IMPROVEMENT OF SOIL BY USING BITUMEN EMULSION

Submitted in partial fulfilment of the requirements
for the degree of
Bachelor of Engineering

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CERTIFICATE

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This is to certify that the project entitled "Improvement of Soil by using Bitumen Emulsion" is a bonafide work of Aftab Alam Gulam Husain Siddique (15DCES58), Rameez Irfan Faquih (15DCES65), Jamali Mohammad Zahran (15DCES68), Shaikh Arfan Mohammad Razik (15DCES86), submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Bachelor of Engineering" in Department of Civil Engineering.

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Project Report Approval for B. E.

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Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Soil is one of nature's most abundant construction materials. Almost all type of constructions are built with or upon soil. If the sub-grade is not good enough, cracks may appear in the whole structure which may ultimately lead to failure. Conventionally, the sub-grade is normally replaced with stronger soil materials to improve the strength, but this practice is not economical. In this project, an attempt has been made to increase the strength of soil by adding bituminous emulsion instead of replacing it with stronger soil. The soil has been classified by conducting soil tests such as sieve analysis, liquid limit test, plastic limit test, shrinkage limit test, standard proctor test. The initial strength of soil has been determined by conducting soil tests such as California bearing ratio tests and unconfined compression test. The results obtained is then compared with the soil treated with 7% (by weight) of bitumen emulsion at different grades of bitumen emulsion and conclusion were drawn on to which grade would be suitable for the chosen soil.

Keywords : Soil improvement, Bitumen emulsion, Shear strength, CBR, Subgrade improvement.

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Abbreviation Notation & Nomenclature.

C	– Cohesion
G_S	– Specific of soil solids or Grain specific gravity
I_C	– Consistency Index
ID	– Density Index
I_f	– Flow Index
I_L	– Liquidity Index
I_P	– Plasticity Index
I_S	– Shrinkage Index
I_T	– Toughness Index
V_X	– Volumetric Shrinkage
W_L	– Liquid Limit
W_P	– Plastic Limit
W_O	– Optimum Moisture Content
W_S	– Shrinkage
V_O	– Unit Weight of Soil in the Natural State
t	– Shear Stress
ϕ	– Angle of Internal Friction
σ	– Normal Stress
w	– Water Content

Chapter 1

Introduction

1.1 Background.

The foundation is very important and has to be strong enough to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, we need to have proper knowledge about their properties and factors which affect their behavior to work with soil. The process of soil stabilization helps to achieve the required properties in a soil needed for the type of construction work.

1.2 Problem Statement.

The safety of any geotechnical structure is dependent on the strength of soil; if the soil fails, the structure founded on it can collapse. Understanding shear strength is the basic to analyze soil stability problems like: lateral pressure on earth retaining structure, Slope stability, bearing capacity. According to above study we are able to know the importance of shearing strength of soil. While constructing any structure, structure may be of any form. It directly depends upon the relation between soil, structure and its loading.

1.3 Proposed Solution.

In this report, the soil is improved by using bituminous emulsion. Bitumen emulsion is a mixture of water or oil & bitumen. As bitumen is an oil product it cannot be mixed with water. Hence an emulsifier (a surface-active agent) is added with water before bitumen. Addition of emulsifier with water before adding bitumen into minute particles and keeps it dispersed in suspension.

The soil sample for the project is taken from the AIKTC vicinity. The work has been carried out by performing different experiments related to soil. The shear strength of the soil is tested by Unconfined compression test. The soil which is used for testing is taken from different location of campus vicinity.

The term emulsion means that dispersion of small droplets of one liquid in another liquid. Types of emulsion are oil –in-water (continuous phase is water and the disperse phase is an oily) and water-in-oil (continuous phase is an oil and the disperse phase is water). Here the emulsifier is used as kerosene with water.

1.4 Objectives.

The objectives of this study are:

1. To find the shear strength of natural soil using unconfined compressive test.
2. To find the bearing strength of natural soil using CBR test.
3. To find the shear strength of soil mixed with bitumen emulsion using unconfined compressive test.
4. To find the bearing strength of soil mixed with bitumen emulsion using CBR test.
5. To compare the shear strength of natural soil with that of soil mixed with bitumen emulsion.
6. To compare the bearing strength of natural soil with that of soil mixed with bitumen emulsion.
7. To suggest the optimum grade of bitumen emulsion for soil improvement.

Chapter 2

Review of Literature

2.1 Introduction

During the literature review for this work, we referred quite a few books on soil, technical and research papers from various national and international journals. This part focuses on the literature on improvement of soil using bitumen emulsion and on various studies related to improvement of soil using bitumen emulsion.

2.2 Summaries of Relevant Literature

Elifas Bunga (2011), has analyzed the effect of soil stabilization with emulsified asphalt on soil characteristics that can increase its strength. The soil used in this study was sandy clay loam. Soil sample was taken in its original and disturbed forms. Emulsified Asphalt type CSS-1S used for soil stabilization. Disturbed soil sample was mixed up with emulsified asphalt, cast and kept for three days then tested. The concentrations of emulsified asphalt used in this study were 1.5%, 3%, and 4.5% respectively toward dry soil weight. Test performed was Atterberg's limits, direct shear tests. The results of the study indicate that stabilization material for emulsified asphalt can improve physical, chemical, and mechanic characteristics of sandy clay loam. Plasticity and shear strength of soil increase in line with the increase of emulsified asphalt concentration.

Parithosha Perika (2015), has improve the shear strength of soil by using Bitumen Emulsion. Medium Setting Emulsion (MS) is used as a stabilizing agent. Bitumen sand stabilization is an effective process as bitumen makes soil stronger and improves resistance capacity against water and frost. Attempt made to improve Geotechnical properties of soil and Bitumen Emulsion is environmentally accepted. Main objective is to maximize CBR value by checking conditions to increase the CBR value of soil subgrade. Cationic emulsions are positively charged bituminous droplets and Anionic emulsions have negatively charged bituminous droplets. Best results are obtained if soil emulsion mix is left for five and half (5&1/2) hours after mixing.

