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A LABORATORY STUDY ON THE USE OF BITUMEN EMULSION IN SUB-GRADE SOILS USING WASTE PRODUCTS AS FILLERS

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Abstract - Soil is one of the most abundant construction materials of the nature used from the base of the structure. Almost all type of construction is built with or upon the soil. The most important part of a road pavement is subgrade soil and its strength. If the sub grade is not enough good the whole structure will face failure such as cracks, then stabilization is normally needed. Sub grade is sometimes replaced with stronger soil material or stabilized so as to improve the strength. Increase in sub grade strength may lead to economy in the structural thicknesses of a pavement. Cement, fly ash, lime, fibers etc. are very commonly used for soil stabilization. The main objective of this experimental study is to improve the properties of the soil by adding bitumen emulsion. In this study, the whole laboratory work revolves around the basic properties of soil and its strength in terms of CBR. Besides the bitumen emulsion, stone dust and brick dust are a kind of solid waste materials that are generated from stone crushing industry and brick kilns respectively which are abundantly available. It is estimated that each crusher unit produce 15%-20% stone dust. Disposal of such wastes poses lots of geo-environmental problems such as landfill disposal problems, health and environmental hazards. The best way to eliminate these problems is to make use of such waste products. Keeping this in view a little crushed stone dust and brick kiln dust are added to provide better soil strength. It is observed that excellent soil strength results by using cationic bitumen emulsion (CMS) with little quantity of the above two waste products used as fillers. The appropriate mixing conditions for the soil with CMS Bitumen emulsion have been first attempted.

Keywords: Sub grade, CBR, Bitumen

Stabilization, bitumen emulsion, Crushed stone dust, Brick kiln dust.

I. INTRODUCTION

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 behaviour 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. Therefore the main thing related to soil stabilization is nothing but the process of maximizing the CBR strength of soil for a given construction purpose. 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. In Kashmir valley and also in many states in north India the karewa soils are available in abundance and almost all roads and railways are constructed with karewa soils. The transportation costs of such soils are very high. To keep this in mind an experimental study was conducted in the laboratory to see the effect of bitumen emulsion on the karewa soils using the crushed stone dust and brick kiln dust as fillers. In this project locally available karewa (wudder) soil-sample from the IUST Kashmir campus is taken as experimenting material. Medium setting emulsion (MS) is used as stabilizing agent in this particular study. There is no any particularly following process or method for soil bitumen stabilization and most importantly there is no any code for bitumen soil stabilization in Indian Standard.

The main objective of this experimental study is to improve the properties of the soil by adding bitumen emulsion as stabilizing agent. An attempt has been made to use emulsion for improving the strength and geotechnical properties of soil. Very mostly, 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, Classification of soil, Grain size Distribution of soil sample, liquid limit and plastic limit tests 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 later with stone dust and brick dust. So the main objective is to maximize the CBR value by checking some conditions to increase the CBR value of the sub grade soil.

II. LITERATURE REVIEW

Bitumen emulsion is used as chemical stabilizer. Brick dust and stone dust are used here as a fillers. 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 karewa soil is used, as it is available in abundance in the Kashmir valley and also in many states in India. Some similar works, done before, are discussed below.

Razouki et al. (2002) proposed 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 use in road bases and surfaces.

Paul et al. (2011) suggested an introduction to soil stabilization in pavement taking a mixture of bitumen and well-graded gravel or crushed aggregate. After compaction it gave an exceedingly steady waterproof mass of sub base or base course quality. The fundamental system involved in asphalt stabilization of fine-grained soils is a waterproofing wonder. Soil particles or soil agglomerates were covered with asphalt that forestalls or abates the entrance of water which could regularly bring about abatement in soil quality.

Marandi and Safapour (2012) worked on Base Course Modification through Stabilization using cement and bitumen. The main objective of this research was to analyze the use of bitumen emulsion in base course stabilization. So that it was examined as replacement with conventional pavement in regions with low quality materials.

Yuehuan et al. (2010) worked on foamed bitumen stabilization for Western Australian pavements. Currently, the popularity of soil cement stabilization had been challenged by a new innovative soil improvement technique, known as foamed bitumen stabilization. Very few of work have been done on it and application of this type of stabilization is currently applied in flexible pavement sub grade stabilization. He found in his experimental study that optimum percentage of bitumen content utilized is 3 to 5percent.

