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EXPERIMENTAL STUDY ON SUB-BASE LAYER STABILIZATION THROUGH BITUMEN EMULSION APPLICATION

[1] CHALLA VENKAIAH, [2] Dr T. SURESH BABU[3], [3] K PRAVALLIKA
[1]Research Scholar, [2]Professor, [3]Assistant Professor
[1]Highway Engineering,
[1]Visvodaya Engineering College, Kavali, Nellore, Andhra Pradesh India

Abstract: This experimental study aims to investigate the effectiveness of bitumen emulsion in stabilizing the sub-base layer of road construction. The sub-base layer plays a crucial role in providing structural support and preventing deformation of the road surface. In this research, bitumen emulsion is introduced as a stabilizing agent to enhance the mechanical properties of the sub-base layer. The study involves laboratory testing of different sub-base materials treated with varying concentrations of bitumen emulsion. The mechanical characteristics, including strength, durability, and moisture susceptibility, are evaluated through standard testing procedures. The experimental results will provide insights into the optimal dosage of bitumen emulsion required for achieving the desired stabilization effects. The findings of this research have implications for the improvement of road construction practices, especially in areas where sub-base layer stability is a critical factor. The use of bitumen emulsion as a stabilizing agent offers a potential sustainable solution, contributing to the longevity and performance of road infrastructure.

***Index Terms* -** sub-base layer, bitumen emulsion, stabilization, road construction, mechanical properties, laboratory testing.

I. INTRODUCTION

Starting from the base, soil is a standout amongst the most abundant construction materials of nature. Just about all kind of construction is based with or upon the soil. Long term performance of pavement structures is altogether affected by the strength and durability of the subgrade soils. In-situ sub-grades frequently don't provide the support required to achieve acceptable performance under the traffic loading with increasing environmental demands. Despite the fact that stabilization is a well-known option for improving soil engineering properties yet the properties determined from stabilization shift broadly because of heterogeneity in soil creation, contrasts in micro and macro structure among soils, heterogeneity of geologic stores, and because of chemical contrasts in concoction interactions between the soil and utilized stabilizers. These properties require the thought of site-specific treatment alternatives which must be accepted through testing of soil-stabilizer mixtures.

Whether the pavement is flexible or rigid, it rests on a soil foundation on an embankment or cutting, normally that is known as subgrade. It may be defined as a compacted layer, generally occurring local soil just beneath the pavement crust, providing a suitable foundation for the pavement. The soil in subgrade is normally stressed to certain minimum level of stresses due to the traffic loads. Subgrade soil should be of good quality and appropriately compacted so as to utilize its full strength to withstand the stresses due to traffic loads for a particular pavement. This leads the economic condition for overall pavement thickness. On the other hand the subgrade soil is characterized for its strength for the purpose of design of any pavement.

Improvement of soil engineering properties is referred to soil stabilization. There are two primary methods of soil stabilization. One is mechanical method and the other one is chemical or additive methods. Soil is a gathering or store of earth material, determined regularly from the breakdown of rocks or rot of undergrowth that could be uncovered promptly with force supplies in the field or disintegrated by delicate reflex means in the lab. The supporting soil beneath pavement and its exceptional under course is called sub grade soil. Without interruption soil underneath the pavement is called regular sub grade. Compacted sub grade is the soil compacted by inhibited development of distinctive sorts of substantial compactors.

Presently every road construction project will use one or both of these stabilization strategies. The most well-known type of mechanical soil stabilization is compaction of the soil, while the addition of cement, lime, bituminous or alternate executors is alluded to as a synthetic or added substance strategy for stabilization of soil. American Association of State Highway and Transportation Officials (AASHTO) classification system is a soil classification system specially designed for the construction of roads and highways used by transportation engineers. The system uses the grain-size distribution and Atterberg limits, such as Liquid Limits and Plasticity Index to classify the soil properties. There are different types of additives available. Not all additives work for all soil types. Generally, an additive may be used to act as a binder, after the effect of moisture, increase the soil density. Following are some most widely used additives: Portland cement, Quicklime or Hydrated Lime, Fly Ash, Calcium Chloride, Bitumen etc. But, mechanical soil stabilization alludes to either compaction or the introduction of sinewy and other non-biodegradable reinforcement of soil. This practice does not oblige compound change of the soil and it is regular to utilize both mechanical and concoction intends to attain detailed stabilization. There are a few routines used to accomplish mechanical stabilization like compaction, combining, soil reinforcement, expansion of graded aggregate materials and mechanical remediation.

1.2 Overview of the project

The Indian Road Congress encodes the accurate outline methodologies of the pavement layers based upon the subgrade quality. Subgrade quality is generally communicated as far as CBR. That is the California Bearing Ratio communicated in rate. Consequently, in all, the pavement and the subgrade together must sustain the activity volume.

1.3 Objective and scope of work

- The main objective of this experimental study is to improve the properties of the gravely soil by adding bitumen emulsion as stabilizing agent and little bit cement as filler.
- An attempt has been made to use emulsion for improving the strength and geotechnical properties of gravel soil. Very mostly, use of use of bitumen emulsion is environmentally accepted.
- To achieve the whole project some experimental investigation is needed in laboratory. The experiments which to be conducted are Specific Gravity of the soil sample, Grain size Distribution of soil sample and liquid limit plastic limit test to identify the material and Standard Proctor test to obtain maximum dry density and optimum moisture content of soil sample, CBR test of soil sample mixing with emulsion and cement.
- So the main objective is to maximize the CBR value by checking some conditions to increase the CBR value of soil subgrade.
- The entire project work can be divided by following cases

Case A: Normal available tested soil is used for testing

Case B : Normal available soil tested with 3% SS, MS & RS emulsion added

Case C: Normal available soil tested with 3% SS, MS & RS emulsion and 2% cement added

Case D : Normal available soils tested mixing with 3% of SS, MS & RS emulsion and 2% of cement added and wait 5 hour before testing.

