A LABORATORY STUDY ON USE OF BITUMEN EMULSION IN GRAVEL ROAD

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Certificate

Thisis to certify that the work in the thesis entitled. "**A LABORATORY STUDY ON USE OF BITUMEN EMULSION IN GRAVEL ROAD**" by **Tridib Goswami** is a record of an original work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of **Master of Technology** in **Department of Civil Engineering** with specialization in **Transportation Engineering**. Neither this project nor any part of it has been submitted for any degree or academic award elsewhere.

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Abstract

Starting from the base, soil is one of nature's most abundant construction materials. 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 strength of soil is poor, then stabilization is normally needed. Subgrade is sometimes stabilized or replaced with stronger soil material so as to improve the strength. Such stabilization is also suitable when the available subgrade is made up of weak soil. 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 gravel soil by adding bitumen emulsion. An attempt has been made to use emulsion for improving the strength of gravel soil expressed in terms of CBR values which may prove to be economical. In this study, the whole laboratory work revolves around the basic properties of soil and its strength in terms of CBR. A little cement added to provide better soil strength. It is observed that excellent soil strength results by using cationic bitumen emulsion (CMS) with little quantity of cement used as filler. The appropriate mixing conditions for gravelly soil with CMS Bitumen emulsion have been first attempted. This is followed by deciding four particular material conditions to show the variation in dry density and CBR value to achieve the best possible strength properties of gravel soil.

Keywords: *Gravel soil, CBR, Bitumen Stabilization, bitumen emulsion*

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ACRONYMS

VA	Air void
BC	Bituminous concrete
SMA	Stone mastic asphalt
DBM	Dense bound macadam
OBC	Optimum Binder Content
MORTH	Ministry of Road Transport & Highways
Gsb	Bulk specific gravity of aggregates
Gse	Effective specific gravity of aggregates in mix
Ga	Apparent specific gravity of aggregates
VFB	Voids filled with bitumen
CBR	California bearing ratio
Wb	Percent by weight of bitumen content
G	Actual specific gravity of aggregate
OMC	Optimum moisture content
WP	Plastic Limit
WL	Liquid Limit
IP	Plasticity Index
RS	rapid setting bitumen emulsion
MS	medium setting bitumen emulsion
SS	slow setting bitumen emulsion
OPC	Ordinary Portland Cement

CHAPTER 1

INTRODUCTION

1.1 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.

Any land-based structure depends upon its foundation characteristics. For that reason, soil is a very critical element influencing the success of a construction project. Soil is the earliest part of the foundation or one of the raw materials used in the whole construction process. Therefore the main thing related to us soil stabilization is nothing but the process of maximizing the CBR strength of soil for a given construction purpose. So many works have been done on cement, lime or fly ash stabilization. But very few works have been found on bitumen soil stabilization.

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.

In this project locally available red coloured laterite type gravel soil is taken as experimenting material. Medium setting emulsion (MS) is used as stabilizing agent in this particular study. Bitumen sand stabilization is an effective process as bitumen makes soil stronger and improves resistance capacity against water and frost. Actually bitumen is a very effective agent for sand stabilization but for soil stabilization it is being very costly. 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. This experiment study deals with some specific tests like Modified Compaction Test, CBR Test and the main objective is to optimize the strength of soil or improve the dry density property. In this project also attempt was made to maximize optimizing stability changing the mixing process with bitumen emulsion.

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.

CHAPTER 2

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) 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. (2002) 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 (1993) 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.

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 subbase 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. What's more, asphalt stabilization can enhance durability qualities by making the soil impervious to the unfavorable impacts of water, for example, volume. In non-iron materials, for example, sands and gravel, pounded gravel, and smashed stone, two fundamental systems are dynamic: waterproofing and adhesion. The asphalt coating on the union less materials gives a film which anticipates or hinders the entrance of water; subsequently reducing the inclination of the material to lose quality in the vicinity of water. The second instrument had been distinguished as adhesion and characteristics of gravelly soils.

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. Stabilization of soils and aggregates with bitumen shows it differs greatly from cement stabilization. The basic mechanism involved in bitumen stabilization was a waterproofing phenomenon.

Jones et al. (2012) conducted an experimental study on bitumen soil stabilization. Here asphalt emulsion is a mix of asphalt binder, water, and emulsifying agent. In this case, a series of Indirect Tensile Strength (ITS), Unconfined Compressive Strength (UCS) and Marshal Tests were carried out. It is liquid at ambient temperature to facilitate handling at lower application temperatures. It accelerates breaking of the emulsion and for additional early strength to accommodate traffic during curing of the layer.

Cokca et al.(2003) concentrated on the impacts of compaction dampness content on the shear quality of an unsaturated mud. In this study, the impacts of compaction dampness substance and soaking on the unsaturated shear quality parameters of mud were investigated. Experiments were carried out on specimens compacted at optimum dampness content, on the dry side of optimum and on the wet side. It was found that edge of erosion reductions quickly with increasing dampness substance, the union segment of shear quality attained its top worth at around optimum Moisture substance and afterward diminishes.

Hussain (2008) did an excellent work to establish the correlation between CBR value and un-drained shear strength value from Vane Shear Test. 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.

L. Lauren (2011) performed an experimental take a shot at soil stabilization products like the polymer emulsion for having all the earmarks of being the stabilization executors for what's to come. Every one of the three polymer-emulsions was utilized as a part of this testing project performed eminently making solid examples that all gave suitable CBR qualities to ways. The CBR test was utilized for this venture on the grounds that it has been effectively related with quality capability of the subgrade, subbase, and base course material for utilization in street and runway development.

Martinet al. (2009) developed a paper deals with foam bitumen stabilization. Foamed bitumen is a mixture of bitumen, air and water. Here 2 percent of cement and 3.5 percent of bitumen foam was used. From here it has been found that Rehabilitation using foamed bitumen had proved to be successful because of its ease and speed of construction, its compatibility with a wide range of aggregate types and its relative immunity to the effects of weather.

A. P. Chritz (2006) discussed about performance evaluation of mixed in place bituminous stabilized shoulder gravel. Here it was showed an economical maintenance of gravel shoulders, a very common problem is facing by highway agencies.

Nikraz (2012) worked on Bitumen-cement Stabilized Layer in Pavement Construction Using Indirect Tensile Strength (ITS) Method. In this study, the goal was to mix and blend Portland concrete and bitumen emulsion with soil for upgrading the quality, strength and durability of the dirt. So as to upgrade the soil quality and decrease its weakness to water, soil stabilization is obliged to be connected to the soil. In accordance with this, enhanced burden exchange was added to the asphalt establishment by having the bond impact which really supports the firmness and Bitumen emulsion impacts which enhance versatility and soil penetrability of the settled layer.

Yuehuan et al. (2010) worked on foamed bitumen stabilization for Western Australian pavements. Currently, the popularity of soil cement stabilization had been challenged by anew 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 subgrade stabilization. Numerous Australian roadway and way offices have committed noteworthy investigation and stores to investigate this system so as to attain a more adaptable and weakness safe balanced out material suitable for an extensive variety of pavement conditions. Percent of froth bitumen utilized as 3 to 5 percent. It was one kind of mix design however here after the mix design process stabilization done and CBR quality tried.

From those literature review part it can be observed that different types of work had been done previously on bitumen soil stabilization. But in India the number of work on it is very few. Actually in India there is no any appropriate code for bitumen soil stabilization. As from those papers it is very difficult to get any actual idea about how to mix bitumen emulsion with soil and what will be its actual quantity. This experimental investigation is mainly to make a process for mixing bitumen emulsion with soil.

Framework of the study:

Selection of material and methodology those are the first criteria for any type of experimental investigation. To know the soil physical properties following tests are conducted like specific gravity test, grain size distribution test by sieve analysis and plastic limit and liquid limit test. After that the important part is to choose mixing procedure and the cases or different conditions for conducting the next tests. To determine the maximum dry density of the material modified proctor test has been conducted. But the actual goal is to increase the strength. So CBR test are conducted in different cases and conditions and make a comparative experimental study. So the methodology is how to achieve maximum bearing capacity or maximize the CBR value. In the next page Methodology part is in chart form.