III. EXPERIMENTAL STUDY FLOW CHART

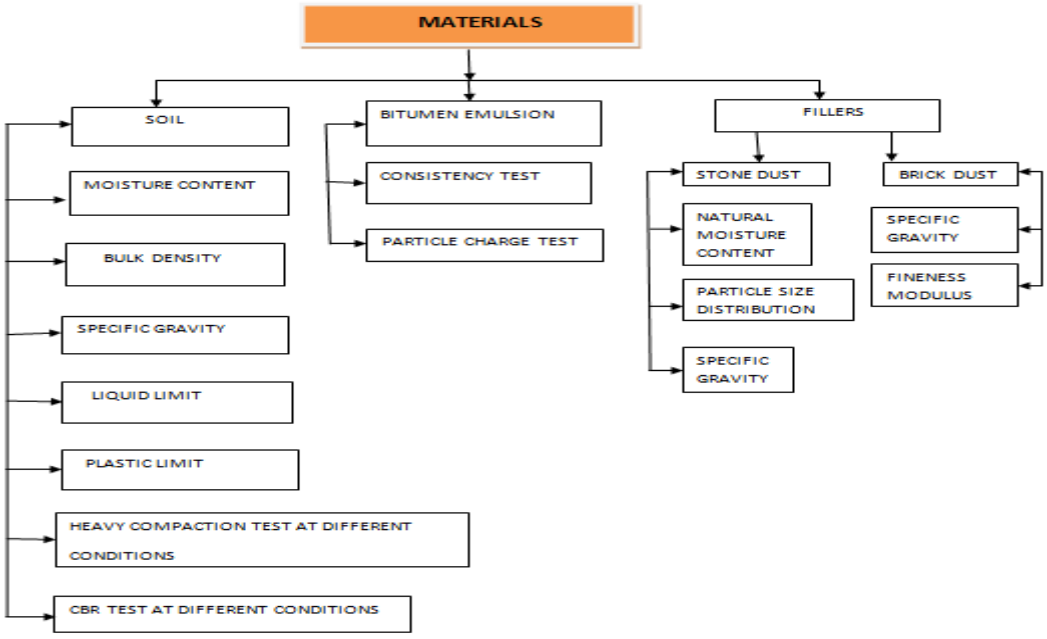


Fig.1: Methodology Flow Chart

IV. MATERIALS USED

Soil: The soil for this study was procured from the campus of Islamic university of science & Technology, Awantipora, J&K. The material was extracted from 50cm below the ground surface. Index properties of the soil were determined as per IS codes.

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 remains very little time 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. In this case mixing the soil with slow setting bitumen emulsion is not so much effective and rapid setting is not easy to work with soil. So here we use cationic medium setting emulsion as main stabilizing agent. In cationic emulsion the emulsifier used is a long chain amine. The bitumen globules are positively charged due to NH3+ group cover which is formed around bitumen droplets and provide stability for emulsion by electrostatic repulsion .The term cationic is derived from the migration of particles of bitumen under an electric field towards the cathode (negative electrode), and hence the emulsion is called cationic .

Crushed stone dust: Stone dust is a multipurpose material for yard construction and also named as fine aggregate or crushed stone. Stone dust is a kind of solid waste material that is generated from stone crushing industry which is abundantly available. It is estimated that each crusher unit produce 15% - 20% stone dust. Disposal of such wastes poses lots of geo environmental problems such as landfill disposal problems, health and environmental hazards. The best way to eliminate these problems is to make use such waste. Keeping this in view an experimental study was conducted on locally available karewa soil by using the stone dust as filler.

Brick kiln dust: In India, brick kiln industries are the third largest industry where the coal is used to baking the clay brick. As per population are increasing the growth of brick kilns is increasing to fulfill the demand of the clay bricks. But result has some losses in the form of environmental pollution and residue of brick kiln called brick kiln dust. Large amount of waste is obtained like brick dust, broken pieces and flakes of bricks (brick bat). These wastes are utilized for the low laying areas or dumped as the waste. So there is a need to utilize this waste product.

V. EXPERIMENTAL RESULTS

Bitumen emulsion:

The details of the cationic bitumen emulsion used in this study are given below in table 1;

Table1: Details of Cationic bitumen emulsion

Name of the company	Veekay Industries Bari Brahamana Jammu
Type	MS
Application	Maintenance
Water Content	39%

Bitumen emulsions are subjected to their own test procedures some of the tests used for determining their properties are as follows:

Consistency test:

Also known as the Engler viscosity test, this test measures the rate of flow of the bitumen emulsion at 25 degree Celsius. The emulsion is heated to 25 degree Celsius and poured into a standard container. The time taken by 200 ml of emulsion to pass through a standard orifice at the bottom of the container is measured. From the ASTM charts the viscosity corresponding to the time value is obtained.