Satyendra Kumar Varma (2015), has used fine soil obtain from local field from Chittorgarh district. The main objective of this experimental study is to improve the properties of soil by adding bitumen emulsion as stabilizing agent and little bit cement as filler. In the experiment bitumen emulsion is used with filler material (cement). CASE A- First sample without mixing any material. CASE B- Secondly, they mix 3% emulsion. CASE C- Thirdly they mix 3% emulsion and 2% cement. The soil was tested for specific gravity, liquid limit test, plastic limit and grain size distribution as to be well known physical properties of soil material. Modified proctor test has been executed for 3000 gm. Soil sample taken for each trial. From this test maximum dry density of the specimen was found from this study it is clear that there is a considerable improvement in California Bearing Ratio (CBR) of subgrade due to use of bitumen emulsion if proper mixing is done, it is seen that it best result are obtained if the soil emulsion mix is left for four hours after mixing. In each case state of condition, it was found that CBR value has increased consecutively from case A TO case D.

Simarpreet Singh Batra (2016), has used local soil from Amritsar and cationic bitumen emulsion is used in this project. The proportion of bitumen is 0%, 2%, 5%, 6%, 7% along with different quantity of water content. The test perform is direct shear test. The result shown that at 7%

bitumen emulsion the cohesion between soil particle was reduced to 0.16 N/mm^2 but at the same time the angle of internal friction was drastically increased to 67.3 which result in approx. 65% increase in shear strength of soil due to sticking property of bitumen.

Mr. A. Ghosh (2017), has review about 18 papers and come to a conclusion that there is considerable improvement of CBR value of sub grade due to use of MS (medium setting) bitumen emulsion if proper mixing is done. It is seen that it best results are obtained if the soil emulsion mix is left for about five and half hours after mixing. CBR value has increased up to fifty percent of the unmodified soil CBR. Observing its economic cost and quality of stabilization improvement, it is clear that this type of stabilization may be applicable in gravel soil. Cost of emulsion is so high that the amount of emulsion also depends upon budget and importance of structure. It was shown that un-drained shear strength value and CBR value increased with increasing plasticity index. Finally, it was achieved that shear strength and CBR value is inversely proportional to the water content of that material.

Mayank Chandra (2017), has improve the shear strength of soil by using Bitumen Emulsion. The soil used was gravel soil by adding hydrocarbon emulsion. They want to improve the soil strength in terms of CHE. By using Cationic Bitumen Emulsion (CMS), excellent improvement in soil results. They have also attempted black soil with CMS bitumen emulsion. For strengthening the properties of black soil, variations were done by them in dry density & CBR value. They used red coloured dirt sort gravel soil as an experimental material. The tests conducted are: - Optimum wet content of soil sample. Liquid limit, Plastic limit. Grain size distribution of soil sample. Customary Proctor check to get dry density. Optimum wet content of soil sample. Cosmic radiation check of soil sample mix with emulsion and cement. After knowing natural properties of soil, The Direct Shear test was conducted in accordance with IS 2720 (Part 13): 1986 on untreated soil, mixture of soil and Bitumen Emulsion at different water content. At 6% Bitumen emulsion, cohesion between soil particles reduced to 0.1638 N/mm^2 but at same time angle of internal friction was drastically increased resulting in app. 65% increase in their strength of soil

N. Vijay Kumar (2017), has used Laterite soil and various strength increasing tests are conducted on laterite soil by using the admixtures bitumen emulsion and also egg shell powder and coconut shell ash. The admixture bitumen emulsion is added at 5%,10%, & 15% proportions. Similarly egg shell powder and coconut shell ash are also added at the same proportions. The various test conducted are sieve analysis, plastic limit, Liquid limit, Specific Gravity, Compaction, Unconfined Compressive Test, CBR Test, Direct Shear Test The results which came after carrying out all tests found successful which indicates that the admixture added (bitumen and ESP and CSA) can be surely used as a laterite soil stabilizer. From the result it is proved that these admixtures were effective in the stabilizing the soil at 10% and with further increase in admixture lowers the strength of soil. The bitumen emulsion can be mostly used in road construction and building foundations. Egg shell powder and Coconut shell ash which are environmentally bio-degradable can also be applied in building foundations and mostly effective in agricultural fields.

R. Deby Linsha (2017), has used is laterite soil and kerosene are used as a bitumen emulsifier. The various proportions are prepared with 10%,20% and 25 % of bitumen emulsion mixed to the soil sample. Test performed before and after mixing of bitumen emulsion are particle sieve analysis, Atterberg's limits, direct shear tests, relative density, unconfined compression test, California bearing ratio, modified proctor compaction, specific gravity and both results are compared. The results show that the strength of the soil is good when 10 % bitumen emulsion is added.

2.3 Conclusion

From this study it is clear that there is a considerable improvement in California Bearing Ratio (CBR) of subgrade due to use of MS bitumen emulsion if proper mixing is done. It is seen that it best results are obtained if the soil emulsion mix is left for about five and half hours after mixing. it is clear that this type of stabilization may be applicable in gravel soil and clayed soil. Result indicate that with the increase of bitumen emulsion in the soil sample till 7% proportion ratio the soil strength is increased. As in above papers no one has changed the bitumen emulsion grade. So, in our project we will be changing the grade of bitumen and mixing it with soil sample which is explained in the next section.

Chapter 3

Methodology

Methodology involves collection of soil sample from Anjuman-I-Islam's Kalsekar Technical Campus, study of soil properties by conducting tests (particle sieve analysis, Atterberg's limits, water content, unconfined compression test, California bearing ratio, modified proctor compaction, specific gravity), addition of bitumen Emulsion to the soil of different grade, and comparison of test results.

3.1 Classification of Soil

The soil sample is taken from the AIKTC vicinity. The sample is collected in an undisturbed state in the form. The undistributed soil samples is used to perform tests to obtain majority of its engineering properties, such as strength, moisture content etc. The test we are going to perform depends upon the soil type found in the college vicinity. The classification of the soil is done according to IS: 2720 -1975.

Gravel (mm)	Sand (mm)			Silt (mm)			Clay (mm)		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
	2	0.6	0.2	0.06	0.02	0.006	0.002	0.0006	0.0002

Fig.3.1 Classification of Soil

3.2 Grain size analysis

In accordance with IS 2720 (Part 4):1985.

3.2.1 Apparatus for grain size analysis

Set of fine sieves, 4.75mm, 2.36mm, 1.18mm, 600micron, 425, 300, 150, and 75 microns, Weighing balance with accuracy of 0.1% of the mass of the sample, Oven, Mechanical shaker.