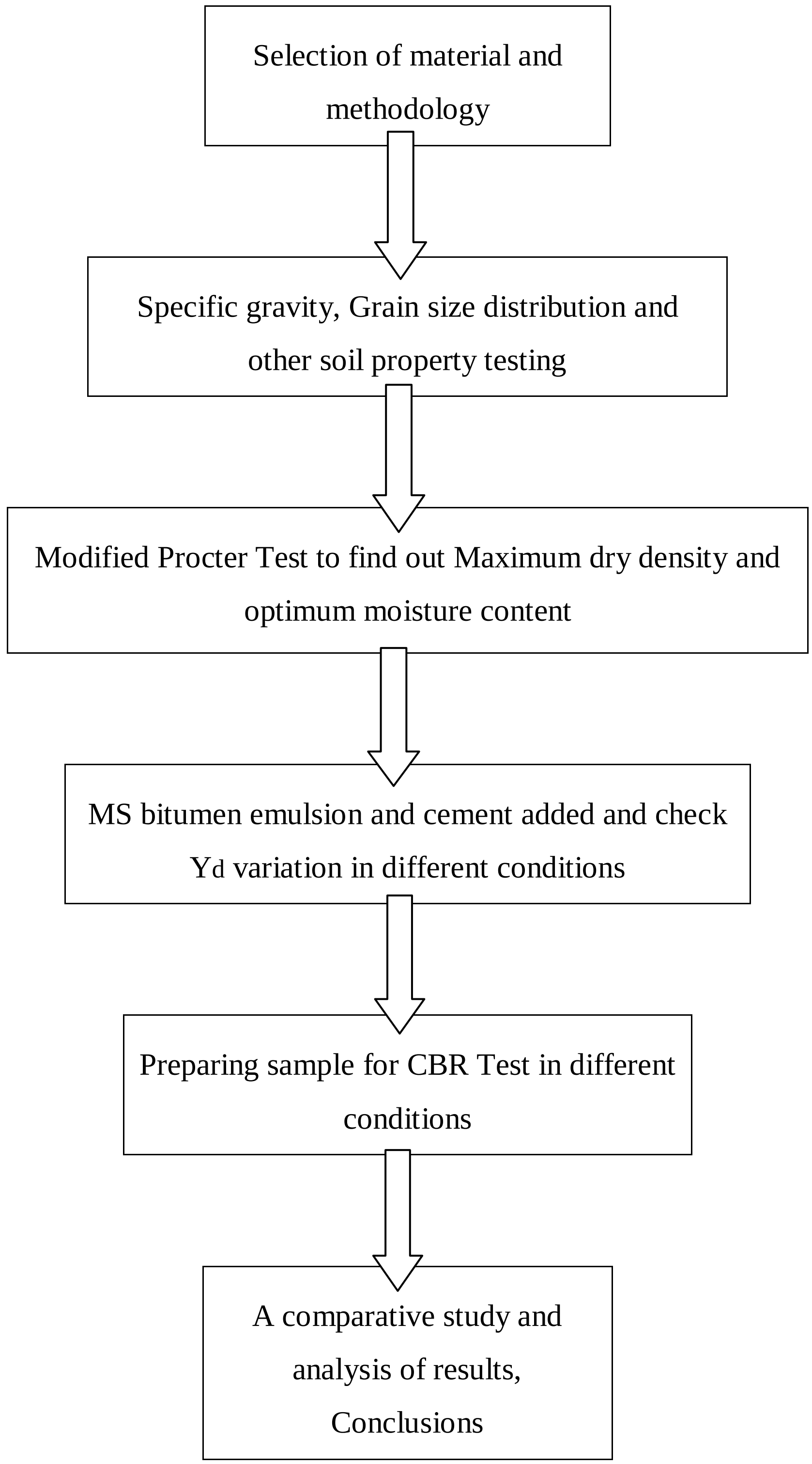

Fig. 2.1.1: Methodology Flow Chart

CHAPTER 3

EXPERIMENT PROGRAMME

3.1 One of Soil Properties, 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 is Specific Gravity

$$G = (M_2 - M_1) / ((M_4 - M_1) - (M_3 - M_2))$$

Here,

M_1= Weight of bottle

M_2= Weight of bottle and Dry soil

M_3= Weight of bottle, Dry soil and Water

M_4= Weight of bottle and Water

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

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

Table 3.1.1: Standard Specific Gravity

3.2 Particle Size Distribution

The composition of soil particles are of a variety of sizes and shapes. The range of particle size present in the same soil sample is from a few microns to a few centimeters. Many physical properties of the soil such as its strength, permeability, density etc are depended on different size and shape of particles present in the soil sample.

Sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample, are the two methods of finding Particle size distribution. Both are followed by plotting the results on a semi-log graph where ordinate is the percentage finer and the abscissa is the particle diameter i.e. sieve sizes on a logarithmic scale. The sieve analysis for coarse grained soil has been conducted.

Well graded or poorly graded are mainly the types of soil found. Well graded soils have different particles of different size and shape in a good amount. On the other hand, if soil has particles of some sizes in excess and deficiency of particles of other sizes then it is said to be poorly or uniformly graded.

The results from sieve analysis of the soil when plotted on a semi-log graph with particle diameter or the sieve size in millimeter as the X-axis with logarithmic axis and the percentage finer as the Y-axis. This semi-log graph gives a clear idea about the particle size distribution. From the help of this curve, D10 and D60 are resolute. This D10 is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D10 and D60 gives the uniformity coefficient (Cu) which in turn is a measure of the particle size range in the soil sample.

3.3 Liquid limit and Plastic Limit Test

The liquid limit of a soil is the dampness substance or the existing moisture, communicated in rate of the mass of the broiler dried soil at the limit organized between the liquid and plastic states. The dampness content at this limit condition is self-assertively defined as the liquid limit and is the dampness content at a consistency as determined by method for the standard liquid limit mechanical assembly.

The liquid limit is the moisture content corresponding to the boundary between liquid state and plastic states of soil mass. At liquid limit the soil has such a low shear strength (17.6g/cc) which flows to standard dimension for a length of 12mm of a groove when jarred 25 times using the standard liquid limit device or apparatus. Casagrande apparatus is one of the apparatus used for determining the liquid limit of a soil material. The water content at which 25 drops of the cup to make the groove too close, is called as the liquid limit.

The plastic limit (PL) is the moisture content at which the soil remains in plastic state. It is the water content at which the soil just begins to crumble when rolled into a thread of 3mm diameter.

Plasticity Index (IP) = Liquid Limit (WL) - Plastic Limit (WP)

In one sentence the transition state from the liquid limit state to plastic limit is called liquid limit (WL) at this stage all soil posses a certain small shear strength. The transmission from the plastic stated to the semisolid state is termed as plastic limit (WP).

3.4 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 (Y_d). 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 3.4.1: Modified Proctor test apparatus

(Source: www.testersinchina.com)

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 %

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

3.5 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.

3.6 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.

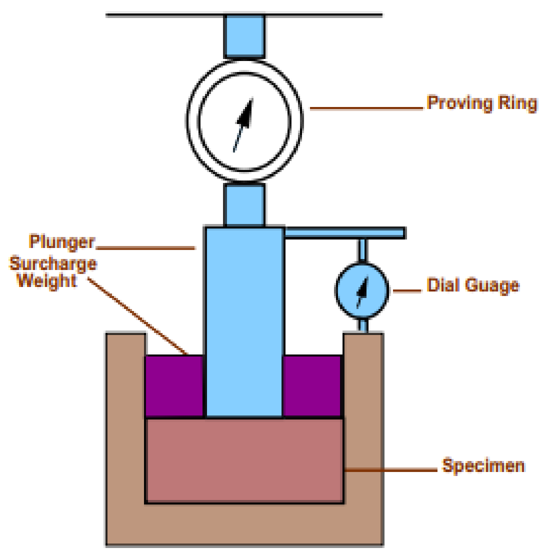

Fig. 3.6.1: California Bearing Ratio Testing Machine

(Source: www.cdeep.iitb.ac.in)

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.

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

Table 3.6.2: Standard load in different penetration

The CBR test is done on a compacted soil (by 30 blows) in a cylindrical CBR mould of 150 mm diameter and 175 mm height gave separable collar of 50 mm and a separable punctured base plate of hard metal. A displacer plate, 50 mm profound inside the mold throughout the example readiness by which example of 125 mm profound is acquired as actual depth. The dry density and water content be stayed same as would be kept up throughout field compaction. By and large, CBR qualities of both drenched and in un-soaked specimens are determined. Each one surcharge opened weight; 147 mm in measurement with a focal entire 53 mm in distance across and weighing 2.5 kg is considered give or take equal to 6.5 cm of construction. A minimum of two surcharge weights are issued which are set on the example. Load is connected so that the penetration is roughly 1.25 mm/min. The load readings are recorded at distinctive penetrations, 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 8, 9, 10, 11, 12, and 12.5 mm. The most extreme load and penetration is recorded in the event that it happens for a penetration of short of 13 mm.

The curve is mainly convex upwards although the initial portion of the curve may be concave upwards due to surface irregularities. A correction is then applied by drawing a tangent to the curve at the point of greatest slope. The corrected origin will be the point where the tangent meets the abscissa. The CBR values are usually calculated for penetrations of 2.5 mm and 5mm. For the most part the CBR values at 2.5mm penetration will be more excellent than 5mm penetration and in such a case the previous is taken as the CBR esteem for design purposes of an asphalt structure and that is the reason CBR is an essential determination of asphalt thickness. In the event that the CBR worth comparing to a penetration of 5mm surpasses that for 2.5mm, the test is rehashed. On the off chance that indistinguishable results take after, the bearing ratio relating to 5mm penetration is taken for design.