Particle charge test:

It identifies the charge on the bitumen particles in an emulsion. A positive and the negative electrodes are left in a sample of emulsion for half an hour. If there is bitumen deposited on the negatively electrode at the end of the test, the emulsion is cationic. If bitumen is deposited on the positive electrode, the emulsion is anionic. The bitumen emulsion used in this study is cationic.

Table 2: Properties of bitumen emulsion

Property	Value
Residue after evaporation	61 %
Water content	39 %
Particle charge	Positive (+ve)
Viscosity	30 pascal second @ 25 degree Celsius
Emulsion	NH3+

Fig.2: Bitumen emulsion sample

Crushed Stone dust: Stone dust for this study was taken from Tengpuna, Pulwama J&K. Index properties of the stone dust were determined as per IS codes and are presented in Table-3.The stone dust is classified as **SP.**

Table 3: Index properties of stone dust

Property	Value
Natural moisture content (%)	8.85
Particle size distribution Silt (%) Sand (%)	 95.8 4.2
Specific gravity	2.79

Brick Kiln Dust (BKD)

In this experimental study brick kiln dust was collected from brick kiln at Dialgam, Anantnag J&K. Then the physical properties of BKD are obtained through experiments in the lab. Experimental results have been shown below:

Table 4: Index properties of BKD

S. No.	Lab. Experiments	Result
1	Fines Modulus	3.92
2	Specific Gravity	2.52

Soil Tests:

Moisture content

Moisture content or water content is the quantity of water contained in a soil mass. Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio which can range from 0 (completely dry) to the value of the materials porosity at saturation.

The moisture content of the soil sample as measured by oven drying method was **19 %.**

Bulk density test

Bulk density is defined as the mass of particles of the material divided by total volume they occupy. The total volume includes particle volume, inter particle void volume, and internal pore volume. Bulk density is not an intrinsic property of a material, it can change depending on how the material is handled.

The bulk density as measured by the core cutter was **1.818 g/cc.**

Specific gravity test

Specific gravity of soil is very important property to understand the soil condition. The ratio between the weight of the soil solids and weight of an equal volume of water is termed as Specific Gravity. Specific gravity is determined by using pycnometer method as per IS: 2720 (Part III)-1980. Here M1 is empty bottle weight, M2 is mass of bottle and dry soil, M3 is weight of bottle, dry soil and water and M4 is weight of bottle with water.

Table 5: Specific gravity test result

Sample No.	M1(gm)	M2(gm)	M3(gm)	M4(gm)	Sp. Gravity
1	38	54	102	92	2.66
2	35	56	98	85	2.625
3	32	56	101	86	2.66

Here soil sample is tested three times and the average specific gravity value comes **2.648.** But here no temperature correction is done. This test has been done in room temperature nearly 25 degree Celsius.

Liquid limit and Plastic limit Test The soil used in this study was course grained soil obtained from IUST Awantipora, J&K campus. The soil was tested for specific gravity, liquid limit, plastic limit and grain size distribution as to be well known about physical properties of this particular soil material. From these experimental results a proper idea about the type of soil has been found.

Table 6: Index properties of soil

Property	Value
Liquid limit	28.91
Plastic limit	21.67
Plasticity index	7.24

Grain size distribution (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 soil sample was taken and dried in oven for 24 hours. Mostly used test for grain size distribution analysis is sieve analysis. Twelve 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.