Fig. 3.2 Mechanical shaker

3.2.2 Procedure for grain size analysis

Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving.

Dry Sieving:

1. 2000gm of the soil sample was taken.
2. Sieve analysis using a set of standard sieves as given in the data sheet were conducted.
3. The sieving was done by mechanical sieve shaker for 10 minutes.
4. Weight of the material retained on each sieve were noted.
5. The percentage retained on each sieve is calculated on the basis of the total weight of the soil sample taken.
6. From these results the percentage passing through each of the sieves is calculated.
7. The grain size curve for the soil in the semi-logarithmic graph is drawn.

3.3 Liquid Limit & Plastic Limit Test

In accordance with IS 2720 (Part 5) – 1985.

3.3.1 Liquid Limit Test

A) Apparatus for Liquid Limit Test

Casagrande's liquid limit device, Grooving tools of standard types, Oven, Evaporating dish, Spatula, IS Sieve of size 425 μm, Weighing balance, with 0.01g accuracy.

Fig.3.3.1 Casagrande's liquid limit device

B) Procedure for Liquid Limit Test

1. A portion of the paste is placed in the cup of the liquid limit device.

2. Levelled the mix so as to have a maximum depth of 1cm.

3. The grooving tool was drawn through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.

4. For normal fine-grained soil: The Casagrande's tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.

5. After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.

7. About 10g of soil near the closed groove is taken and its water content is determined.

8. The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. The test was then repeated for 3 more times.

9. By altering the water content of the soil and repeating the foregoing operations, 4 readings were obtained in the range of 15 to 35 blows.

10. Liquid limit is determined by plotting a 'flow curve' on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points

3.3.2 Plastic Limit Test

A) Apparatus for Plastic limit test

Porcelain evaporating dish about 120mm diameter, Spatula, Container to determine moisture content, Container to determine moisture content, Oven, Ground glass plate – 20cm x 15cm, Rod – 3mm dia. and about 10cm long.

Fig.3.3.2 Plastic limit apparatus

B) Procedure for Plastic limit test

1. 10g of the soil was taken and rolled it with fingers on a glass plate. The rate of rolling was in between 80 to 90 strokes per minute to form a 3mm dia.
2. If the dia. of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.
3. Repeated the process of alternate rolling and kneading until the thread crumbles.
4. The pieces of crumbled soil thread is collected and kept in the container used to determine the moisture content.

3.4 Shrinkage Limit Test

In accordance with IS 2720-1972**.**

3.4.1 Apparatus for Shrinkage Limit Test

Oven, Sieve 425-micron, Mercury, Desiccator, Weighing balance, with 0.01g accuracy.

Fig 3.4 Shrinkage limit apparatus

3.4.2 Procedure for Shrinkage Limit Test

1. 100 gm. of soil sample from a thoroughly mixed portion of the material passing through 425 microns IS sieve was taken.

2. About 30 gm. of above soil sample was placed in the evaporating dish and thoroughly mixed with distilled water to make a paste.

3. The weight of the clean empty shrinkage dish was determined and recorded.

4. The dish was filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula.

5. Then the dish with wet soil was weighed and recorded immediately.

6. The wet soil cake was air dried until the color of the pat turns from dark to light. Then it was oven dried at a temperature of 1050 C to 1100 C for 12 to 16 hours. The weight of the dish with dry sample was determined and recorded. Then the weight of oven dry soil pat was calculated (W_0).

7. The shrinkage dish was placed in the evaporating dish and the dish was filled with mercury, till it overflows slightly. Then it was being pressed with plain glass plate firmly on its top to remove excess mercury. The mercury from the shrinkage dish was poured into a measuring jar and the volume of the shrinkage dish was calculated. This volume was recorded as the volume of the wet soil pat (V).

8. A glass cup was placed in a suitable large container and the glass cup removed by covering the cup with glass plate with prongs and pressing it. The outside of the glass cup was wiped to

remove the adhering mercury. Then it was placed in the evaporating dish which was clean and empty.

9. Then the oven dried soil pat was placed on the surface of the mercury in the cup and pressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish.

10. The mercury so displaced by the dry soil pat was weighed and its volume (V_o) was calculated by dividing this weight by unit weight of mercury.

3.5 Standard Proctor Compaction Test

In accordance with IS 2720 (Part 7):1980.

3.5.1 Apparatus for Standard Proctor Compaction Test

Cylindrical mould& accessories [volume = 1000cm3], Rammer [2.6 kg], Balance [1gaccuracy], Sieves [19mm], Mixing tray, Trowel, Graduated cylinder [500 ml capacity], Metal container.

Fig.3.5 Standard Proctor Apparatus

3.5.2 Procedure for Standard Proctor Compaction Test

1. 5 Kg. of soil was taken and the water was added to it to bring its moisture content to about 4 % in coarse grained soils and 8% in case of fine grained soils with the help of graduated cylinder
2. The mould with base plate attached was weighed to the nearest 1 gm (M_1). The extension collar was to be attached with the mould.
3. Then the moist soil in the mould was compacted in three equal layers, each layer being given 25 blows from the 2.6 Kg rammer dropped from a height of 310 mm. above the soil.
4. The extension was removed and the compacted soil was leveled off carefully to the top of the mould by means of a straight edge.
5. Then the mould and soil was weighed to the nearest 1 gm. (M_2).
6. The soil was removed from the mould and a representative soil sample was obtained water content determination.
7. Steps 3 to 6 were repeated after adding suitable amount of water to the soil in an increasing order.

3.6 Unconfined Compressive Strength Test

In accordance with IS 2720 (Part10)-1991.

3.6.1 Apparatus for Unconfined Compressive Strength Test

Unconfined compressive test, proving ring type. Proving ring, capacity 1 KN, accuracy 1 N, Dial gauge, accuracy 0.01 mm, Weighing balance, Oven, Stopwatch, Sampling tube, Split mould, 38mm diameter, 76mm long, Sample extractor, Knife, Vernier calipers, Large mould.