CHAPTER 4
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 M_1 is empty bottle weight, M_2 is mass of bottle and dry soil, M_3 is weight of bottle, dry soil and water and M_4 is weight of bottle with water.

Table 4.1.1: Specific gravity test result

Sample No	M_1 (gm)	M_2 (gm)	M_3 (gm)	M_4 (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

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 Liquid limit and Plastic limit Test

The gravel soil used in this study was course grained soil obtained from local road routes in Rourkela NIT 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.

Liquid Limit (WL): 28.91%

Plastic Limit (WP): 21.67%

Plasticity Index (IP): 7.24%

4.3Grain 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 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 4.2.1: Sieve analysis result

Sieve No. #	Sieve size	Mass of soil retained in each sieve (gm)	Percent retained (%)	Cumulative retained (%)	Percent finer (%)
1/2 Inch	12.5 mm	0	-----	0	100
3/8 Inch	9.5 mm	99.1	4.95	4.95	95.05
1/4 Inch	6.3 mm	318.8	15.94	20.84	79.16
#4	4.75 mm	397.5	19.88	40.77	59.33
#8	2.36 mm	510.2	25.51	66.28	33.72
#16	1.18 mm	255.1	12.71	79.03	20.97
#30	600 micron	166.2	8.31	87.34	12.66
#50	300 micron	132.1	6.61	93.95	6.05
#80	150 micron	48.7	2.44	96.39	3.61
Pan	-----	72.3	3.6	100	0

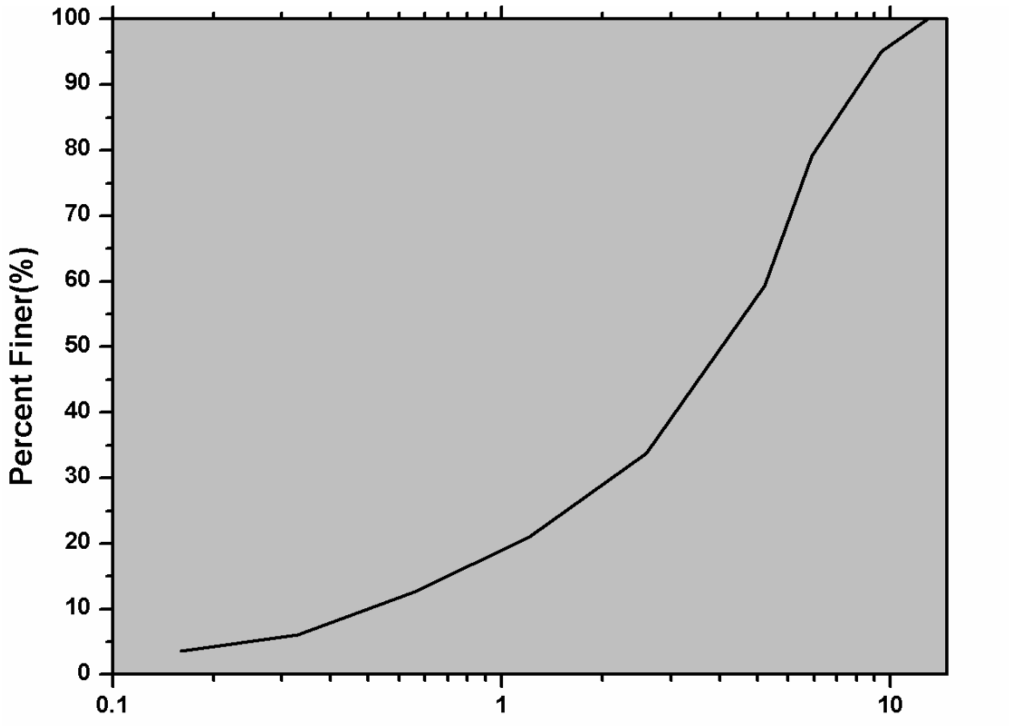

Fig 4.2.2: Grain size distribution graph

4.4 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%.

Yuehaun et al. had been done an experimental study on foamed bitumen stabilization for Western Australian pavements. And similarly a work was developed on foam bitumen stabilization by Martin in Queensland in 2011. The common matter on both works is to provide the optimum value on bitumen content percentage 3% to 4%. After testing in different percentage 3%, 5% and 7% 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.

As I previously said very few works had done on bitumen soil stabilization. Only bitumen sand stabilization IS code is available. So, how to mix the gravel 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 gravel 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 2% cement added

***Case D* :** Normal available soils tested mixing with 3% of emulsion and 2% of cement added and wait 5 hour before testing

In this four particular condition modified proctor test is performed and plotted with moisture content percentage in X axis and corresponding dry density value in Y axis. From carves of graphs plotted, there is a crown point where the value of dry densityis maximum. Here corresponding moisture content is optimum moisture content. In this four particular conditions tested modified proctor graph listed below. Those graphs strictly indicate that Case D gives the optimum value.

