximum compaction of the soil founds a continuous rise. A sharp rise in MDD was obtained when cohesion in soil was from 30% to 50%.

All test results declared moisture content value of 10% for achieving Maximum Dry Density.

Specific gravity as determined from Pycnometer test saw a continuous decline on adding cohesion in the soil but found to be within permissible range that is from 2.74 to 2.44 when the cohesion percentage ranges from 10% to 30%.

The results from Falling Head Permeability test saw an appreciable decline in the permeability of cohesionless soil when infused with cohesion. Permeability decreases rapidly as the cohesion reaches from 10% to 30%, however the curve falls gradually still after. Therefore to avoid any volumetric changes in the soil, the cohesion percentage can be kept between 20% and 40% for ground improvement.

The results from the Direct Shear Test on cohesionless soil when mixed with cohesion, the angle of internal friction drops as the cohesive soil increases in the mix, however the cohesion value saw a continuous rise. As observed for both shear parameters, the cohesion percentage from 30% to 50% can be considered an optimum mix with an adequate balance of cohesion and angle of internal friction in the soil.

As per the results analysis and comparison after performing above tests, the best possible mix or percentage of cohesion found appropriate for improving the cohesionless soil can range from 30% to 40%.

REFERENCES

[1] Mahdi O. Karkush, Sarah Yassin, Using sustainable material in improvement the geotechnical properties of soft clayey soil, Journal of Engineering Science and Technology Vol. 15, No. 4 (2020) 2208 – 2222, August 2020,

[2] K. M. Ganesh, A.S.S. Vara Prasad, M. Jagapathi Raju, Experimental Study on Building Demolished Waste Stabilized Expansive Soil with Potassium Chloride, International Journal of Engineering & Technology, 7 (3.31) (2018) 214-218,

[3] Hanna Paul, Sobha Cyrus, Stabilization of weak sub grade soil using demolished concrete aggregate, December 2016, Indian Geotechnical Conference IGC2016, 15-17 December 2016, IIT Madras, Chennai, India,

[4] Ali Arisha, Alaa Gabr, S El-Badawy, Using blends of Construction & Demolished waste materials and recycled clay 2016, doi: 10.1016/j.proeng.2016.06.14.

[5] I.S. Code 2720-1980 (Part 3) for the procedure adopted for determining the Specific Gravity of soil.

[6] I.S. 2720-1980 (Part 7) for performing I.S. Light Compaction Test.

[7] I.S. Code 2720-1986 (Part 13) for the methodology to determine the shear parameters using Direct Shear test.

[8] I.S. Code 2720-1986 (Part 17) for the methodology for determining the Vertical Permeability of soil mix.