Fig 3.6 Unconfined Compression Tester

3.6.2 Procedure for Unconfined Compression Test

1. Soil was mixed with water. This sample was than filled in the mould which was oiled in advance. The mould was having the same internal diameter as that of specimen which was tested.
2. The mould was opened carefully and sample was taken out
3. Two or three such samples were prepared for testing.
4. The initial length and diameter of the specimen was measured.
5. The specimen was kept on bottom of the loading device. Adjusted upper plate to make contact with the specimen. The dial gauge (compression) was set to zero. The dial gauge reading provides the deformation in the sample and in turn strain.
6. The specimen was compressed until crakes are developed or the strain curve was well past its peak or until a vertical deformation of 20% was reached. The dial reading was taken approximately at every 1 mm deformation of the specimen.
7. The proving ring reading provides the corresponding load in- turn axial stress on the sample.
8. The procedure were repeated for three times.

3.7 California Bearing Ratio

In accordance with IS 2720 (Part 16) – 1987.

3.7.1 Apparatus for California Bearing Ratio

CBR mould, inside diameter = 150 mm, total height =175 mm, with detachable extension collar, 50 mm high, and detachable base plate, 10 mm thick. Spacer disc, 148 mm diameter, 47.7 mm high. Rammers, light compaction, 2.6 kg, drop 310 mm, heavy compaction, 4.89 kg, drop 450 mm. Slotted masses, annular, 2.5 kg each, 147 mm diameter, with a hole of 53 mm diameter in the center. Cutting collar, steel which can fit flush with the mould both outside and inside. Expansion measuring apparatus, consisting of a perforated plate, 148 mm diameter, with a thread screw in the center and an adjustable contact head to be screwed over the stem, and a metal tripod. Penetration piston, 50 mm diameter, 100 mm long. Loading device, capacity 50 KN, equipped with a movable head (or base) at a uniform rate of 1.25 mm minute. Two dial gauges, accuracy 0.01 mm. IS sieve, 4.7 mm and 20 mm size.

Fig 3.7 California Bearing Ratio Apparatus

3.7.2 Procedure for California Bearing Ratio

Preparation of test specimen:

Remoulded specimen: The remoulded specimen at Proctors maximum dry density or any other density was prepared at which C.B.R was required. The specimen was maintained at optimum moisture content. The material used were pass through 20 mm I.S. sieve and it is retained on 4.75 mm I.S. sieve. The specimen was prepared either by dynamic compaction.

Procedure for Penetration Test:

1. The mould assembly with the surcharge weights was placed on the penetration test machine.

2. The penetration piston were set at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample was established.

3. The stress and strain dial gauge were set to read zero. The load was applied on the piston so that the penetration rate was about 1.25 mm/min.

4. The load readings were recorded at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. The maximum load and corresponding penetration was noted.

Table 3.1 Quantity of soil required in kg or gm for above tests

TEST	QUANTITY(gm)
Grain size analysis	800
Water content	100
Standard proctor test	5000
Liquid limit	120
Plastic limit	30
Total	6050
CBR test	20000
Unconfined compressive strength test	500
Total	20500
Total= 6050+ (20500)	**26550**

Table 3.2 Quantity of bitumen required in kg or gm

TEST	QUANTITY
CBR test	7% of soil sample 385 gm/grade
Unconfined compressive test	7% of soil sample 35 gm/grade
Total	**420 gm/grade**

Chapter 4

4.Result and Discussion

The characteristic study on the collected soil sample was conducted and then the respective tests are conducted for the bitumen emulsion mixed soil sample of three different grades. The test results are compared and given below.

4.1 Grain size distribution.

Table 4.1 Grain size distribution.

Size of Opening (mm)	Mass of soil retain (gm)	Percentage retain	Cumulative Percentage Retain	Percentage finer
4.75	435	21.75	21.75	78.25
2.36	335	16.75	38.25	61.75
1.18	560	28	66.25	33.75
0.6	280	14	80.25	19.75
0.425	105	5.25	85.5	14.5
0.3	60	3	88.5	11.5
0.15	155	7.75	96.25	3.75
0.075	35	1.75	98	2
Pan	35	1.75	100	0
Total	2000			100

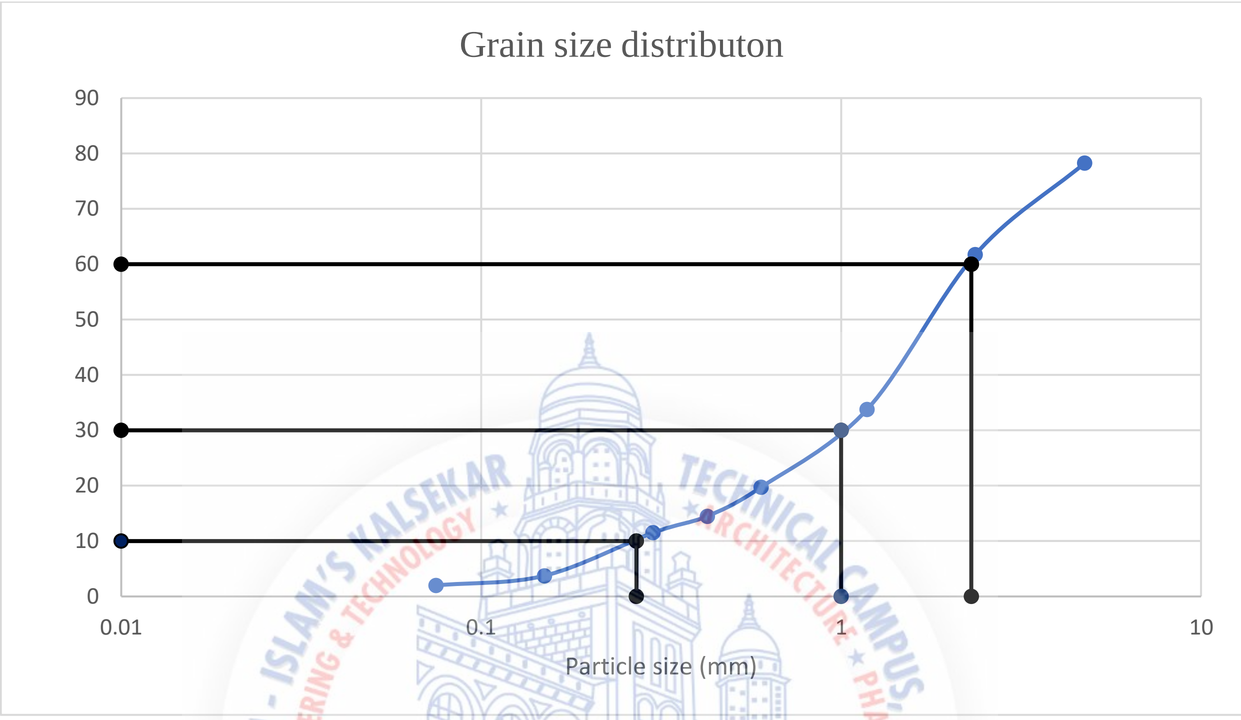

Fig 4.1 Grain size distribution Graph

From figure no.4.1 it was observed that the value of $D_{10} = 0.29$, $D_{30} = 1$ and $D_{60} = 2.3$, therefore Cu =7.93 Cc = 1.49.