II. LITERATURE REVIEW

Bitumen emulsion is used as chemical stabilizer. Cement is used here as a binder only to improve strength of road. Previously lots of work was done on sand bitumen stabilization and gravel soil bitumen stabilization in different places. This study is being inspired from those researches. Here gravel red coloured soil is used, as it is available in many states of India. Some similar works, done before, is discussed below.

Chinkulkijniwat and Man-Koksung (2010)
Ref 1
They directed a test research on compaction aspects of non-gravel and gravelly Soils using a little compaction device. The standard delegate test has been broadly utilized and acknowledged for characterizing soil similarity for field compaction control. Here additionally indicates about the influence of gravel size and gravel content on standard delegate test results. In this study a relationship developed between the summed up optimum water substance of the fine division in the gravelly soil and the gravel content in standard molds using compaction results from the proposed little device.
Razouki et al.
Ref 2
He propose an experimental study on Granular Stabilized Roads. Bitumen was used as a stabilizing agent may act as a binder or as a water-proofing material. Soil-bitumen systems had found the greatest used in road bases and surfaces.
Michael
Ref 3
He had proposed about Bench-Scale Evaluation of Asphalt Emulsion Stabilization of Contaminated Soils. In this study, it was discussed about the application of ambient temperature asphalt emulsion stabilization technology and discussed to the environmental fixation of soils contaminated by organic contaminants.

III. EXPERIMENT PROGRAMME

3. 1 Materials used

1. Bitumen emulsion 2. Soil

3.1.1 Bitumen Emulsion

Emulsified Bitumen usually consists of bitumen droplets suspended in water. Most emulsions are used for surface treatments. Because of low viscosity of the Emulsion as compared to hot applied Bitumen, The Emulsion has a good penetration and spreading capacity. The type of emulsifying agent used in the bituminous emulsion determines whether the emulsion will be anionic or cationic. In case of cationic emulsions there are bituminous droplets which carry a positive charge and Anionic emulsions have negatively charged bituminous droplets.

Based on their setting rate or setting time, which indicates how quickly the water separates from the emulsion or settle down, both anionic and cationic emulsions are further classified into three different types. Those are rapid setting (RS), medium setting (MS), and slow setting (SS). Among them rapid setting emulsion is very risky to work with as there is very little time remains before setting. The setting time of MS emulsion is nearly 6 hours. So, work with medium setting emulsion is very easy and there is sufficient time to place the material in proper place before setting. The setting rate is basically controlled by the type and amount of the emulsifying agent. The principal difference between anionic and cationic emulsions is that the cationic emulsion gives up water faster than the anionic emulsion.

Over a time of time, which may of years, the asphalt stage will in the long run separate from the water. Asphalt is insoluble in water, and breakdown of the emulsion includes the combination of droplets. The asphalt droplets in the emulsion have a little charge. The wellspring of the charge is the emulsifier, and ionisable segments in the asphalt itself. However when two droplets do attain enough vitality to defeat this hindrance and approach nearly then they hold fast to one another. Over a time of time, the water layer between droplets in floccules will thin and the droplets will combine. Components which constrain the droplets together, for example, settlement under gravity, dissipation of the water, shear or solidifying will quicken the flocculation and mixture process. In this case mixing with soil slow setting bitumen emulsion is not so much effective and rapid setting is not easy to work with soil. So here I use medium setting emulsion as main stabilizing agent.

Today the main utilization of bitumen is in the pavement industry for construction and maintenance. Bitumen emulsions are a scattering of bitumen in a watery continuous stage, settled by the expansion of an emulsifier. They are ready as emulsions at high temperatures, however connected as robust scatterings at encompassing temperatures. In pavement engineering bitumen items are commonly added with aggregate. The solid adhesion that happens between the bitumen and mineral aggregate empowers the bitumen to go about as a binder, with the mineral aggregate providing mechanical quality for the way. From the review of present scenario bitumen emulsion acts as a key tool for mainly for road maintenance and construction. But effectively here emulsion is going to use as a soil stabilizing agent.

The bitumen emulsion used in this study is carried from Chennai and it has following properties.

Table 3.1 Physical properties of Bitumen emulsion

Colour	Block
Specific gravity	0.97-1.02
Viscosity	20-300

3.1.2 Soil :

The soil used for this study is a gravel soil which is collected from the local availability.

To find out the physical properties of soil sample collected, the following experiments are carried out.

3.2 Tests conducted on soil

3.2.1 Specific Gravity

The ratio between the mass of any substance of a definite volume divided by mass of equal volume of water is defined as Specific Gravity. For soils, it is the number of times the soil solids are heavier in the assessment to the equal volume of water present. So it is basically the number of times that soil is heavier than water. Specific gravities for different type of soils are not same. In the time of experiment it should be cared about the temperature correction and water should be gas-free distilled water. This specific gravity of soil is denoted by 'G'. Specific gravity is very a very important physical property used to calculate other soil engineering properties like void ratio, density, porosity and saturation condition.