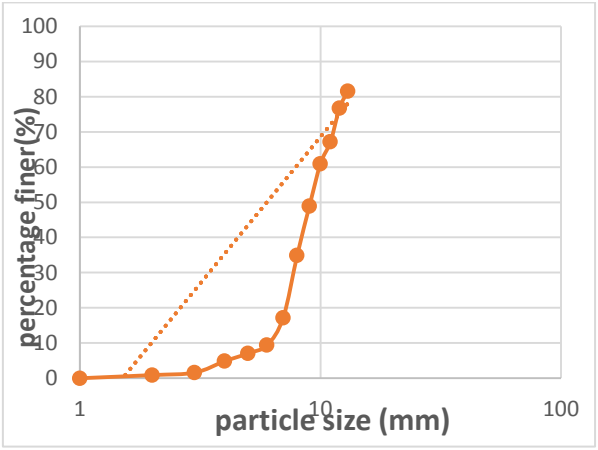


Fig. 3: Grain size distribution graph

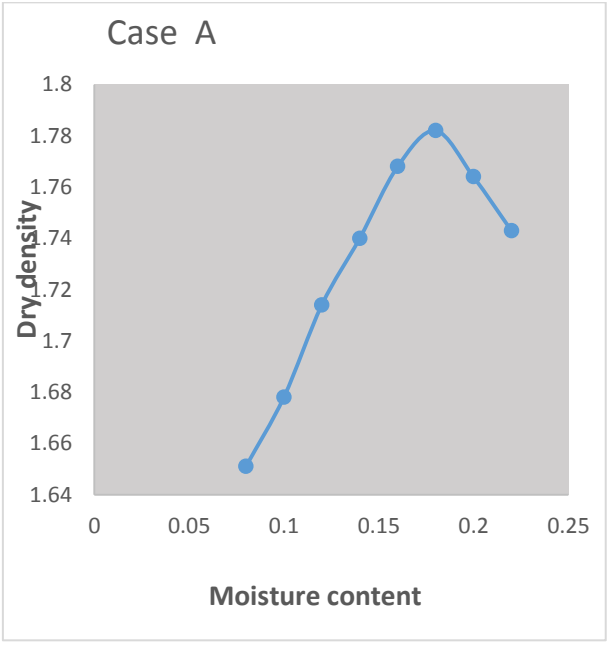
Compaction Test Very commonly used modified proctor test has been executed for 3000 gm soil sample taken for each trial. Modified proctor test was followed according to IS: 2720 (Part VII)-1980. From this test, maximum dry density and optimum moisture content was found. As previously mentioned very few works had done on bitumen soil stabilization. Only bitumen sand stabilization IS code is available. So, how to mix the soil with emulsion is the main problem. Therefore four particular conditions for testing are used here to check the variation of maximum dry density of this soil mixing with emulsion.

Case A: Normal available tested soil is used for testing

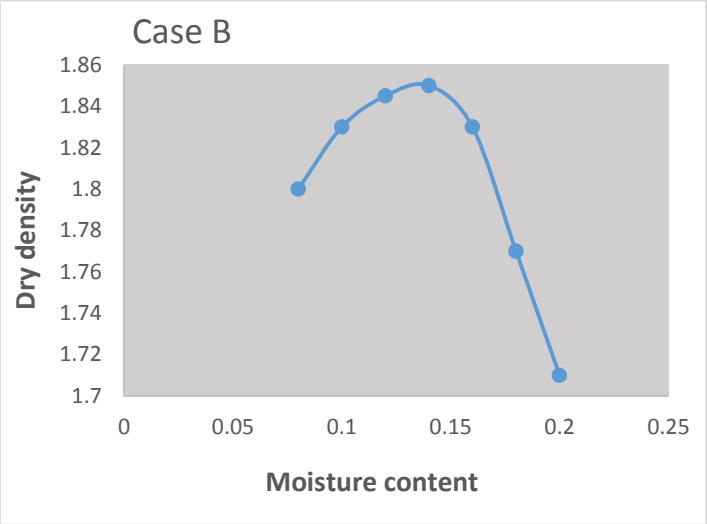
Case B: Normal available soil tested with 3% MS emulsion added

Case C: Normal available soil tested with 3% MS emulsion and 5% stone dust added.

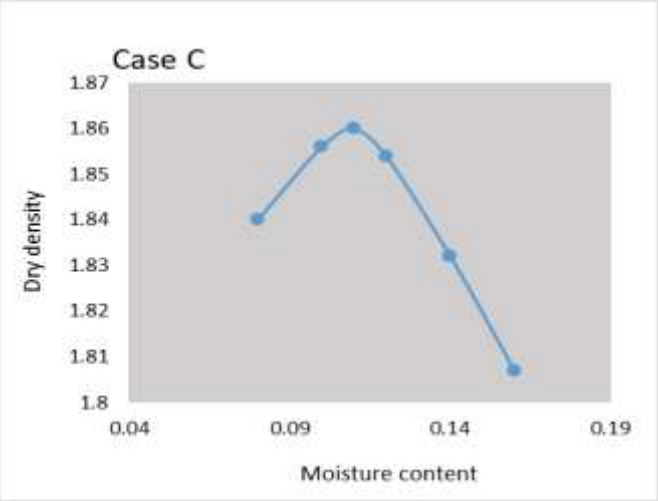
Case D: Normal available soil tested with 3% MS emulsion and5% brick dust added.