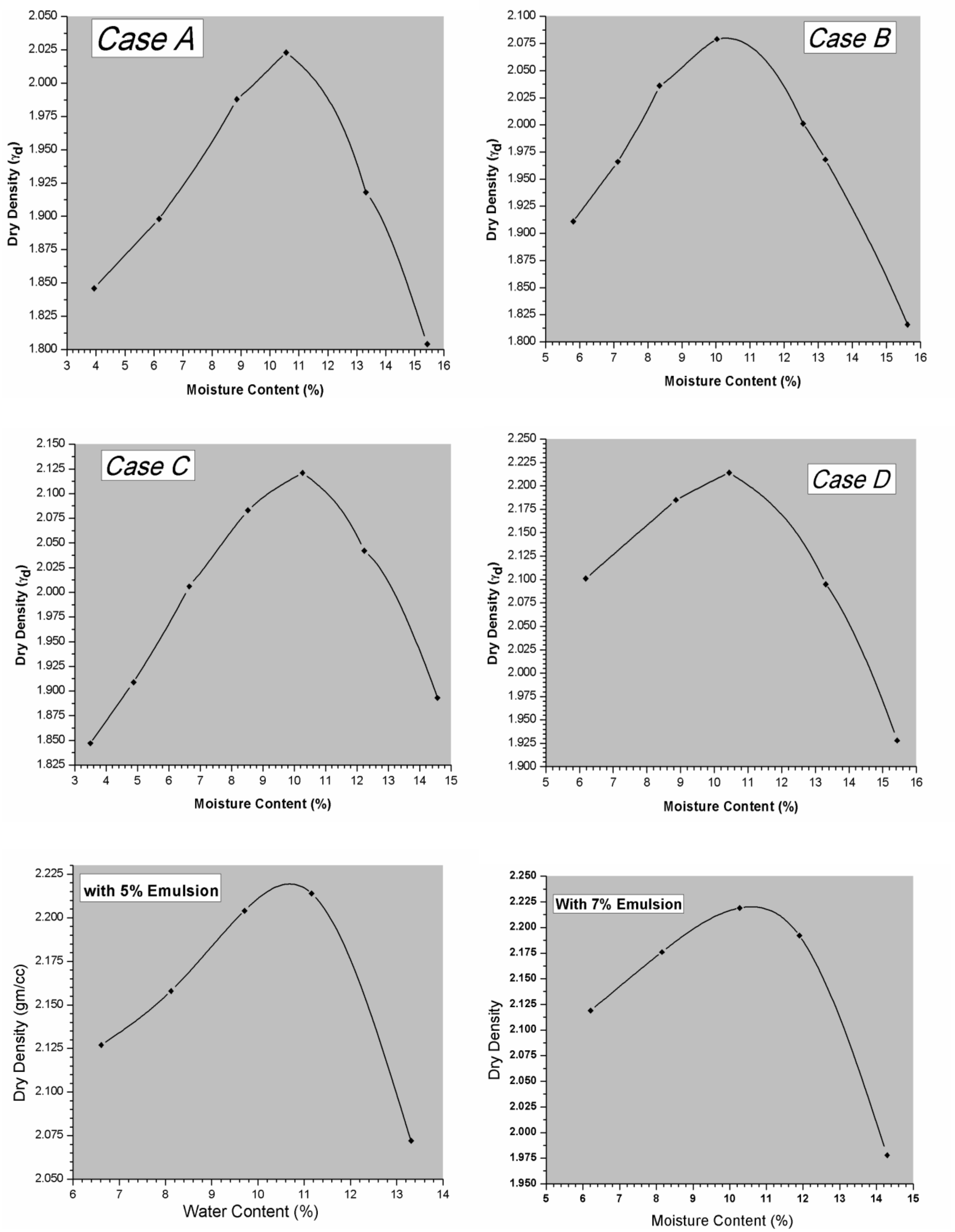

Fig 4.4.1: Modified proctor test graphs

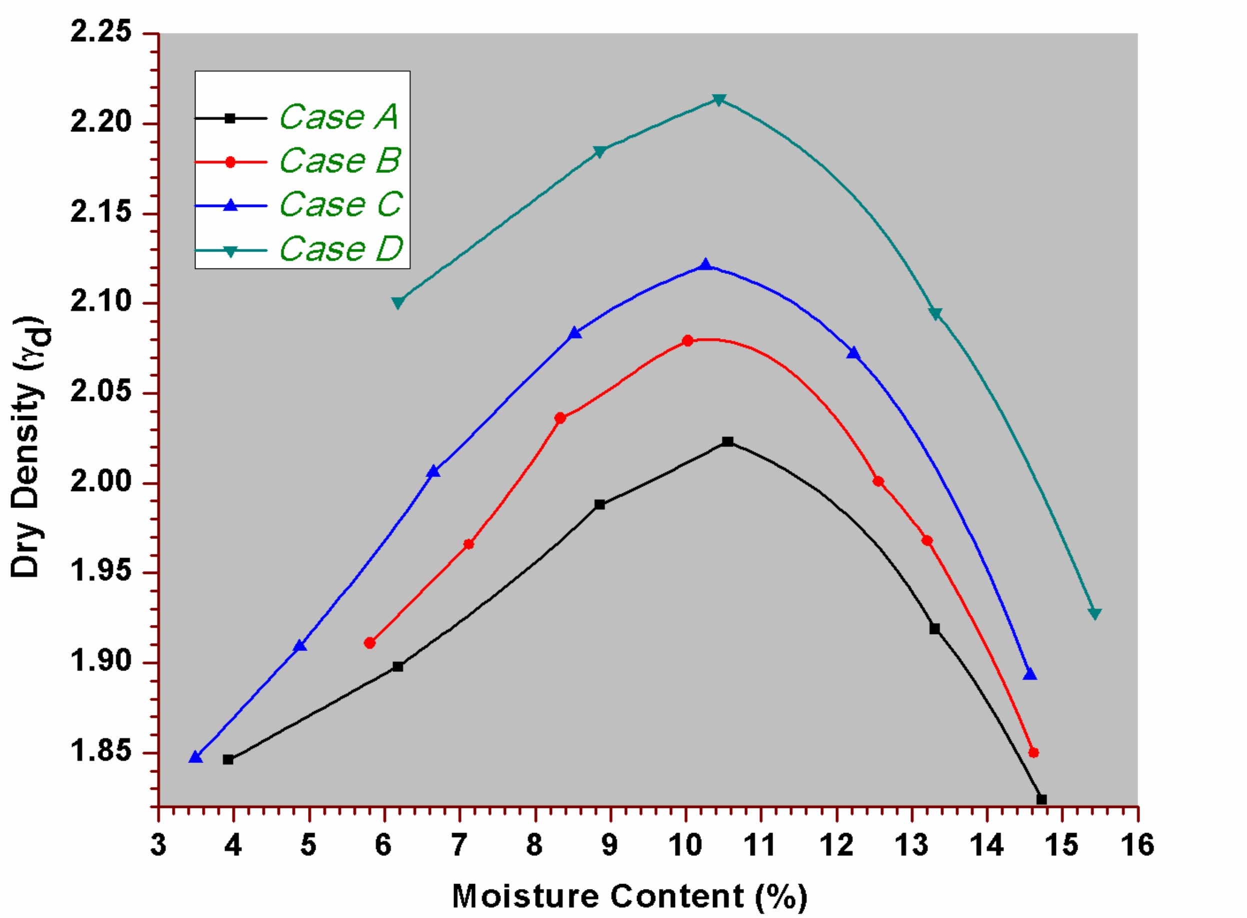

Fig 4.4.2: Modified proctor test comparison graph

From the previous modified proctor result 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 2.212 gm/cc. Little bit of fluctuation in optimum moisture content value in different cases. This Y_d 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.

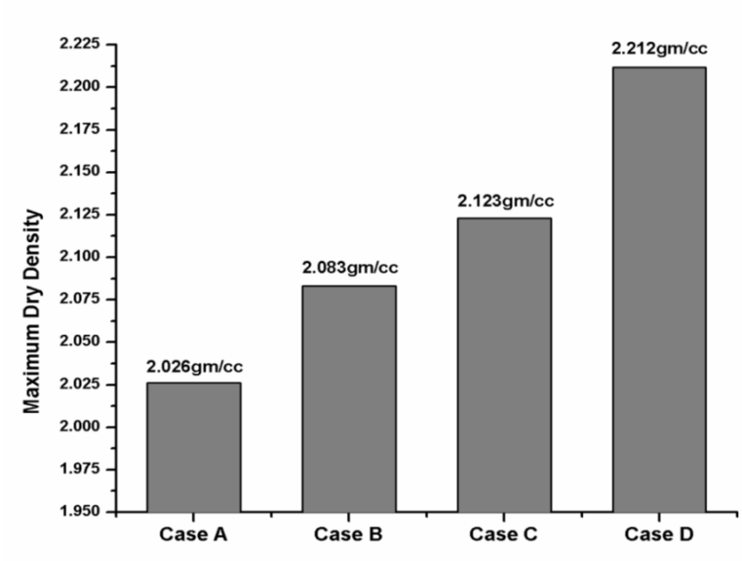

Fig 4.4.3: Variation of maximum dry density value

Now the question arises how this maximum dry density is depending upon mixing bitumen quantity and whether it 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 D. This result gives us a clear idea about used 3% bitumen content.

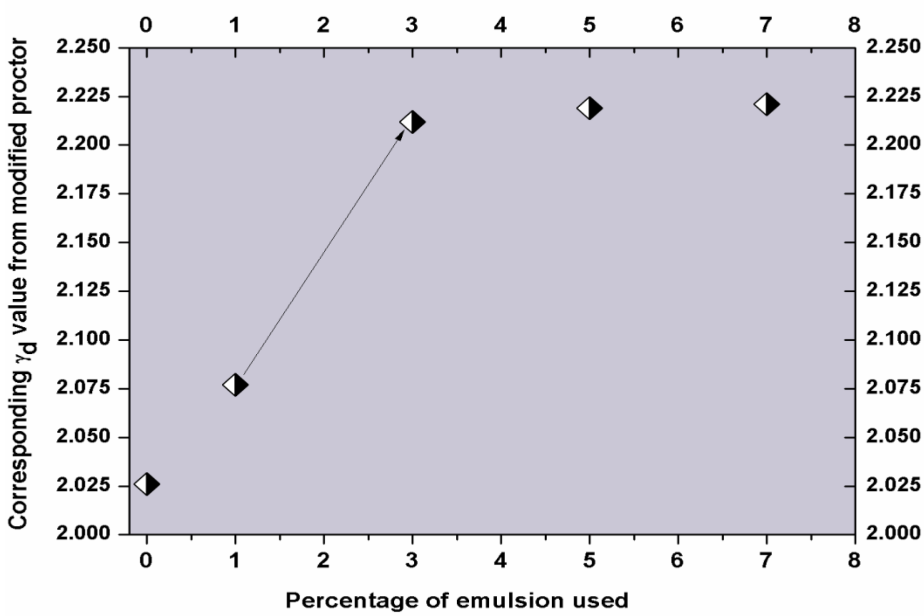

Fig 4.4.4: Variation of MDD with emulsion quantity

4.5 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.

The CBR values at 2.5mm and 5.0mm penetrations are calculated for each specimen from the corresponding graphs which is shown below. Generally the CBR value at 2.5mm penetration is higher and this value is adopted.CBR is defined as the ratio of the test load to the standard load, expressed as percentage for a given penetration of the plunger. This value is expressed in percentage. Standard load of different penetration is discussed before.

Here testing is done on three different testing condition on previously four cases. So total twelve number of CBR value is measured by moulding twelve different specimens, three 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 content and mixing procedure effect on CBR value of a particular soil. CBR value and the CBR graph is case wise shown below.

Case A:

Mould size: standard volume 2250 cc

Case A: Normal available tested soil is used for testing in this case

Used proctor test result of Case A.

Maximum Dry Density value: 2.026 gm./cc

Optimum Moisture Content: 10.52%

CBR test is done in three conditions. First one is in un-soaked condition, secondly in two days of soaking condition and lastly in four days of soaking condition. CBR value at 2.5mm penetration and 5mm penetration is calculated.

