



## A laboratory study on use of bitumen emulsion in gravel road

Insha Parvaiz<sup>1</sup>, ER Sonu Ram<sup>2</sup>

<sup>1</sup> M. Tech student, Department of Civil Engineering, Desh Bhagat University, Mandi, Gobindgarh, Punjab, India

<sup>2</sup> Assistant Professor, Department of Civil Engineering, Desh Bhagat University, Mandi, Gobindgarh, Punjab, India

### Abstract

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. By adding 2% 4% 6% and 8% of bitumen emulsion to gravel soil the strength property of is increased. The characteristic properties of soil i.e. specific gravity, plastic limit, liquid limit, plasticity index and CBR values of gravel soil with bitumen emulsion was studied. From tests it is observed that excellent soil strength results by using bitumen emulsion. 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. The result shows the best strength properties (CBR) of gravel soil at 8% of adding bitumen emulsion.

**Keywords:** subgrade soil, CBR, Stabilization, bitumen emulsion

### 1. Introduction

#### General

Most of the stabilization has to be undertaken in soft soils (silty, clayey, peat, or organic soils) in order to achieve desirable engineering properties. Fine grained granular materials are the easiest to stabilize due to their large surface area in relation to their particle diameter. 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.

#### Soil Stabilization

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.

### Literature Review

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.

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.

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.

J.P.Serfass *et al.* (2004) said that the cold mixes are evaluative materials in their early life. The author prepared two types of cold mixes and evaluated material characteristics at different states: fresh mature and aged. The author incorporated different curing procedures and the effect of temperature, relative humidity and time have been evaluated. The mechanical behavior has been characterized by compressive strength and stiffness modulus. The author used 0/14mm grave-emulsion, made of semi crushed alluvial aggregates, with 4.0% of 70/100 residual bitumen and 0/10mm dense-graded asphalt concrete made of crushed genesis with 5.0% of 70/100 residual bitumen. The result obtained from the tests the author conclude that to obtain cold mixes in a mature state, it is proposed that they are cured 14 days at 35°C – 20% relative humidity as this procedure does not cause any deterioration to the specimen and he also proposed to keep the existing standardized curing 14 days at 18°C – 50% relative humidity as curing to fresh state..

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) [9] 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.

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

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.

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.

### 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.

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.

**Object and Scope of Work**

The main objective of this experimental study is to improve the properties of the gravelly 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. Stabilization of gravel soil by adding bitumen emulsion as following percentages 2% 4% 6% and 8% to gravel soil. 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.

**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.

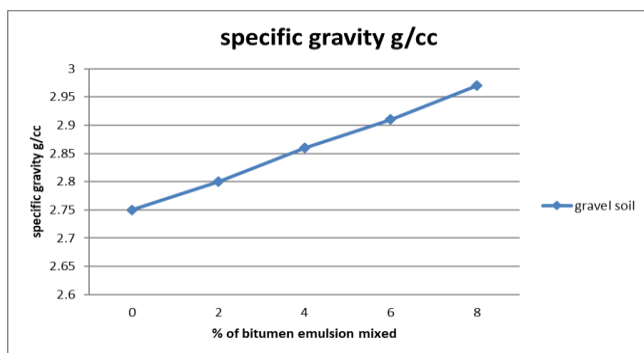
**Methodology**

**specific gravity**

Specific gravity of soil is very important property to understand the soil condition. Tests were done for both the gravel soil and gravel soil with bitumen emulsion at different percentages.it is noted that the gravel soil when added with emulsion at different percentages, specific gravity gets increased with increasing percentage of bitumen emulsion. This increase in specific gravity may be due to the high specific gravity of bitumen emulsion.