Hence as per IS code. If Cu > 6 and Cc is in between 1 to 5 then the soil is well graded.

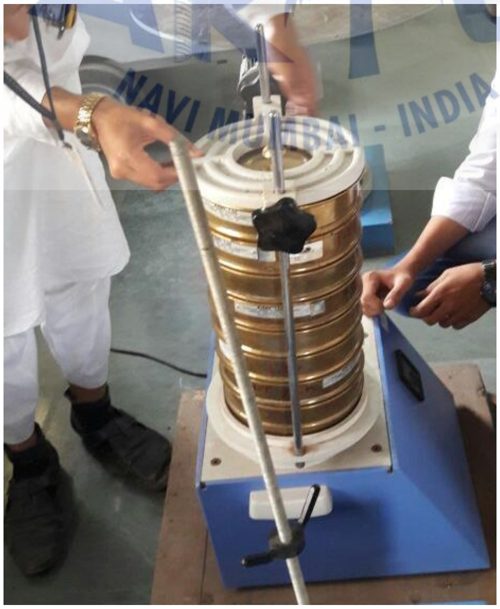

Fig 4.2 Performing Grain size distribution

4.2 Liquid Limit & Plastic Limit Test.

Table 4.2.1 Liquid Limit.

Observation	**1**	**2**	**3**	**4**
No. of blows	15	27	18	30
Wt. of empty can	15.04	15.63	15.05	15.14
Wt. of can plus wet soil	26.03	27.28	28.16	25.81
Wt. of can plus dry soil	21.91	23.1	23.22	21.98
Wt. of water	4.12	4.18	4.94	3.83
Wt. of dry soil	6.87	7.47	8.17	6.84
Water content	59.97089	55.95716	60.46512	55.99415

By referring table 4.2.1 graph was plotted and it was observed that Liquid Limit was 57%

Fig 4.3 Performing Liquid Limit.

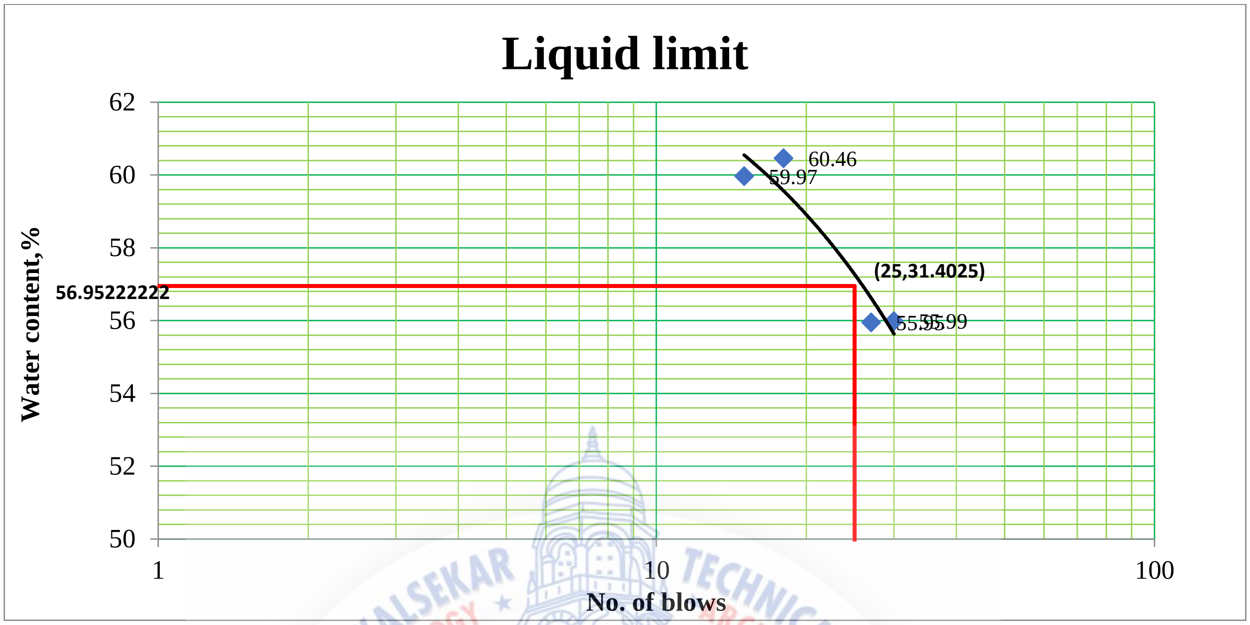

Fig no 4.3(a) Liquid Limit graph

Table 4.2.2 Plastic Limit Test.

Observation	**1**
Wt. of empty can	15.1
Wt. of can plus wet soil	18.1
Wt. of can plus dry soil	17.26
Wt. of water	0.84
Wt. of dry soil	2.16
Water content	38.88889

From Table 4.2.2 it was calculated that Plastic Limit was 38%.

Liquid limit of the soil is 57% and plastic limit of soil is 38% and plasticity index is 19%. Therefore, soil is MH or OH (Inorganic silt of high compressibility or organic clay of medium to high plasticity)

Fig 4.4 Performing Liquid Limit

4.3 Shrinkage Limit Test

Table 4.3 Shrinkage Limit Test.

Observations and calculations	**1**
Mass of empty empty shrinkage dish	30
Mass of shrinkage dish + wet soil	70
Mass of wet soil, M1 = 3-2	40
Mass of shrinkage dish + dry soil	56
Mass of dry soil, Ms = 5-2	26
Volume of Shrinkage dish, V1=286/13.6	21.029
Volume of dry pat, V2=190/13.6	13.9
Shrinkage limit, (%)	26.42

Fig 4.5 Performing Shrinkage Limit Test.