As it is discussed, the ratio between the weight of the soil solids and weight of an equal volume of water is termed as Specific Gravity. The measurement is done in a volumetric flask in an experimental setup where the volume of the soil is found out and its weight is then further divided by the weight of equal volume of water.

$$G = \frac{(M2-M1)}{(M2-M1)-(M3-M4)}$$

Here G= specific gravity

M1 = weight of empty pycnometer

M2 = weight of pycnometer + soil

M3 = weight of pycnometer + soil +water

M4 = weight of pycnometer + water

Specific gravities for different soil are not same generally, the general range for specific gravity of soil can be categorized are:

Table 3.2 Standard Specific Gravity

Type of soil	**Specific gravity**
Sand	2.63 to 2.67
Silt	2.65 to 2.7
Clay and Silty soil	2.67 to 2.9
Organic soil	1+ to 2.6

3.2.4 Compaction Test (Modified Proctor Test)

Proctor Test is essentially for determination of the relationship between the moisture substance and dry density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a stature of 30 cm. It is a research center test system for experimentally deciding the optimum moisture content (OMC) at which a given soil sorts will get most thick and accomplish its maximum dry density (Yd). The name Proctor is given out of appreciation for R. R. Proctor for demonstrating that the dry density of soil for a compactive exertion relies on upon the measure of water the soil holds throughout soil compaction in 1933. His unique test is most generally alluded to as the standard Proctor compaction test, which recently was overhauled to make the new compaction test. That is Modified Proctor Test.

In case of modified proctor all the procedures remain same with only a few little changes. Most importantly here the compaction load is higher. Here rammer size 4.5 kg and that dropped from height of 18 inches. Generally these lab tests are consists of compacting soil at recognized moisture content into a cylindrical mould of standard measurements.

The soil that is normally compacted into the mold to a certain measure of equivalent layers, each one receiving a number blows from a standard weighted sledge at a standard height. This methodology is then rehashed for distinctive qualities of dampness substance and the dry densities are determined for each one case. In this case materials are filled in five equivalent layers with 25 blows in each one layer. The hammer and the mould for modified proctor test are shown below.

Fig 3.1.Modified Proctor test apparatus

The graphical relationship of the dry density to moisture content is then plotted considering the values found to establish the compaction curve. The determined curve comes in parabolic shape and dry density value is increasing up to a maximum limit and after that again the value decreased. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, which is known as the optimal moisture content (OMC). Used formulas are listed below.

Normal wet density = (weight of wet soil in mould gms) / (volume of mould cc)

Moisture content (%) = ((weight of water gms) / (weight of dry soil gms)) 100 %

$$\text{Dry density } \gamma_d \text{ (gm/cc)} = \frac{\text{wet density}}{1+\frac{\text{moisture content}}{100}}$$

3.2.5 California Bearing Ratio Test

CBR is the proportion of force for every unit region needed to enter a soil mass with standard load at the rate of 1.25 mm/min to that needed for the ensuing penetration of a standard material. The accompanying table gives the standard loads utilized for diverse penetrations for the standard material with a CBR quality of 100%.This standard load is taking limestone as a standard material and its CBR value at 2.5 mm, 5 mm, 7.5mm & 10 mm penetration are fixed as standard load for CBR value determination.

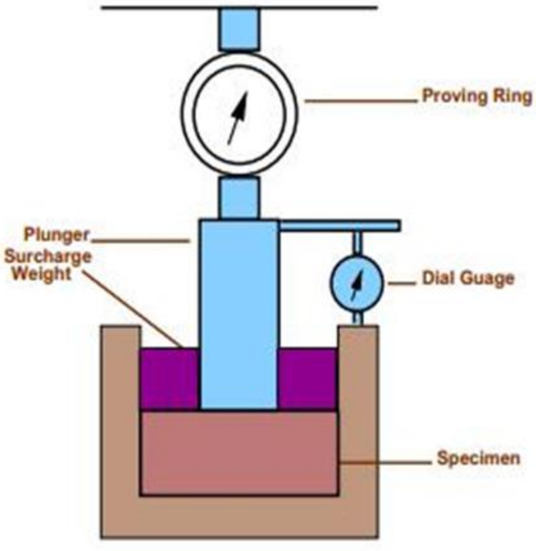

Fig. 3.2. California Bearing Ratio Testing Machine

CBR value is calculated by this formula:

C.B.R. = (Test load /Standard load) 100 %

Standard load is for particular depth of penetration of plunger is given bellow.

Table 3.3: Standard load in different penetration

Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5	2055
7.5	2630
10	3180

IV. RESULTS AND DISCUSSION

4.1 SPECIFIC GRAVITY TEST

Specific gravity of soil is very important property to understand the soil condition. As previously discussed here

M1 = weight of empty pycnometer
M2 = weight of pycnometer + soil
M3 = weight of pycnometer + soil +water
M4 = weight of pycnometer + water

Table 4.1 Specific gravity test result

Sample No	M1 (gm)	M2 (gm)	M3 (gm)	M4 (gm)	Sp. Gravity
1.	114.67	164.67	383.56	351.87	2.73
2.	113.76	163.76	384.41	352.86	2.71
3.	115.34	165.34	385.69	353.94	2.74

Results: Here soil material is tested three times. And the average specific gravity value comes 2.726. But here no temperature correction is done. This test have been done in room temperature nearly 25*C.