**Table 1:** specific gravity of gravel soil and bitumen emulsion mixed soil

Sr. No	sample	Specific gravity
1	Gravel soil	2.75
2	Gravel soil + 2% bitumen emulsion	2.80
3	Gravel soil + 4% bitumen emulsion	2.86
4	Gravel soil + 6% bitumen emulsion	2.91
5	Gravel soil + 8% bitumen emulsion	2.97



**Fig 1:** specific gravity of soil sample

**3.2 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 824 grams 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 2:** sieve analysis result

Sieve no.#	Sieve size	Mass of percent soil retained on each sieve (g)	Percent retained (%)	Cumulative retained (%)	Percent finer (%)
#4	4.75mm	154	18.7	18.7	81.3
#8	2.36mm	72	8.7	27.4	72.6
#16	1.18mm	72	8.7	36.1	63.9
#30	0.600mm	141	17.1	53.2	46.8
#40	0.425mm	85	10.3	63.2	36.5
#50	0.30mm	80	9.7	73.2	26.8
#100	0.15mm	149	18.1	91.3	8.7
#200	0.075mm	45	5.5	96.8	3.2
Pan	.....	24	2.9	99.7	0

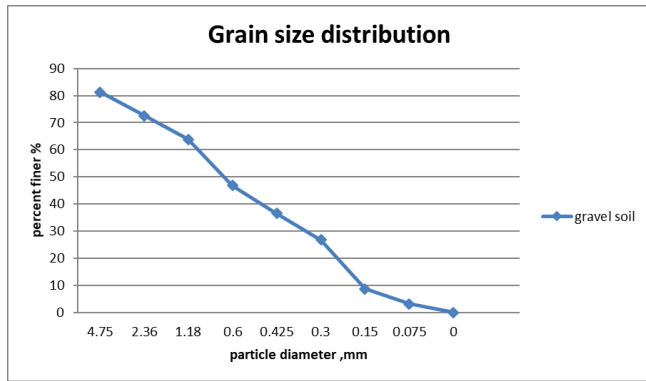


Fig 2: Grain size distribution curve

**Liquid and plastic limit test**

Liquid limit (LL), plastic limit (PL), and plasticity index (PI) of gravel soil and stabilized bitumen emulsion are evaluated. From the liquid limit and plasticity index of untreated gravel soil is found to be inorganic silts of low plasticity (ML) and stabilized gravel soil is found to be inorganic clays of high plasticity (CL) as per Indian standard classification. It shows the plastic limit, liquid limit, plastic index of gravel soil and bitumen emulsion mixed sample results. There is an increase in the percentages of liquid and plastic limits as compared to the normal gravel soil without mixing with emulsion. Thus plasticity index also gets increased.

Table 3: liquid limit, plastic limit, and plasticity index results

Sample	Liquid limit %	Plastic limit %	Plasticity index %
Gravel soil	29	22	7
Gravel soil + 2% bitumen emulsion	29.6	22.4	7.2
Gravel soil + 4% bitumen emulsion	30.2	22.9	7.3
Gravel soil + 6% bitumen emulsion	30.7	23.3	7.4
Gravel soil + 8% bitumen emulsion	31.3	23.8	7.5