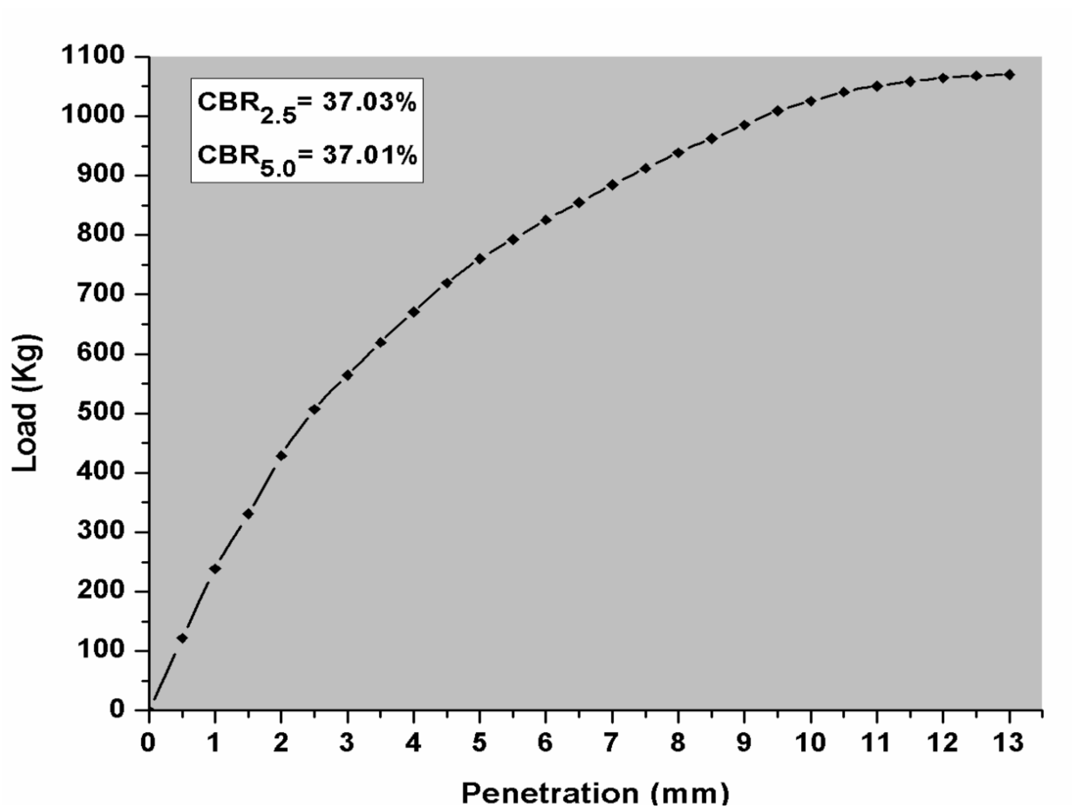

Fig 4.5.1: CBR Test Result, Case A (Un-soaked)

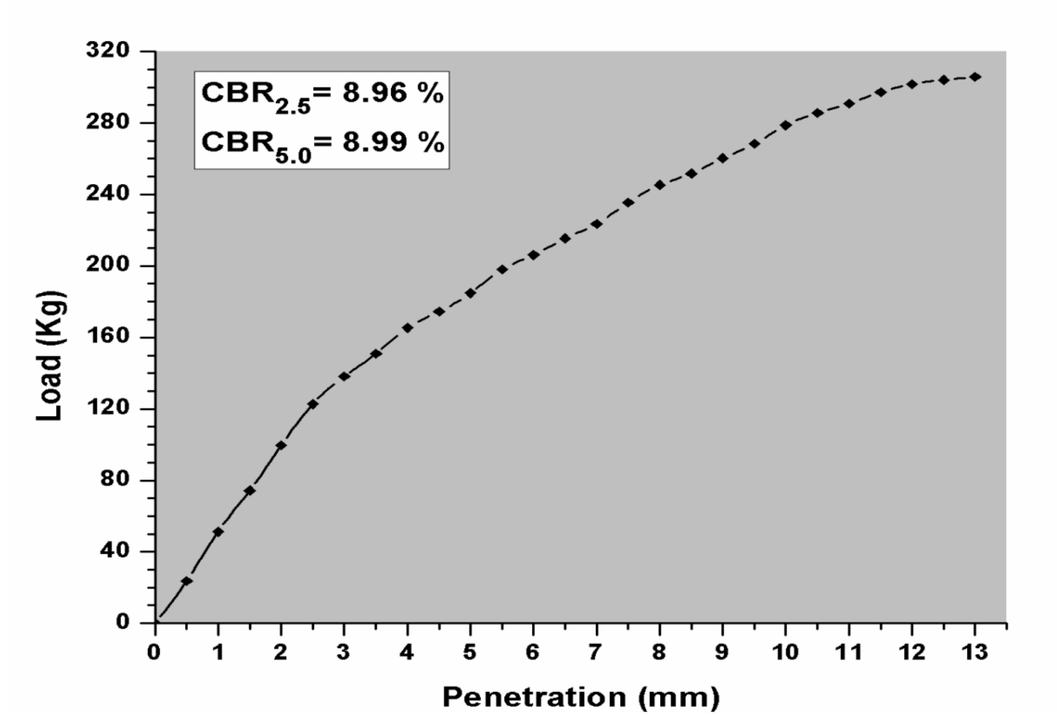

Fig 4.5.2: CBR Test Result, Case A (2 days of soaking)

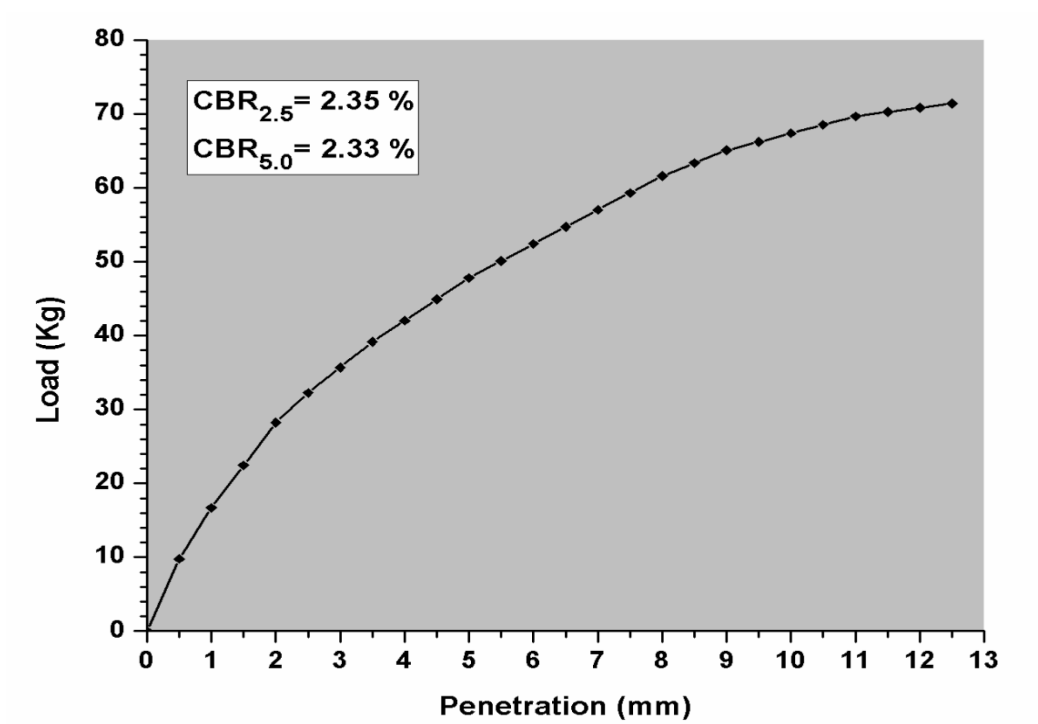

Fig 4.5.3: CBR Test Result, Case A (4 days of soaking)

Case B:

Mould size: standard volume 2250 cc

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

Used proctor test result of Case B.

Maximum Dry Density value: 2.083 gm./cc

Optimum Moisture Content: 10.45%

CBR test is done in three conditions. First one is in un-soaked condition, secondly in two days of soaking condition and lastly in four days of soaking condition. CBR value at 2.5mm penetration and 5mm penetration is calculated.