4.2 Particle size distribution (Dry sieve analysis)

Various physical and engineering properties with the help of which soil can be properly identified are called index properties. Soil grain property depends to individual solid grain and remains unaffected by the state in which a particular soil exists in nature. Here 2000 gm of sample soil was taken and dried in oven for 12 hours. Mostly used test for grain size distribution analysis is sieve analysis. Eleven sieves were used. And the results from sieve analysis of the soil are plotted on a semi-log graph with particle diameter or the sieve size in X axis and percentage finer in Y axis.

Table 4.2 Particle size distribution

Sieve No.	Sieve size	Mass of soil retained in each sieve (gm)	Percent retained (%)	Cumulative retained (%)	Percent finer (%)
1.	4.75 mm	0	11.7	11.7	88.3
2.	2 mm	99.1	31.3	43	57
3.	1.18 mm	318.8	14.6	57.6	42.4
4.	1 mm	397.5	4.3	61.9	38.1
5.	600 micron	510.2	12.9	74.8	25.1
6.	300 micron	255.1	18.6	93.4	6.6
7.	150 micron	166.2	3.7	97.1	2.9
8.	75 micron	132.1	2.1	99.2	0.8
9.	Pan	0.008	0.8	100	0

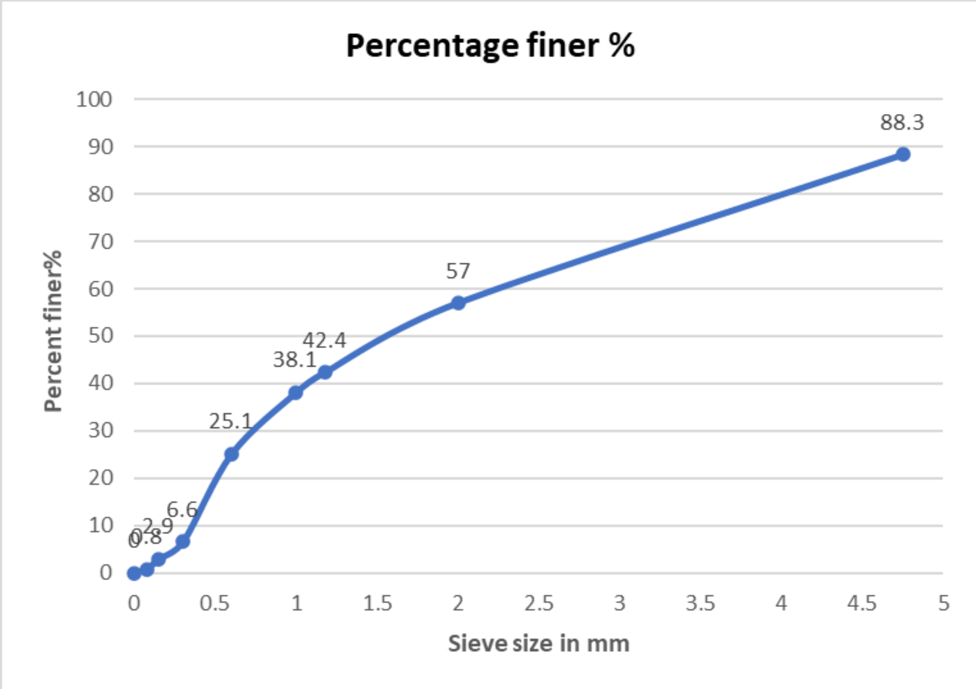

Figure 4.2 Particle size distribution curve

4.3 Liquid limit Test

Soil sample taken = 300gms

The soil sample is sieved through 425µ sieve.

Table 4.3 Liquid limit test results

S.No	Observations	8%	10%	12%	14%	16%
1.	No.of blows	55	50	40	25	22
2.	Container No	1	2	3	4	5
3.	Wt.of container + wetsoil (gms)	88.5	92.55	91.8	101.17	105.6
4.	Wt.of the container + dry soil (gms)	81	84	82	87	90
5.	Wt.of water(gms) (3-4)	7.5	8.55	9.8	14.17	15.6
6.	Wt. of empty container (gms)	46	46	46	45	45
7.	Wt. of oven dry soil(gms) (4-6)	35	38	36	42	45
8.	Water content (%) (5/7)	21.42	22.5	27.2	33.75	34.8

Results: From the graph, The water content for 25 no of blows =33.75%
There fore Liquid limit of soil sample is **33.75%**

4.4 Plastic limit Test

Soil sample taken = 120gms

The soil sample is sieved through 425µ sieve.

S.No	Observations		
1.	Container No	1	2
2.	Wt. of the container + wet soil (gms)	80	85.5
3.	Wt. of the container + dry soil (gms)	74	78.5
4.	Wt. of water(gms) (3-4)	6	7
5.	Wt. of empty container (gms)	47	45
6.	Wt. of oven dry soil(gms) (4-6)	27	33.5
8.	Water content (%) (5/7)	22.22	20.4

Table 4.4 Plastic limit test results

The plastic limit of soil = $\frac{22.22+20.4}{2}$ = **21.56 %**

Plasticity Index (I_P) = LL –PL = 33.75 – 21.56 = **12.19 %**

4.5 Compaction Test

Very commonly used modified proctor test has been executed for 3000 gm soil sample taken for each trial. Modified proctor test was followed according to IS standard. From this test, maximum dry density of the specimen was found to be 2.026gm./cc and OMC of 10.52%.

Case A: Normal available tested soil is used for testing
Case B : Normal available soil tested with 3% SS, MS & RS emulsion added
Case C: Normal available soil tested with 3% SS, MS & RS emulsion and 2% cement added
Case D : Normal available soils tested mixing with 3% of SS, MS & RS emulsion and 2% of cement added and wait 5 hour before testing.