4.4 Standard Proctor Compaction Test.

Table 4.4 Standard Proctor Compaction Test.

Determination no.	1	2	3	4
Volume of mould (cm^3)	1000	1000	1000	1000
Wt. of mould, W1 (g)	7705	7705	7705	7705
Wt. of mould + compacted soil, W2 (g)	9480	9665	9600	9575
Wt. of compacted soil, W = W2-W1	1775	1960	1895	1870
Bulk density, =W/V g/cm^3	1.775	1.96	1.895	1.87
Water Content, w	0.169	0.2546	0.2436	0.2715
Dry density,	1.518392	1.562251	1.523802	1.470704

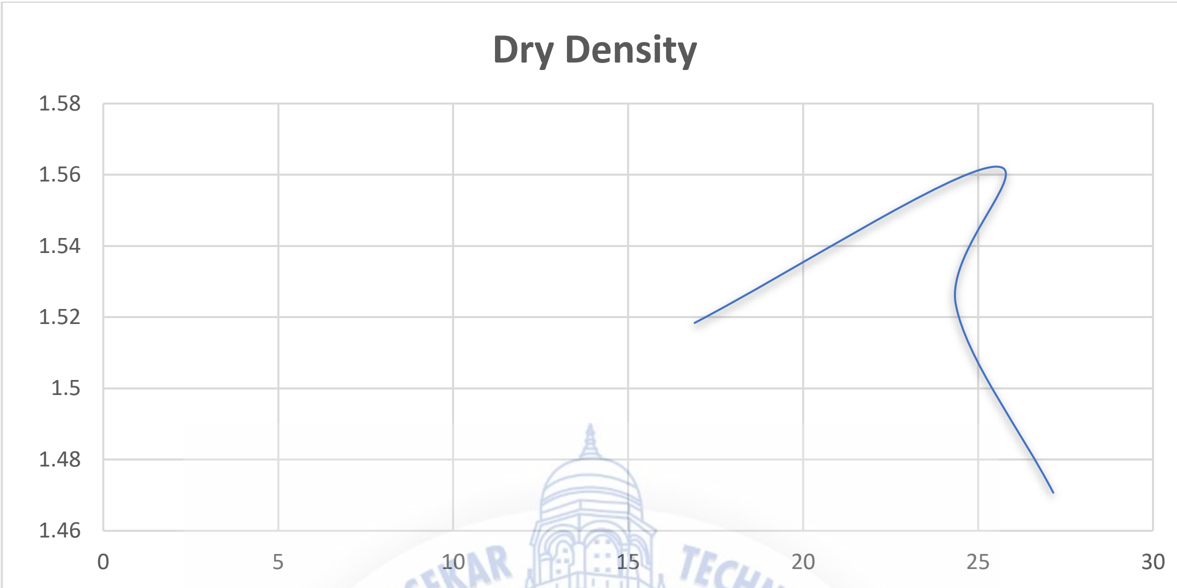

Fig 4.6 Standard Proctor Compaction Graph.

From the graph of dry density versus water content in figure no. it was observed that the optimum moisture content = 25.460 % which gives maximum Dry Density= 1.562 kN/m^3

Fig 4.7 Performing Standard Proctor Compaction Test.

4.5 Unconfined Compression Test.

Table 4.5.1 Soil Without Bitumen Emulsion

Sample no.	DGR	PRR	Deformation = DGR * G/10	Load = PRR * CF	Strain	Concentrated Area	Compressive stress P/A
1	30	6.2	0.03	1.426	0.003947	11.38594452	0.125242135
	60	12.7	0.06	2.921	0.007895	11.43124668	0.255527685
	95	15	0.095	3.45	0.0125	11.48455696	0.300403404
2	40	10.1	0.04	2.323	0.005263	11.40100529	0.203753962
	70	9	0.07	2.07	0.009211	11.44642762	0.180842449
3	40	4.8	0.04	1.104	0.005263	11.40100529	0.096833566
	68	11.3	0.068	2.599	0.008947	11.44338821	0.227118049

From table 4.5.1 which shows UCT results (q_u) of normal soil the maximum value which comes out was 0.227 kN/m^2, so the shear strength was (q_u/2) = 0.113 kN/m^2.

Figure no. 4.8 Performing Unconfined Compression Test.

Table4.5.2 Soil with Rapid Setting (RS) Bitumen Emulsion.

Sample no.	DGR	PRR	Deformation = DGR * G/10	Load = PRR * CF	Strain	Concentrated Area	Compressive stress P/A
1	50	4.2	0.05	0.966	0.006579	11.41610596	0.084617294
	100	6.5	0.1	1.495	0.013158	11.49221333	0.130088083
	150	7.8	0.15	1.794	0.019737	11.56934228	0.155064995
2	50	3.8	0.05	0.874	0.006579	11.41610596	0.076558505
	100	8.1	0.1	1.863	0.013158	11.49221333	0.162109765
	150	9	0.15	2.07	0.019737	11.56934228	0.178921148
	200	9.1	0.2	2.093	0.026316	11.64751351	0.179695005
3	50	3.5	0.05	0.805	0.006579	11.41610596	0.070514412
	100	8.2	0.1	1.886	0.013158	11.49221333	0.16411112
	150	9.8	0.15	2.254	0.019737	11.56934228	0.19482525
	200	13.8	0.2	3.174	0.026316	11.64751351	0.272504513
4	50	0.4	0.05	0.092	0.006579	11.41610596	0.00805879
	100	1.2	0.1	0.276	0.013158	11.49221333	0.024016261
	150	3.4	0.15	0.782	0.019737	11.56934228	0.067592434
	200	8	0.2	1.84	0.026316	11.64751351	0.157973631
	250	12	0.25	2.76	0.032895	11.7267483	0.235359362
	300	14.9	0.3	3.427	0.039474	11.80706849	0.290249862
	350	15.9	0.35	3.657	0.046053	11.88849655	0.307608282

From table 4.5.2 which shows UCT results (q_u) of Soil with Rapid Setting (RS) Bitumen Emulsion the maximum value which comes out was 0.307 kN/m^2, so the shear strength was (q_u/2) = 0.15 kN/m^2.

Table 4.5.3 Soil with Medium Setting (MS) Bitumen Emulsion.