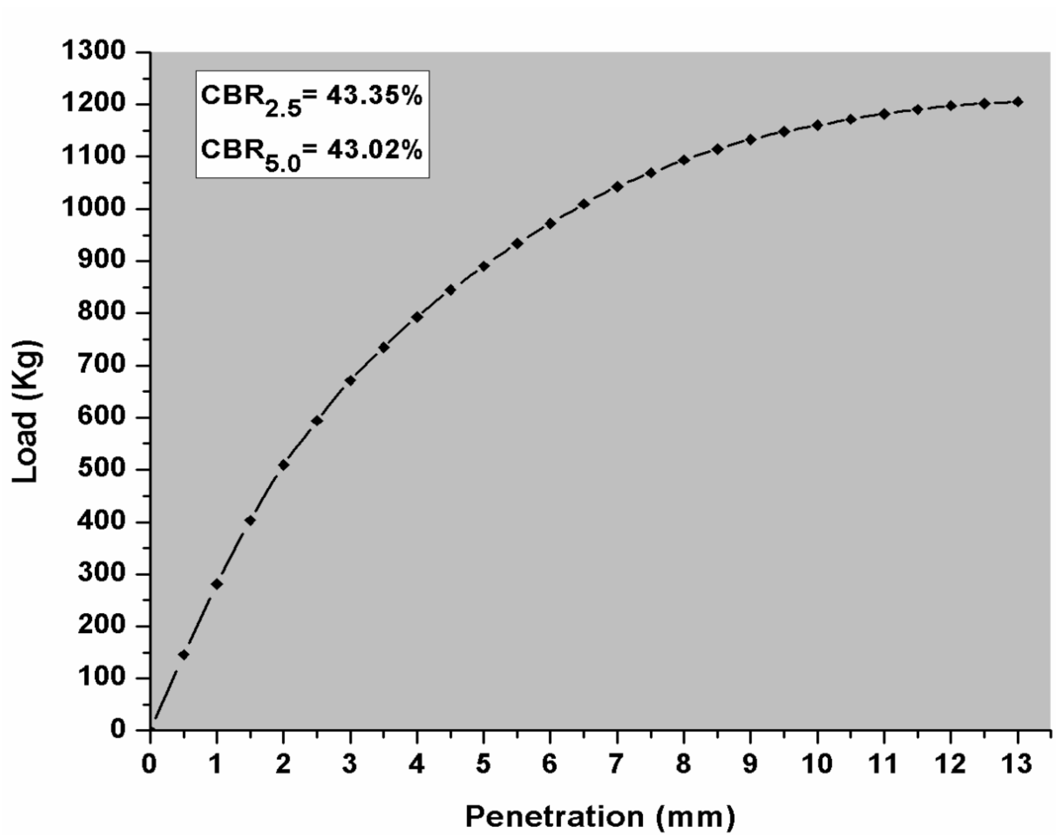

Fig4.5.4: CBR Test Result, Case B (Un-soaked)

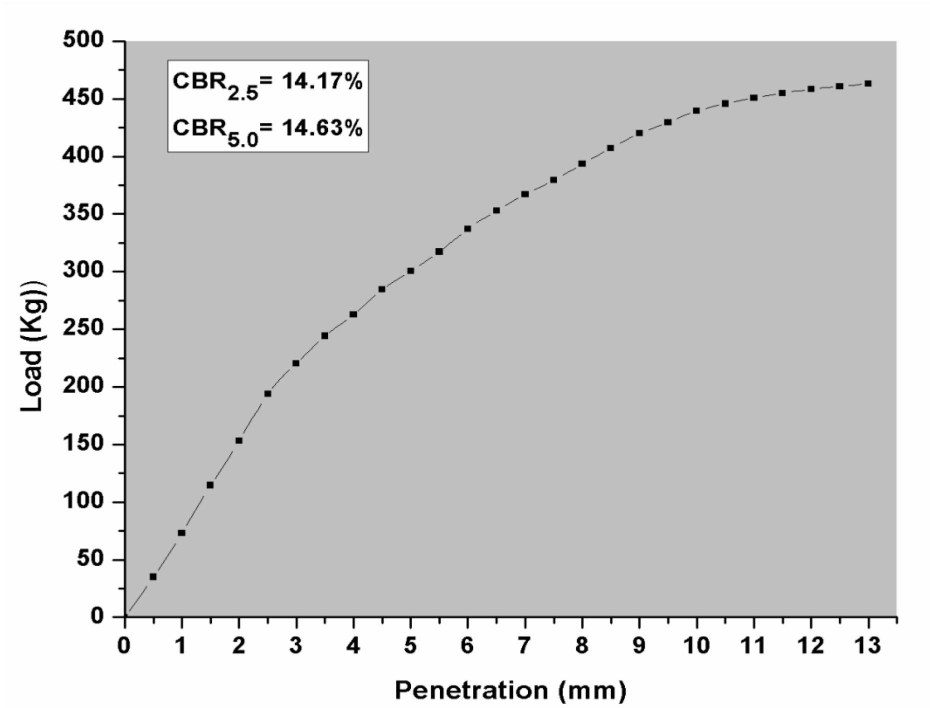

Fig 4.5.5: CBR Test Result, Case B (2 days of soaking)

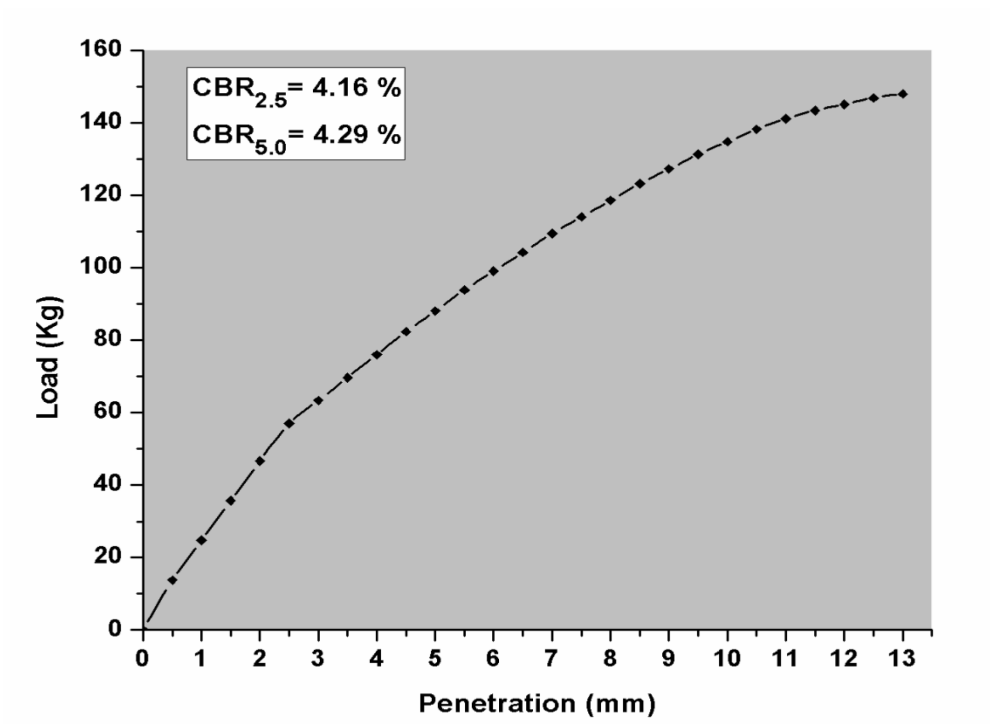

Fig 4.5.6: CBR Test Result, Case B (4 days of soaking)

Case C:

Mould size: standard volume 2250 cc

Case C: Normal available soil tested with 3% MS emulsion and 2% OPC cement added

Used proctor test result of Case C.

Maximum Dry Density value: 2.123 gm./cc

Optimum Moisture Content: 10.25%

CBR test is done in three conditions. First one is in unsoaked condition, secondly in two days of soaking condition and lastly in four days of soaking condition. CBR value at 2.5mm penetration and 5mm penetration is calculated.

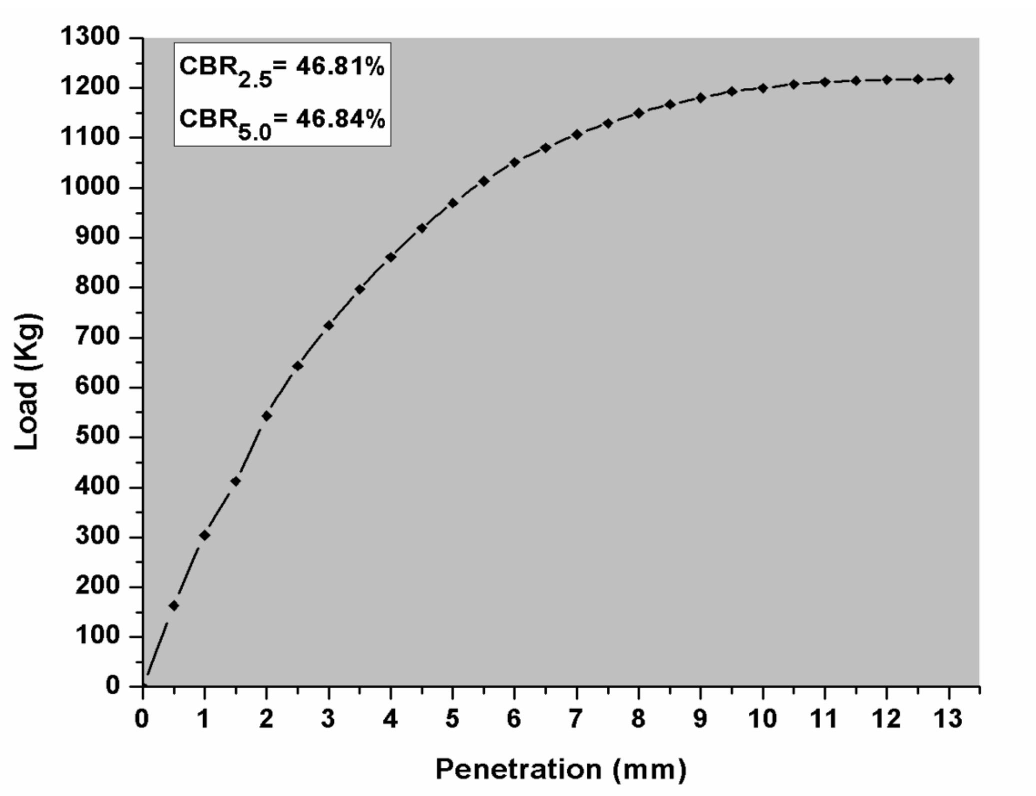

Fig 4.5.7: CBR Test Result, Case C (Un-soaked)