Case (A) : Normal available tested soil is used for testing

Weight of soil taken =5 kg
Passing through 4.75mm IS sieve

Table 4.5 Proctor compaction test results for **Case A**

Trail no.	Wt. of compacted soil (kg)	Optimum Moisture content (OMC) %	Dry density(γd) gm/cm3
1	1725.58	8.33	1.590
2	1805.35	9.25	1.650
3	1915.1	11.62	1.720
4	2044.77	12.88	1.820
5	1845.28	13.62	1.620
6	1635.81	14.50	1.430

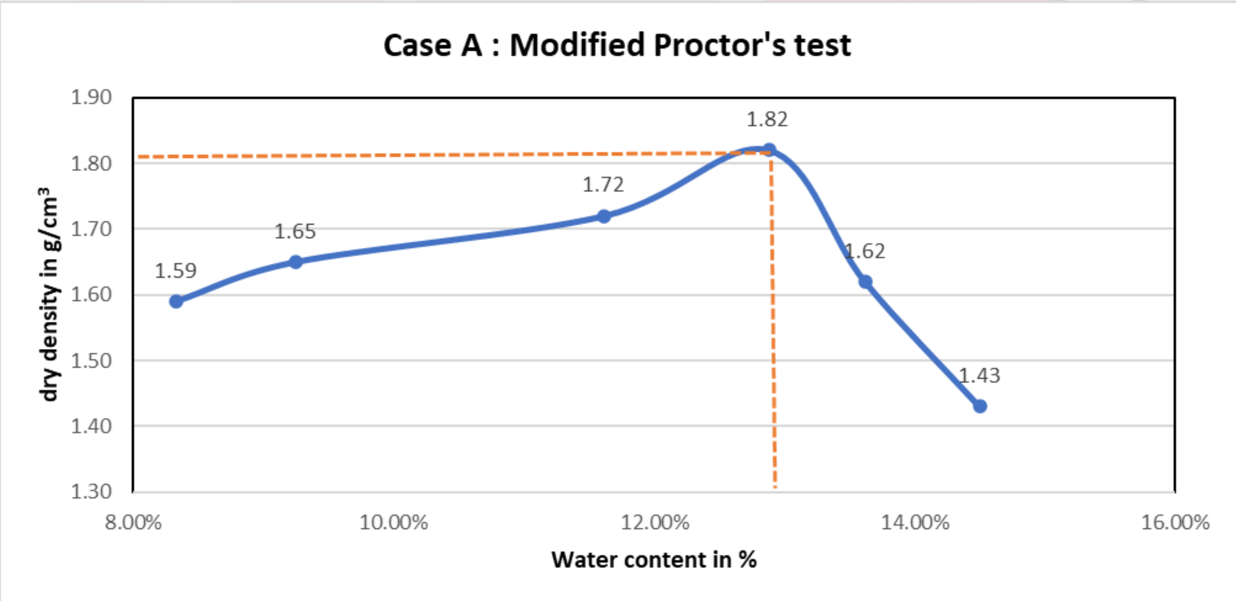

Figure 4.5 Proctor compaction test results for **Case A**

Result : Maximum dry density (MDD)=1.82 g/CC

Optimum moisture content (OMC) =12.8%

Results and Discussions about Case A, Case B, Case C, Case D:

From the previous modified proctor results it is strictly showing how the dry density value for the same material is going to increase from case A to case D, which is the change of maximum dry density value from 2.026 gm/cc up to 2.2 gm/cc. Little bit of fluctuation in optimum moisture content value in different cases. This dry density value is a very important physical property in case of stability of subgrade soil. Bellow the variation of maximum dry density in those special cases are shown bar wise.

It is clearly noticed from the above results, the MS emulsion added to soil will give maximum dry density in all the cases when compared to SS and RS emulsions of bitumen. The variation of dry density for MS emulsion added is shown in following figure.