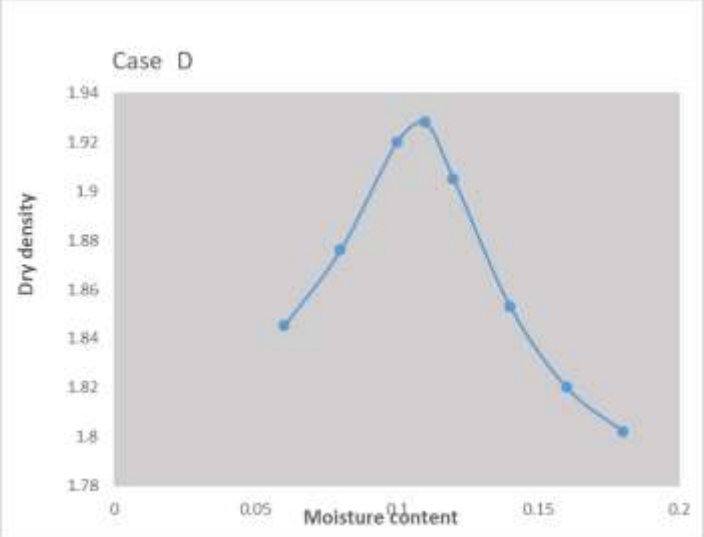
OMC= 18% and MDD=1.782 g/cc



OMC=14% and MDD= 1.85g/cc



OMC=11% and MDD =1.86 g/cc



OMC=11% and MDD =1.928 g/cc

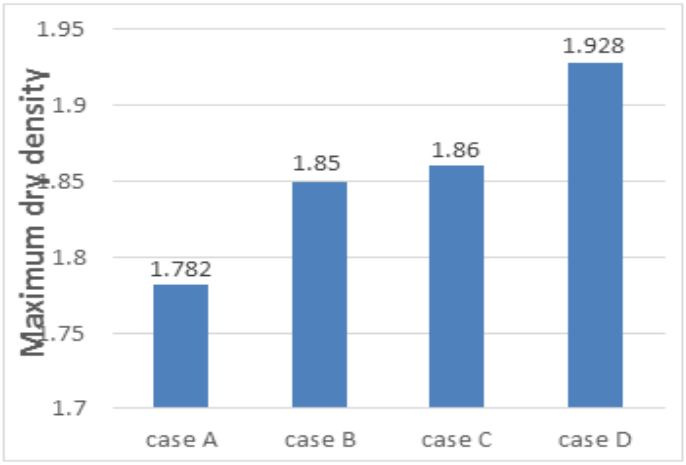


Fig.4: Modified proctor test graphs

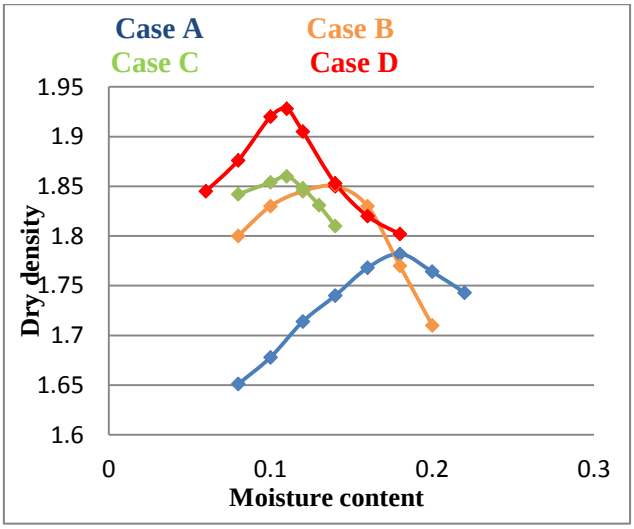


Fig.5: Modified proctor test comparison graph

The above modified proctor results shows that how the dry density value of the same material is going to increase from case A to case D, which is the change of maximum dry density value from 1.782 gm/cc to 1.928 gm/cc. Also some fluctuation in optimum moisture content value in different cases. This Yd value is a very important physical property in case of stability of subgrade soil. The variations of maximum dry density in those special cases are shown bar wise below.