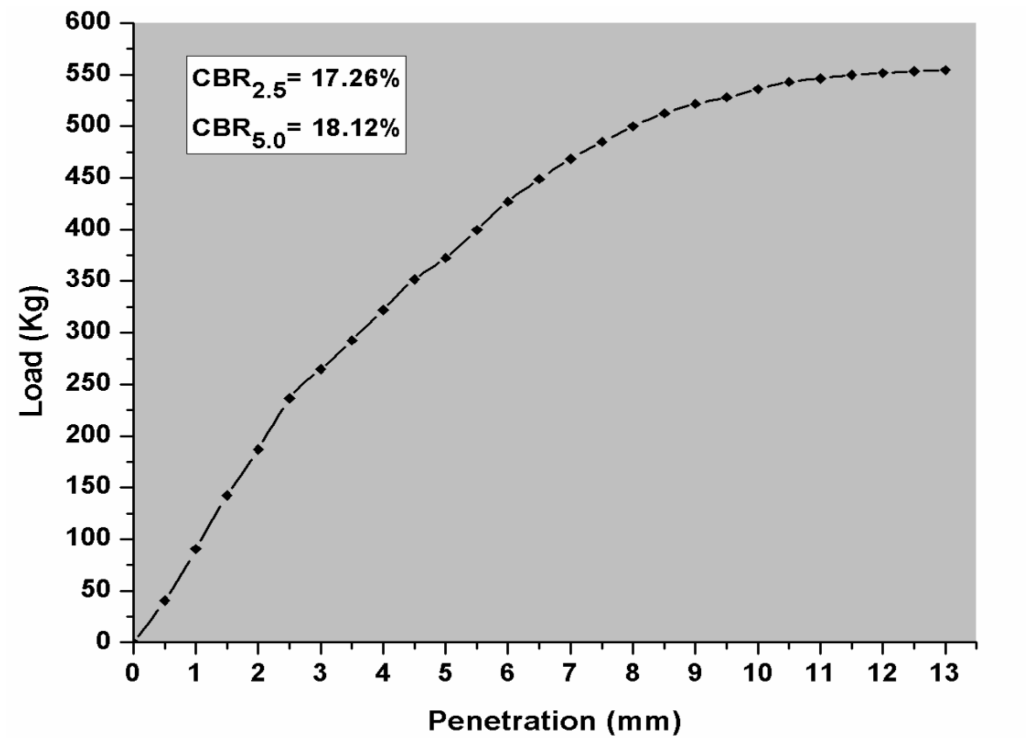

Fig 4.5.8: CBR Test Result, Case C (2 days of soaking)

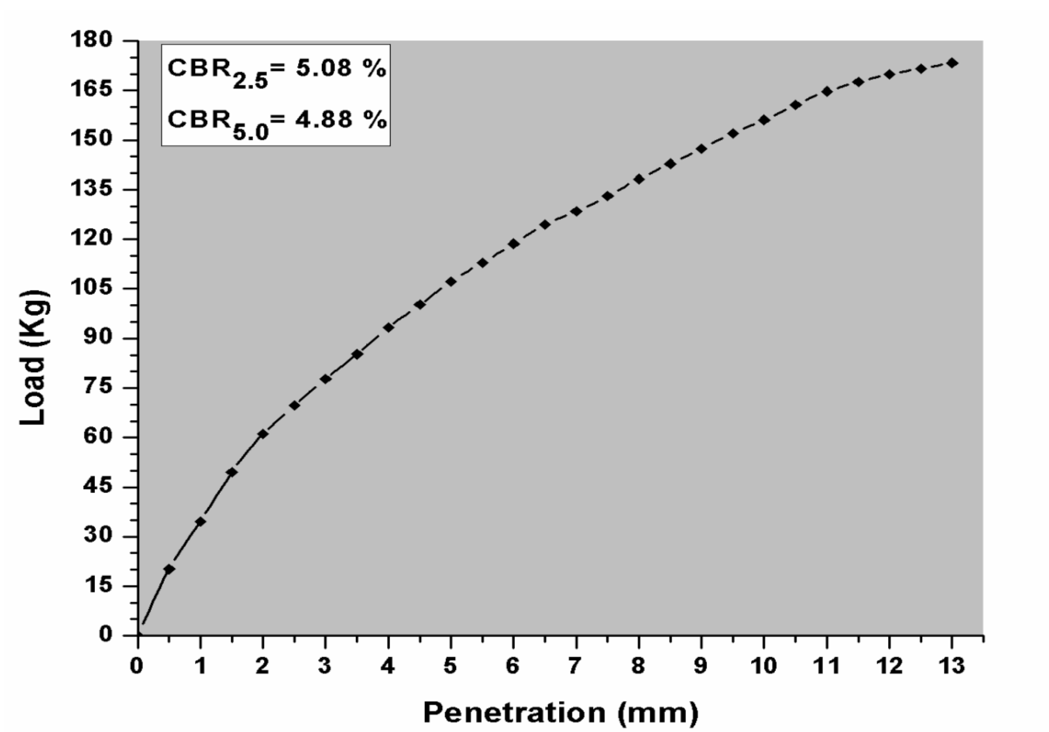

Fig 4.5.9: CBR Test Result, Case C (4 days of soaking)

Case D:

Mould size: standard volume 2250 cc

Case D: Normal available soil tested mixing with 3% of emulsion and 2% of OPC cement added and after 5 hour testing started.

Used proctor test result of Case D.

Maximum Dry Density value: 2.212 gm./cc

Optimum Moisture Content: 10.58%

CBR test is done in three conditions. First one is in unsoaked condition, secondly in two days of soaking condition and lastly in four days of soaking condition. CBR value at 2.5mm penetration and 5mm penetration is calculated.

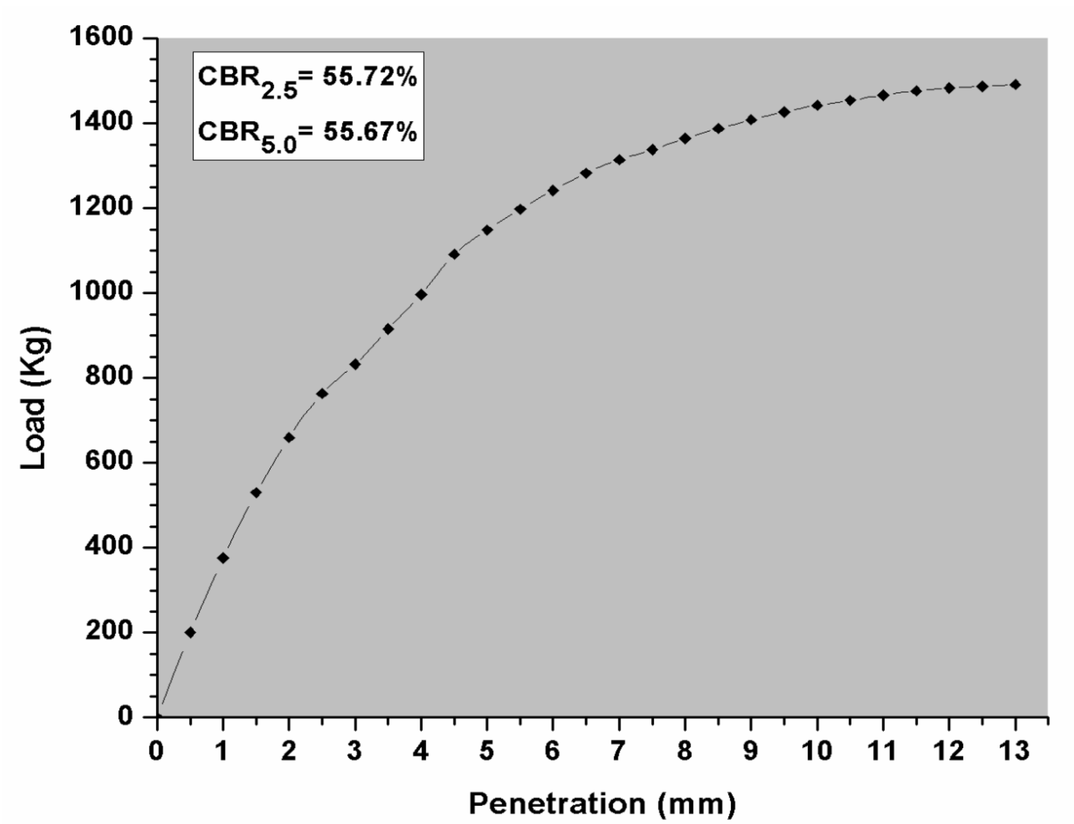

Fig 4.5.10: CBR Test Result, Case D (Un-soaked)