Sample no.	DGR	PRR	Deformation = DGR * G/10	Load = PRR * CF	Strain	Concentrated Area	Compressive stress P/A
1	50	0.4	0.05	0.092	0.00657894	11.41610596	0.00805879
	100	2.3	0.1	0.529	0.01315789	11.49221333	0.046031168
	150	5.8	0.15	1.334	0.01973684	11.56934228	0.11530474
	200	11.2	0.2	2.576	0.02631578	11.64751351	0.221163083

	250	15.8	0.25	3.634	0.03289473	11.7267483	0.309889827
	300	18.4	0.3	4.232	0.03947368	11.80706849	0.35842936
	350	19.2	0.35	4.416	0.04605263	11.88849655	0.37145151
2	50	1.9	0.05	0.437	0.00657894	11.41610596	0.038279252
	100	6.2	0.1	1.426	0.00657894	11.41610596	0.124911244
	150	12.4	0.15	2.852	0.01315789	11.49221333	0.248168035
	200	17.2	0.2	3.956	0.01973684	11.56934228	0.341938194
	250	21	0.25	4.83	0.02631578	11.64751351	0.414680781
	300	22.3	0.3	5.129	0.03289473	11.7267483	0.437376148

From table 4.5.3 which shows UCT results (q_u) of Soil with Medium Setting (MS) Bitumen Emulsion the maximum value which comes out was 0.437 kN/m^2, so the shear strength was (q_u/2) = 0.218 kN/m^2.

Table 4.5.4 Soil with Slow Setting (SS) Bitumen Emulsion.

Sample no.	**DGR**	**PRR**	**Deformation = DGR * G/10**	**Load = PRR * CF**	**Strain**	**Concentrated Area**	**Compressive stress P/A**
1	50	3.2	0.05	0.736	0.00657894	11.41610596	0.06447032
	100	12.6	0.1	2.898	0.01315789	11.49221333	0.252170745
	150	24.6	0.15	5.658	0.01973684	11.56934228	0.489051137
	200	31.2	0.2	7.176	0.02631578	11.64751351	0.61609716
	250	32.8	0.25	7.544	0.03289473	11.7267483	0.64331559
2	50	4	0.05	0.92	0.00657894	11.41610596	0.0805879
	100	18.6	0.1	4.278	0.01315789	11.49221333	0.372252052
	150	32.8	0.15	7.544	0.01973684	11.56934228	0.652068183
	200	39.2	0.2	9.016	0.02631578	11.64751351	0.774070791
	250	41	0.25	9.43	0.03289473	11.7267483	0.804144487
3	50	3.6	0.05	0.828	0.00657894	11.41610596	0.07252911
	100	13.2	0.1	3.036	0.01315789	11.49221333	0.264178876
	150	27.2	0.15	6.256	0.01973684	11.56934228	0.540739469
	200	39.2	0.2	9.016	0.02631578	11.64751351	0.774070791
	250	46.2	0.25	10.626	0.03289473	11.7267483	0.906133544
	300	47.6	0.3	10.948	0.03947368	11.80706849	0.92724117

From table 4.5.4. which shows UCT results (q_u) of Soil with Slow Setting (SS) Bitumen Emulsion the maximum value which comes out was 0.927 kN/m^2, so the shear strength was (q_u/2) = 0.463 kN/m^2.

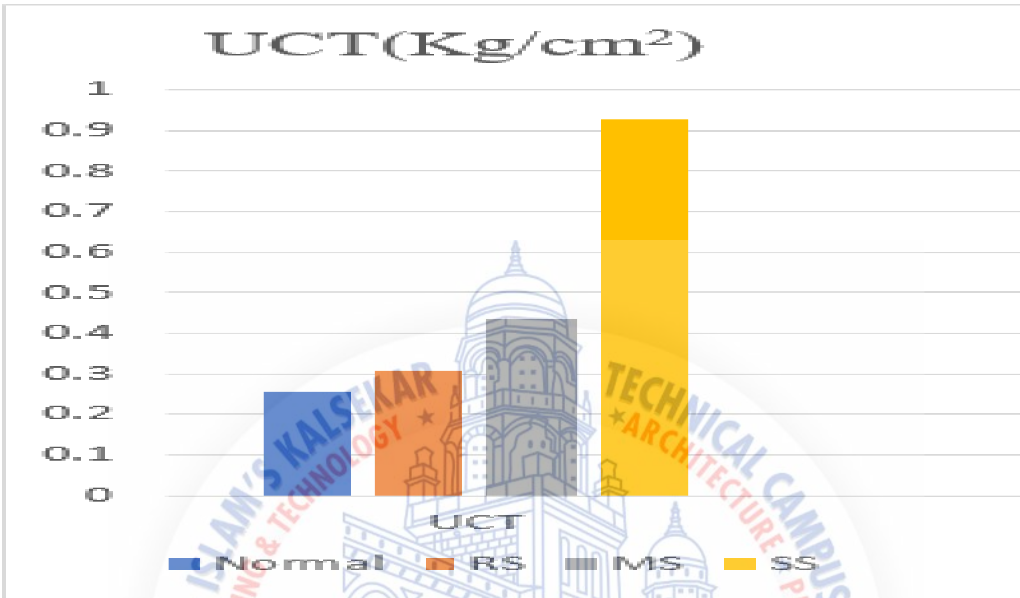

Figure no.4.9 Comparison of Unconfined Compression Test.

4.6 CBR test.

Table 4.6.1 Soil Without Bitumen Emulsion.

DGR	Penetration = DGR*G(mm)	PRR	Load P = PRR * CF (Kg)	Corrected Load	CBR value (%)
50	0.5	0.2	1.048		
100	1	1.6	8.384		
150	1.5	3.8	19.912		
200	2	5.8	30.392		
250	2.5	7.4	38.776	46.5	3.45
300	3	8.7	45.588		
350	3.5	9.6	50.304		
400	4	10.4	54.496		
450	4.5	11	57.64		
500	5	11.7	61.308	64	3.17
550	5.5	12.2	63.928		
600	6	12.6	66.024		
650	6.5	13.1	68.644		

700	7	13.5	70.74		
750	7.5	13.8	72.312		
800	8	14.2	74.408		
850	8.5	14.4	75.456		

The normal curve was with convexity upwards and the loads corresponding to 2.5 and 5mm penetration values are noted. Sometimes a curve with initial upward concavity was obtained, indicating the necessity of correction. In this case, the corrected origin was established by drawing a tangent from steepest point on the curve. The load values corresponding to 2.5 and 5mm penetration values from the corrected origin were noted.