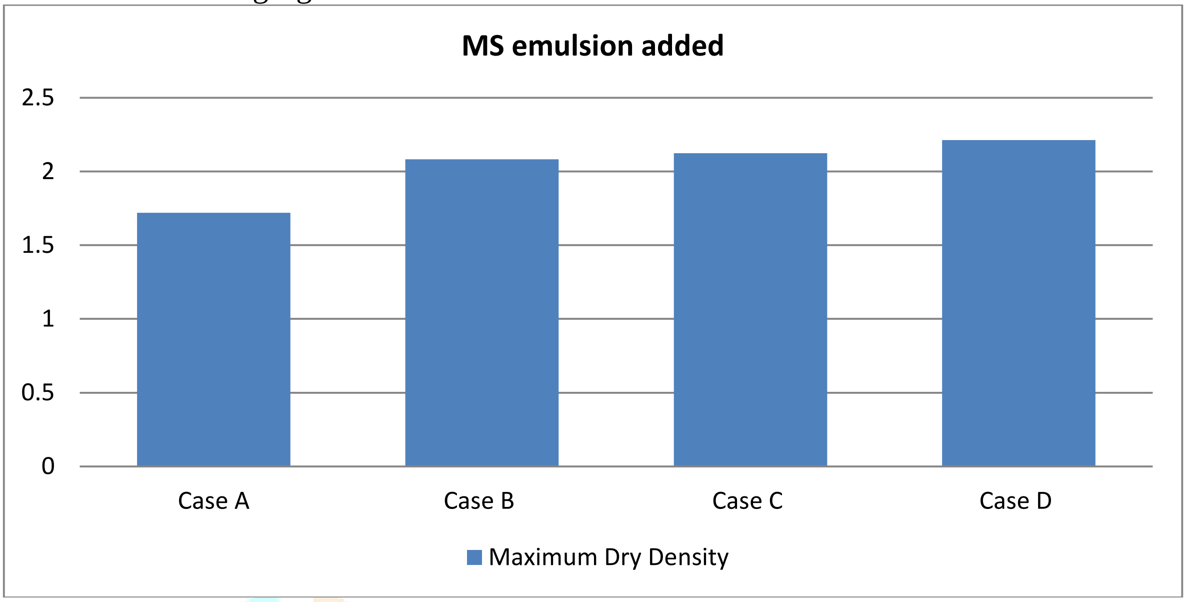

Figure 4.8.4 Variation of MDD for MS emulsion added

This result gives us a clear idea about used 3% bitumen content added to soil will give optimum results following mixing procedure D .

4.9 CBR TEST :

The CBR is the measure of resistance of a material to penetration of a standard plunger under controlled density and moisture conditions. This is an extremely normal test to comprehend the subgrade strength before construction of roadways. The test has been broadly researched for the field connection of flexible pavement thickness necessity. Fundamentally testing is carried out taking after IS: 2720 (Part 16). The test comprises of bringing on a round and cylindrical plunger of 50mm diameter to penetrate a pavement part material at 1.25mm/minute. The loads, for 0.5mm, 1mm, 1.5mm, 2mm, 2.5mm….., 5mm, 5.5mm, 6mm….., up to 12mm to 13 mm are recorded in every 0.5mm of gaping. Penetration in mm are plotted in X axis and load expressed in kg with corresponding points are plotted in Y axis and prepare graph for different specimen.

Case (A)

Normal available tested soil is used for testing

Volume of Mould used 2250cc
Maximum dry density from Proctor's test = 1.72 g/cc
Optimum moisture content = 11.62%

Table 4.9 CBR test results for **Case A**

S.No	Penetration dial gauge reading	Penetration (mm)	Proving ring dial gauge reading	
			Dial guage reading	Load (Kg)
1	0	0	0.00	0.00
2	50	0.5	1.21	33.00
3	100	1.0	2.12	57.81
4	150	1.5	2.15	85.09
5	200	2.0	3.15	114.00
6	250	2.5	4.18	140.18
7	300	3.0	7.44	203.72
8	350	3.5	10.23	279.90
9	400	4.0	12.87	351.00
10	450	4.5	17.54	478.36
11	500	5.0	21.70	591.87
12	600	6.0	26.14	712.91

13	700	7.0	28.45	755.91
14	1000	10.0	35.14	958.37
15	1250	12.5	47.58	1279.64

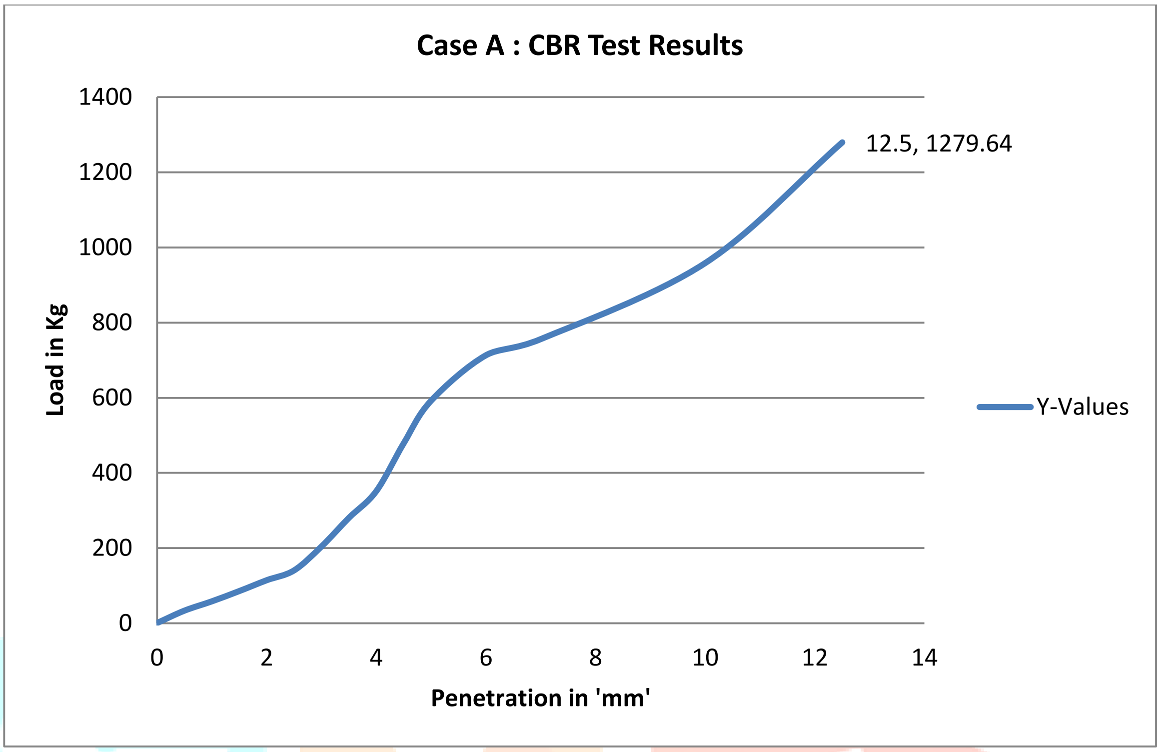

Figure 4.9 CBR test results for **Case A**

Result:

CBR for 2.5mm penetration =**12.4%**   CBR for 5mm penetration=**10.7%**

Result and Discussions about Case A, Case B, Case C and Case D:

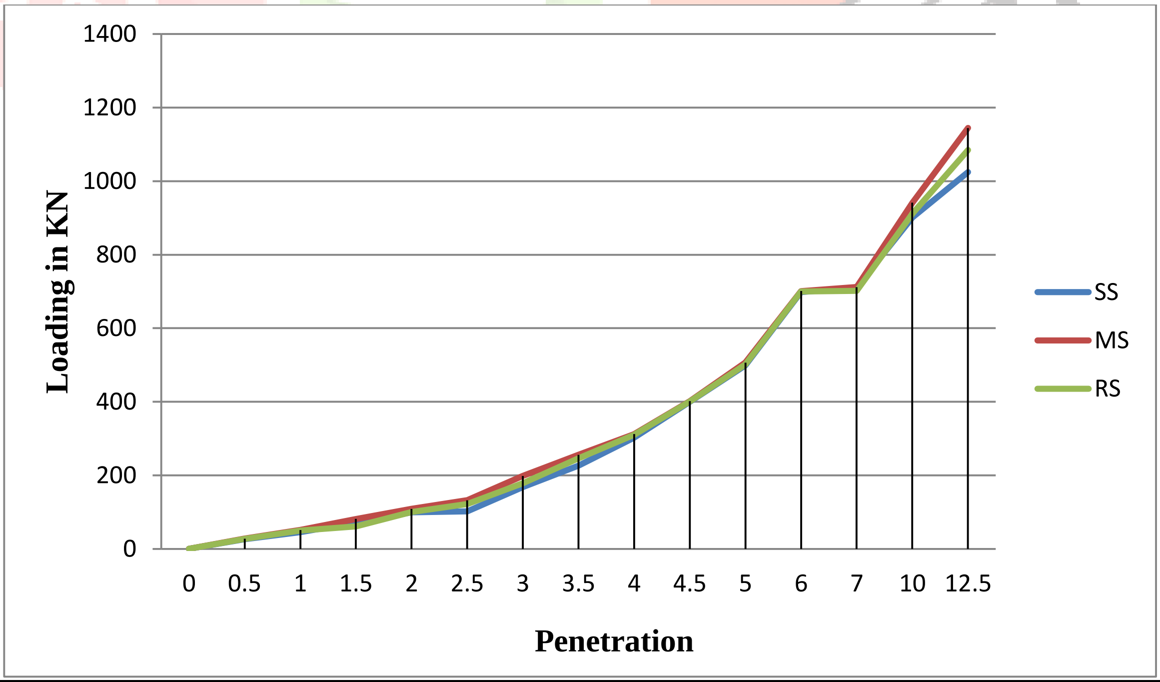

Figure 4.12(iv) Variation of CBR test results for CASE (D) for SS, MS and RS

From the above CBR test results it is strictly showing that the CBR value going to increase from case A to case D for MS emulsion added to soil when compared to SS and RS bitumen emulsions.
The variation of CBR values for MS emulsion added is shown in following figure.