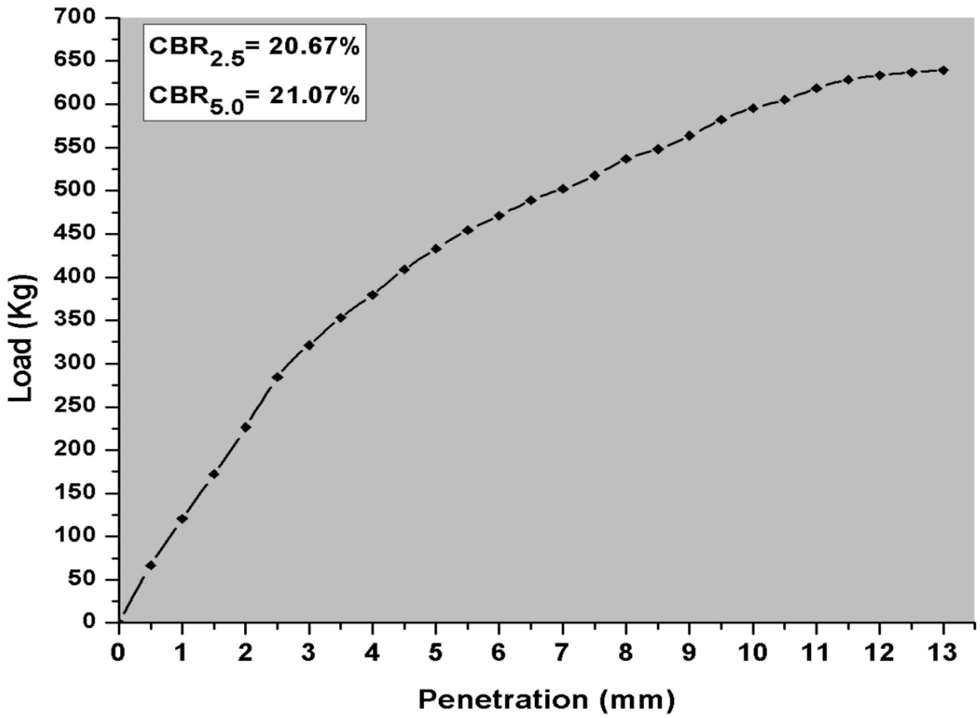

Fig 4.5.11: CBR Test Result, Case D (2 days of soaking)

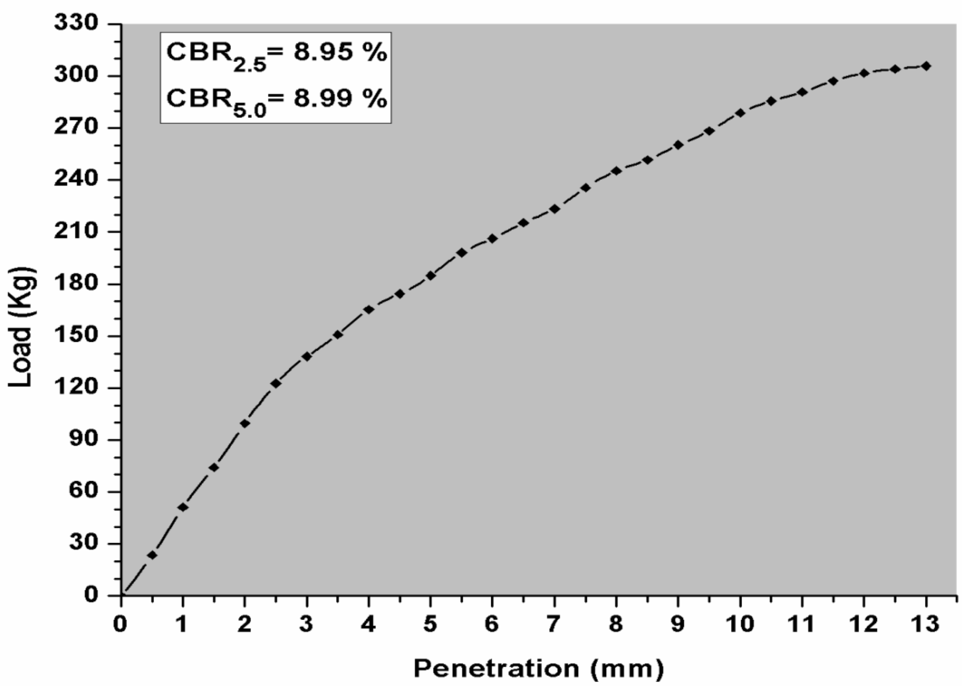

Fig 4.5.12: CBR Test Result, Case D (4 days of soaking)

4.6 Discussion

Subgrade may be defined as a compacted soil layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness, just below of the pavement crust. It provides a suitable foundation for the pavement. So it is very important to improve strength of subgrade soil, it may be by replacing good soil or by stabilization of existing soil. To check the subgrade soil stability CBR test is very commonly used test.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. Following bar gives about a clear idea on this.

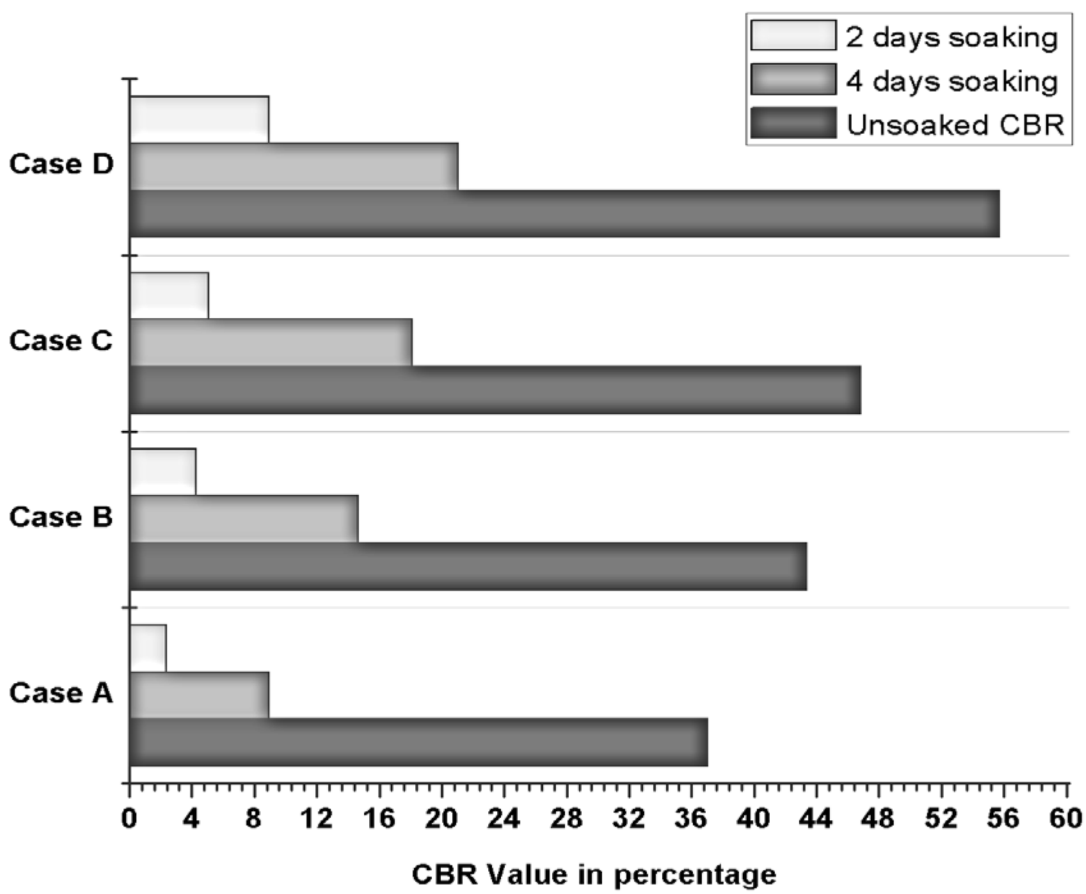

Fig 4.6.1: CBR value comparison bar chart

4.7 Summary

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 it best results are obtained if the soil emulsion mix is left for about five and half 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. Observing its economic cost and quality of stabilization improvement, it is clear that this type of stabilization may be applicable in gravel soil road or in shoulder portion of highways.

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