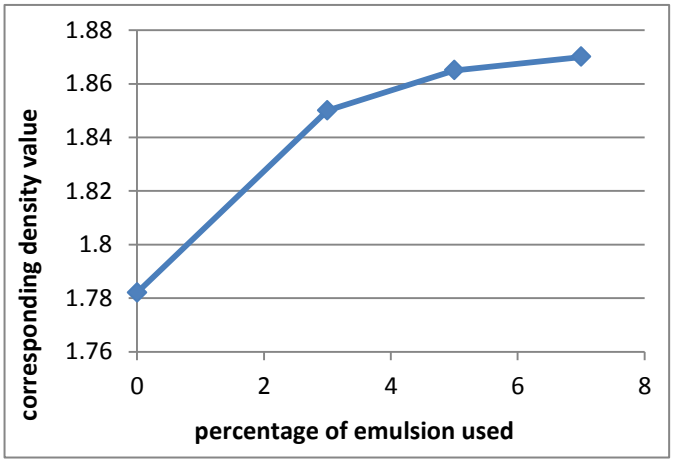


Fig.6: Variation of MDD value

Now the question arises how this maximum dry density is depending upon mixing bitumen quantity and whether 3% is the optimum point or not. So again modified proctor test is done varying the bitumen content 1%, 3%, 5% and 7% following mixing procedure. This result gives us a clear idea about optimum bitumen content.

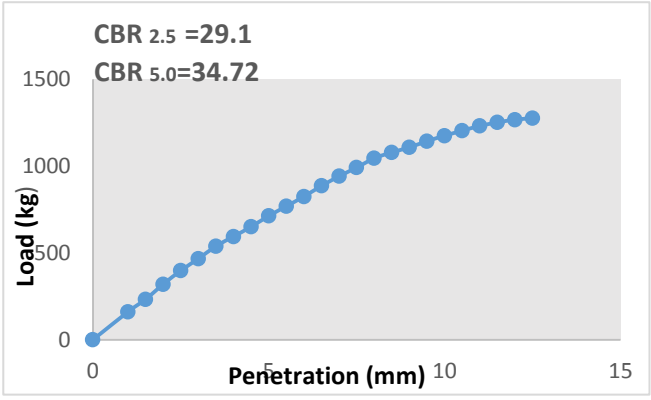


Fig.7: Variation of MDD with emulsion quantity

From the above graph it is clear that the density increases abruptly upto 3 % emulsion as the slope is steep, with further increase in emulsion quantity the density increases but the increase is small as the slope gets decreased continuously. So as earlier said by Yuehuan et. All the optimum bitumen quantity (3% to 5%) is experimentally studied in lab.

Hence 3 % emulsion is taken as optimum in this particular study.

CBR Test

The California bearing ratio (CBR) is a 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).

Here testing is done on two different testing conditions on previously four cases. So total eight number of CBR values are measured by moulding eight different specimens, two different type of specimen for each case. The corresponding CBR value for each type of specimen is written on left above corner of each graph. In this comparative experimental study it is shown that how bitumen emulsion content and the fillers effect CBR value of a particular soil. CBR value and the CBR graph is case wise shown below.

Case A- normal available tested soil is used. Used proctor test result of case A.

Maximum dry density 1.782gm/cc

Optimum moisture content 18%.

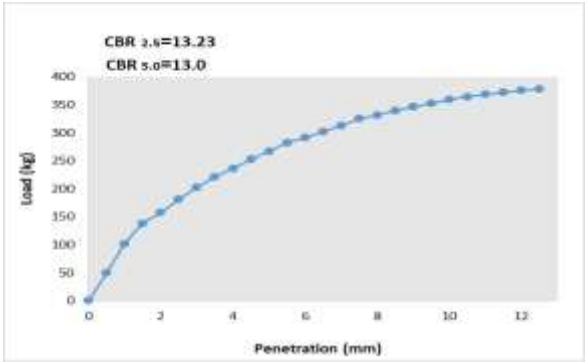


Fig.8: CBR Test Result, Case A (Un-soaked)

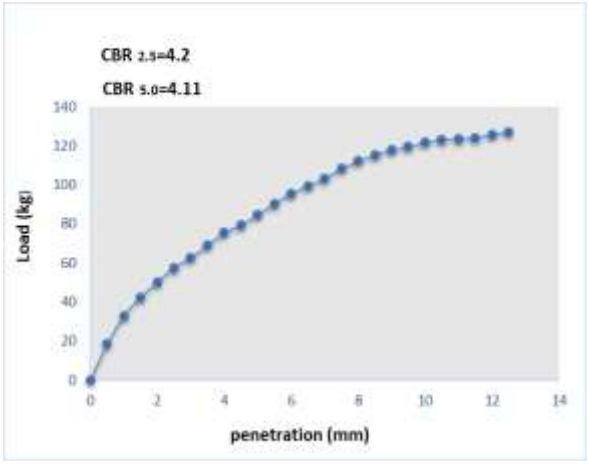


Fig.9: CBR Test Result, Case A (4 days of soaking)

Case B- normal available soil tested with 3% MS emulsion added.