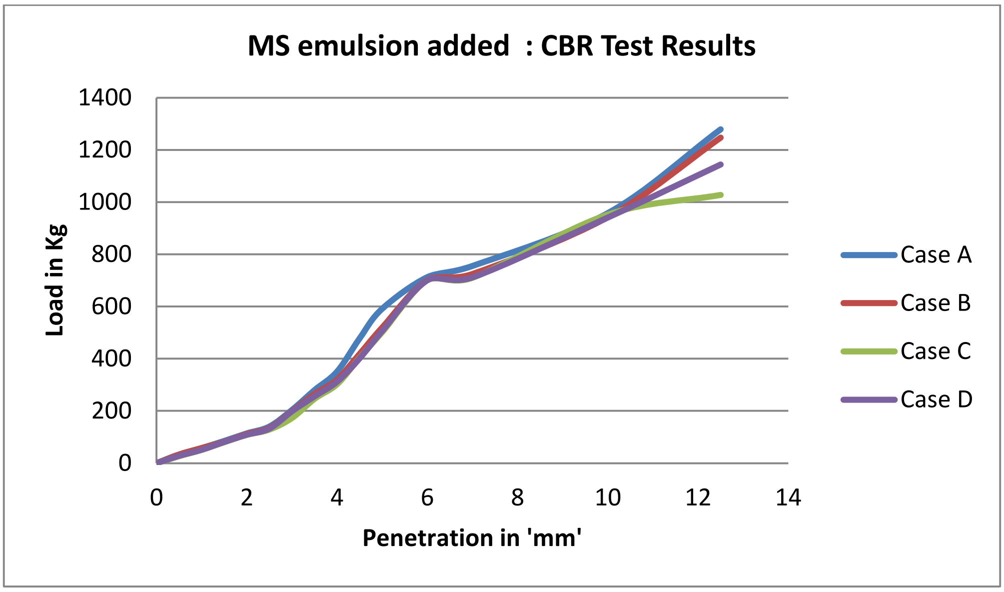

Figure 4.13 (a) Variation of CBR test results for MS emulsion added

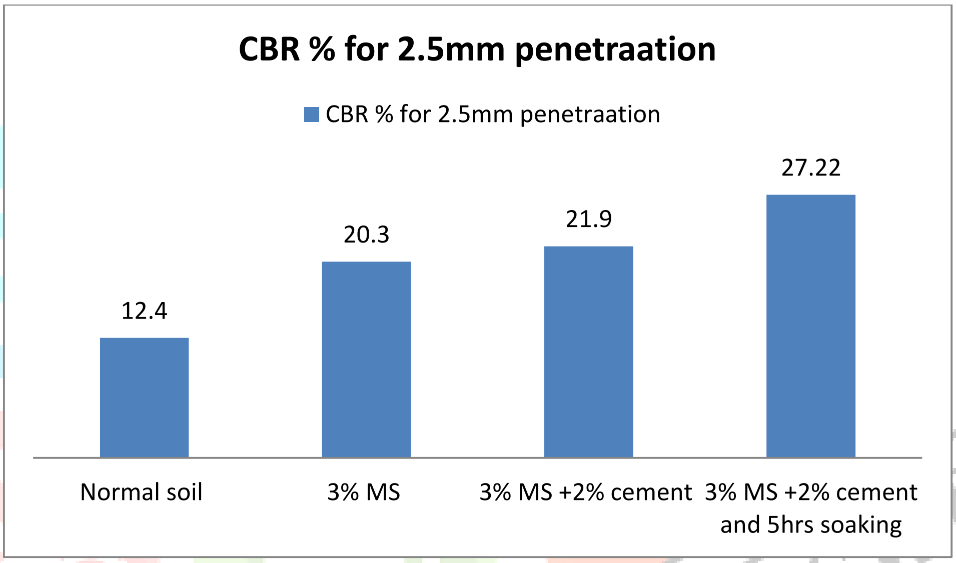

Figure 4.13 (b) Variation of CBR value for 5mm penetration results for **MS emulsion** added to soil from **Case A to Case D**

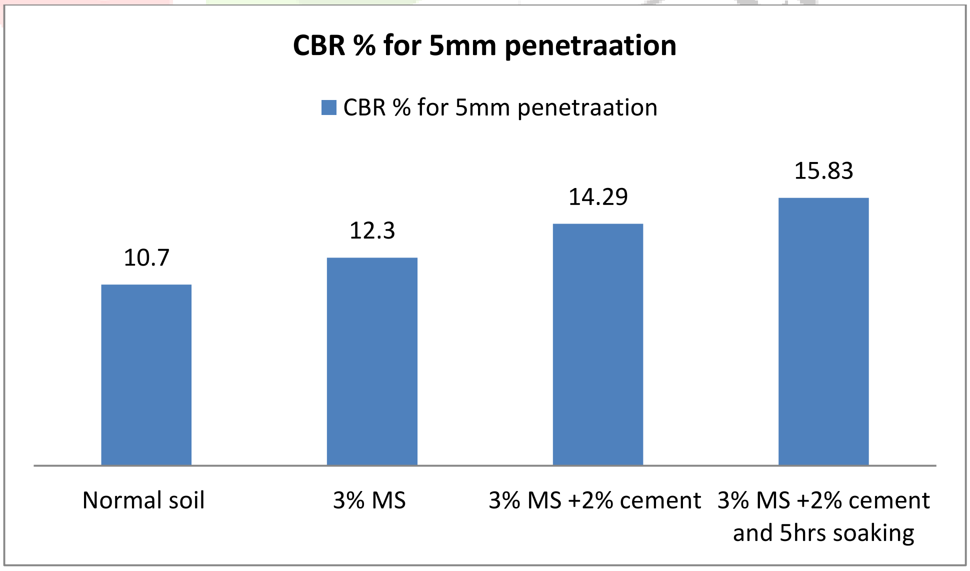

Figure 4.13 (c) Variation of CBR value for 2.5mm penetration results for **MS emulsion** added to soil from **Case A to Case D**

This result gives us a clear idea about used 3% MS emulsion bitumen content added to soil will give optimum results following mixing procedure D.

V. CONCLUSION

- Standard Procter test results achieved after mixing Normal soil with 3% of MS emulsion, the dry density is 2.1 g/cc which is 4% higher than other two samples (SS and RS)
- Standard Procter test results achieved after mixing Normal soil with 3% of MS emulsion and 2% of cement, the dry density is 2.15 g/cc which is 4.8% higher than other two samples (SS and RS)
- Standard Procter test results achieved after mixing Normal soil with 3% of MS emulsion and 2% of cement and awaited for 5 hours, the dry density is 2.15 g/cc which is 2% higher than other two samples (SS and RS)
- CBR test results achieved after mixing Normal soil with 3% of MS emulsion, the CBR achieved is 20.3% which is 7.4% higher than the other two samples (SS and RS).
- CBR test results achieved after mixing 3% of MS emulsion and 2% of cement, the CBR achieved is 21.9% which is 7% higher than the other two samples (SS and RS).
- CBR test results achieved after mixing 3% of MS emulsion and 2% of cement and awaited for 5 Hours, the CBR achieved is 27.22% which is 24% higher than the other two samples (SS and RS).
- From this study it is clear that there is a considerable improvement in California Bearing Ratio (CBR) of sub-grade due to use of MS bitumen emulsion if proper mixing is done.
- It is seen that best results are obtained if the soil emulsion mix is left for about five hours after mixing.
- In each state of condition it was found that CBR value has increased consecutively from Case A to Case D.
- In this particular experimental study CBR value has increased up to fifty percent of the unmodified soil CBR.
- Based on above experimentation and results for the given for the soil stabilization is more effective when 3% of MS emulsion and 2% cement is added to the soil and waited 5 hours.

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