From table no. it was observed that correction was required. After correction CBR values @ 2.5mm = 3.45%, CBR values @ 5mm = 3.17%

Table 4.6.2 Soil with Rapid Setting (RS) Bitumen Emulsion.

DGR	Penetration = DGR*G(mm)	PRR	Load P = PRR * CF (Kg)	Corrected Load	CBR value
50	0.5	0.2	1.048		
100	1	1.4	7.336		
150	1.5	2.2	11.528		
200	2	2.9	15.196		
250	2.5	3.6	18.864	22	1.63
300	3	4.4	23.056		
350	3.5	5.2	27.248		
400	4	5.8	30.392		
450	4.5	6.2	32.488		
500	5	6.8	35.632	36	1.78
550	5.5	7.2	37.728		
600	6	7.4	38.776		
650	6.5	7.8	40.872		
700	7	8.2	42.968		

From table 4.6.2 it was observed that correction was required. After correction CBR values @ 2.5mm = 1.63%, CBR values @ 5mm = 1.78%

Table 4.6.3 Soil with Medium Setting (MS) Bitumen Emulsion.

DGR	**Penetration = DGR*G(mm)**	**PRR**	**Load P = PRR * CF (Kg)**	**Corrected Load**	**CBR value**
50	0.5	0.6	3.144		
100	1	1.2	6.288		
150	1.5	1.8	9.432		
200	2	2.2	11.528		
250	2.5	2.6	13.624	13.624	1.0136
300	3	3	15.72		
350	3.5	3.2	16.768		
400	4	3.5	18.34		
450	4.5	3.7	19.388		
500	5	3.9	20.436	20.436	1.01
550	5.5	4	20.96		
600	6	4.2	22.008		

From table 4.6.3 it was observed that correction was not required. CBR values @ 2.5mm = 1.0136%, CBR values @ 5mm = 1.01%

Table 4.6.4 Soil with Slow Setting (SS) Bitumen Emulsion.

DGR	Penetration = DGR*G(mm)	PRR	Load P = PRR * CF (Kg)	Corrected Load	CBR value
50	0.5	0.4	2.096		
100	1	0.9	4.716		
150	1.5	1.9	9.956		
200	2	2.6	13.624		
250	2.5	3.2	16.768	16.768	1.247
300	3	3.6	18.864		
350	3.5	3.9	20.436		
400	4	4	20.96		
450	4.5	4.2	22.008		
500	5	4.3	22.532	22.532	1.11
550	5.5	4.4	23.056		
600	6	4.6	24.104		
650	6.5	4.7	24.628		
700	7	4.8	25.152		
750	7.5	4.9	25.676		

From table.4.6.4 it was observed that correction was not required. CBR values @ 2.5mm = 1.247%, CBR values @ 5mm = 1.11%

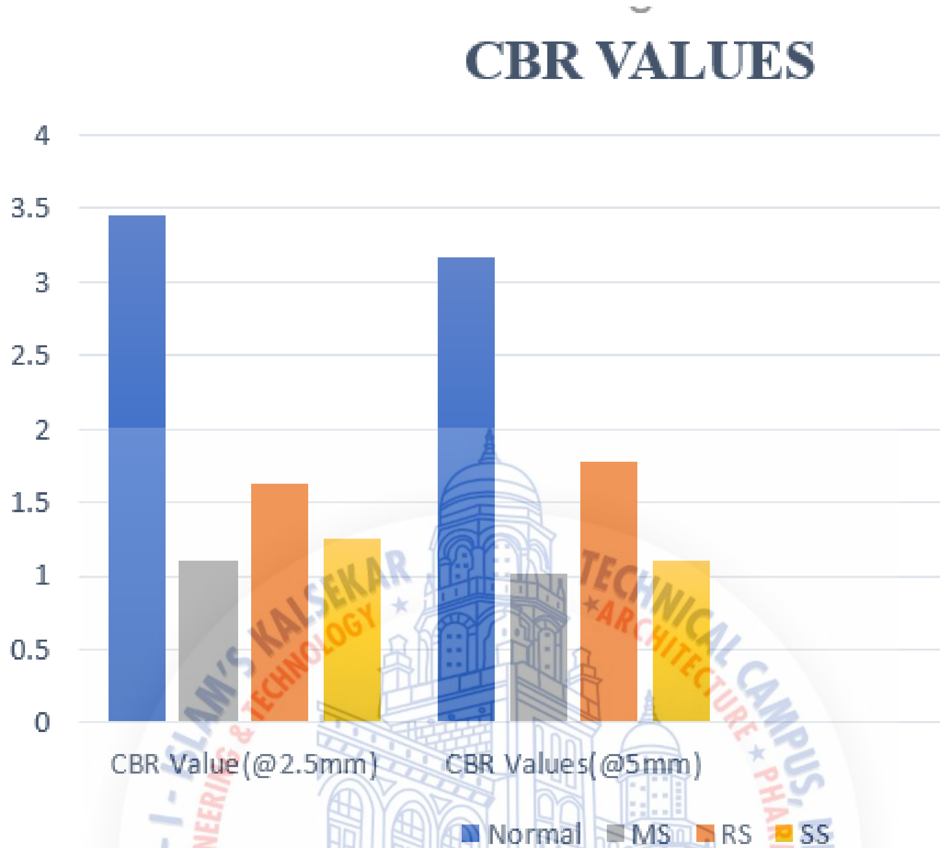

Figure no.4.10 Comparison of CBR Test.

Chapter 5

Conclusion

5.1 Concluding Remark

From this experimental study it is clear that there is a considerable improvement in California Bearing Ratio (CBR) and Shear strength property of soil due to use of bitumen emulsion. In case state of condition, it was found that CBR and Unconfined compression test (UCT) value has increased consecutively From Case 1 to Case 3. It is studied that best result are obtain if the mixture of soil and bitumen emulsion is left for four hours. This type of stabilization may be applicable in roadways.

5.1 Future scope

After adding bitumen emulsion, it can be studied what will be the effect of bitumen emulsion on other soil properties such as liquid limit, plastic limit, shrinkage limit, Dry density, etc.

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