Used proctor test result of case B.

Maximum dry density value 1.85gm/cc. Optimum moisture content 14%

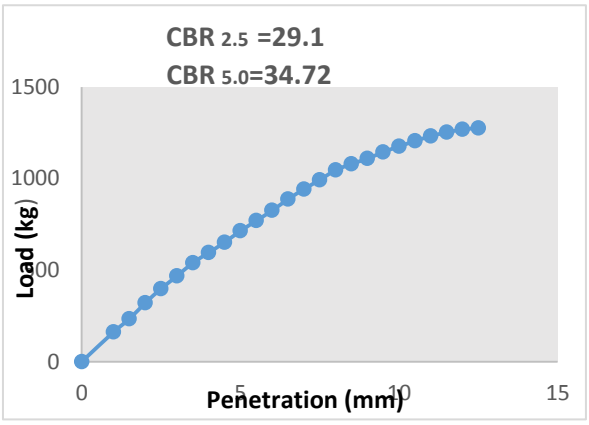


Fig.10: CBR Test result, Case B (Un-soaked)

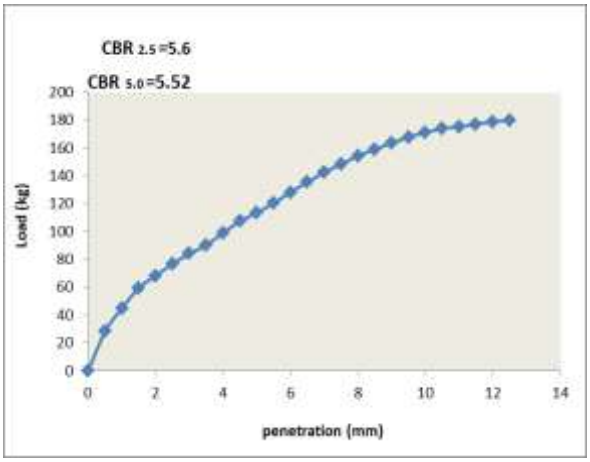


Fig.11: CBR Test result, Case B (4 days of soaking)

Case C- normal available soil tested with 3% MS emulsion and 5% stone dust added. Used proctor test case C. Maximum dry density-1.86 gm/cc. Optimum moisture content-11%

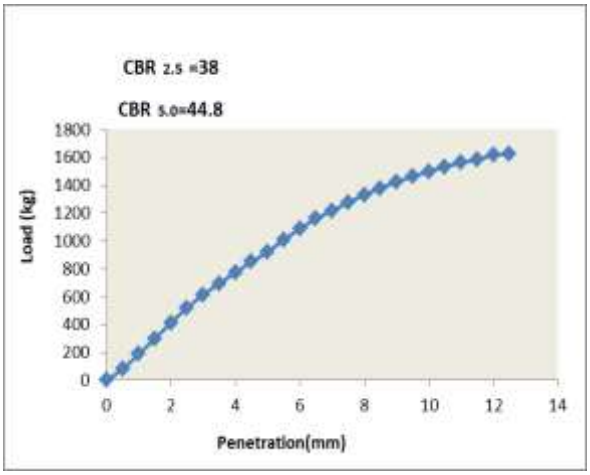


Fig.12: CBR Test Result, Case C (Un-soaked)

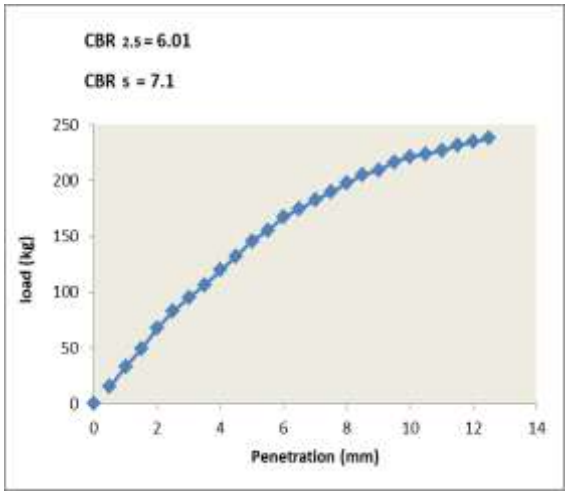


Fig.13: CBR Test Result, Case C (4 days of soaking)

Case D- normal available soil tested mixing with 3% MS emulsion and 5% brick dust added.

Used proctor test result case D

Maximum dry density value-1.928gm/cc Optimum moisture content-11%.

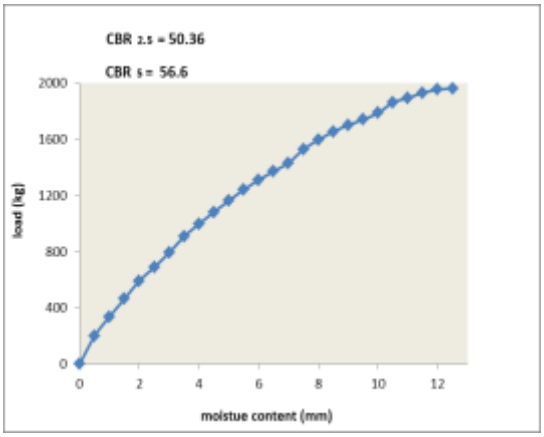


Fig.14: CBR Test Result, Case D (Un-soaked)

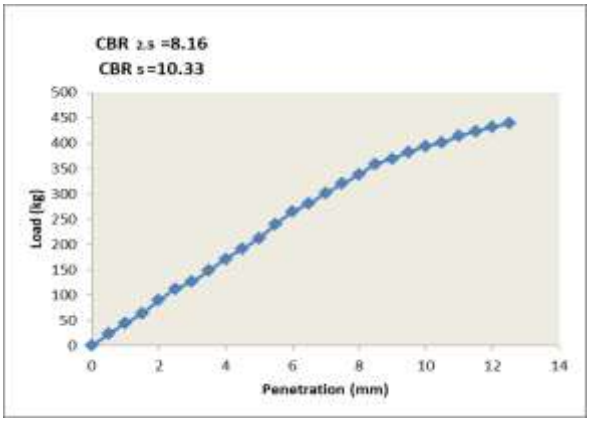


Fig.15: CBR Test Result, Case D (4 days of soaking)

The all CBR results are plotted in a bar to check whether the improvement of CBR is done or not and if done then what would be that condition where CBR value become maximum. The above bar gives a clear idea on this.

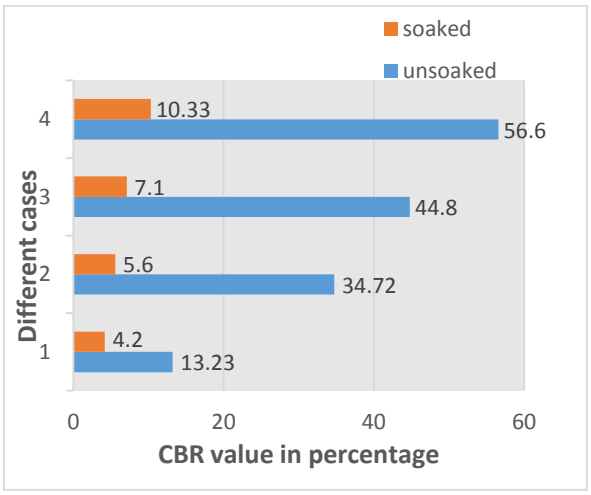


Fig.16: CBR value comparison bar chart

VI. CONCLUSIONS

Based on the analysis of data obtained from laboratory soil testing and secondary data collection, the following conclusions are shown.

- 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.
- Modified result 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 maximum dry density value from 1.782 g/cc to 1.928 gm/cc and also fluctuation in optimum moisture content value in different cases.
- At 5% and 7% MS emulsion, it is seen that maximum dry density of this soil is not so much effectively changed. As it is used as a stabilizing agent, to being applicable it should be economical. So, 3% emulsion is taken in this particular study.
- Adding stone dust and brick dust is effective in decreasing optimum moisture content of soils which is advantageous in decreasing quantity of water during compaction.
- Adding 5 % of both stone dust and brick dust, it is seen that MDD increases in both cases but brick dust remained more effective as it increases MDD more than stone dust.
- From the laboratory investigations it is found that by adding same percentage of both the fillers, the brick kiln dust is more effective than stone crushed dust (as the CBR value increases from 14.2% to 44.8% in case of stone dust whereas it increases from 14.2% to 56.6% in case of brick kiln dust).
- Annually millions of tones of brick powder is produced globally as a waste product from different brick kilns and due to construction and demolition activity, this research concluded that it can be used to increase the strength

parameters of subgrade soil in a way to minimize the amount of waste to be disposed to the environment causing environmental pollution.

- At the end our study concluded that the thickness of the pavement can be reduced to a great extent by adding MS emulsion and brick dust.

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