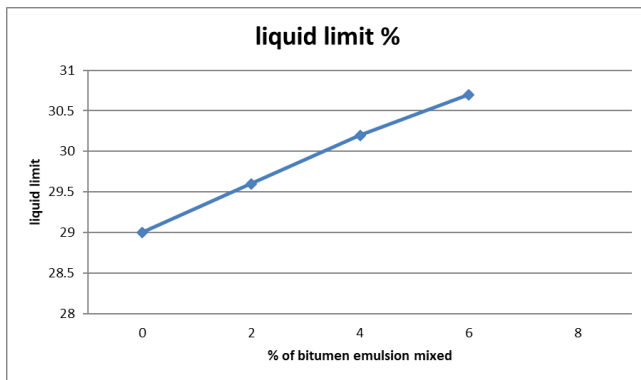


Fig 3: liquid limit for soil sample

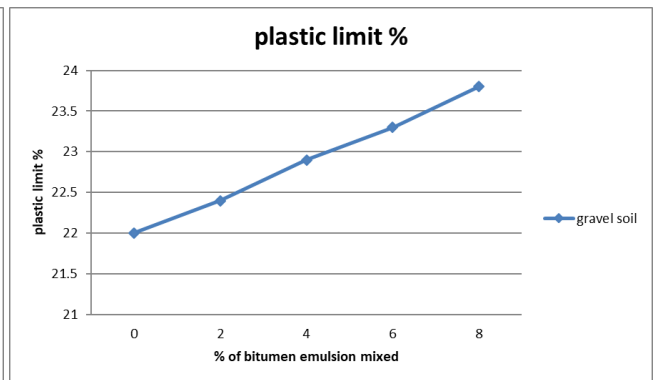


Fig 4: plastic limit for soil sample

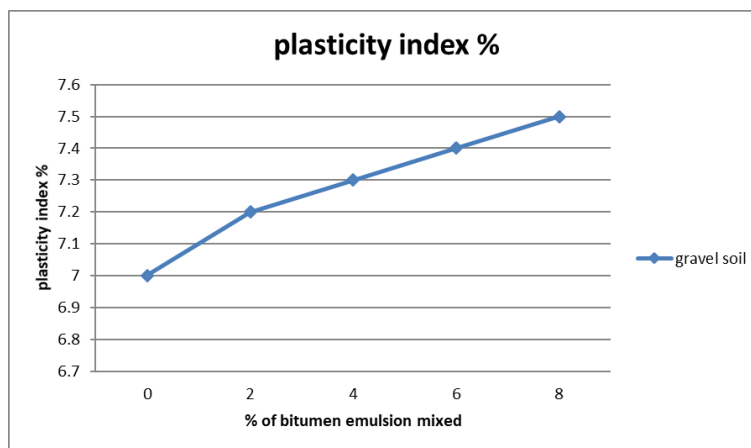


Fig 5: plasticity index for soil sample

**Compaction test**

The compaction characteristics of gravel soil and bitumen emulsion mixture, showing optimum moisture content (OMC) and maximum dry density (MDD) of the compacted soils. OMC gets increased with increase in the bitumen

emulsion percentage. MDD values also gets increased with the bitumen percentage compared to the normal gravel soil. MDD is increased due to the high specific gravity of the mixture.

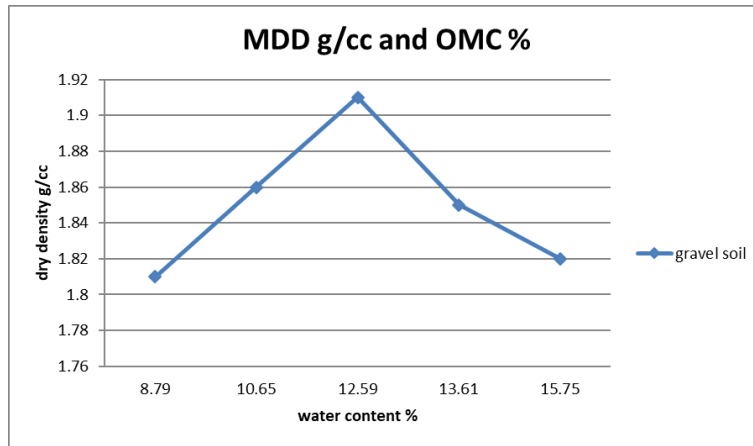


Fig 6: Compaction tests for MDD AND OMC

From graph above, it is evident that;  
Optimum moisture content OMC =12.62% APPROX 13%

Maximum dry density MDD =1.96g/cc APPROX 2g/cc

Table 5: OMC and MDD values of gravel soil and emulsion mixed with soil

Sr. No.	Sample	MDD g/cc	OMC%
1	Gravel soil	2	13
2	Gravel soil + 2% bitumen emulsion	2.04	13.26
3	Gravel soil + 4% bitumen emulsion	2.08	13.52
4	Gravel soil + 6% bitumen emulsion	2.12	14
5	Gravel soil + 8% bitumen emulsion	2.16	14.10

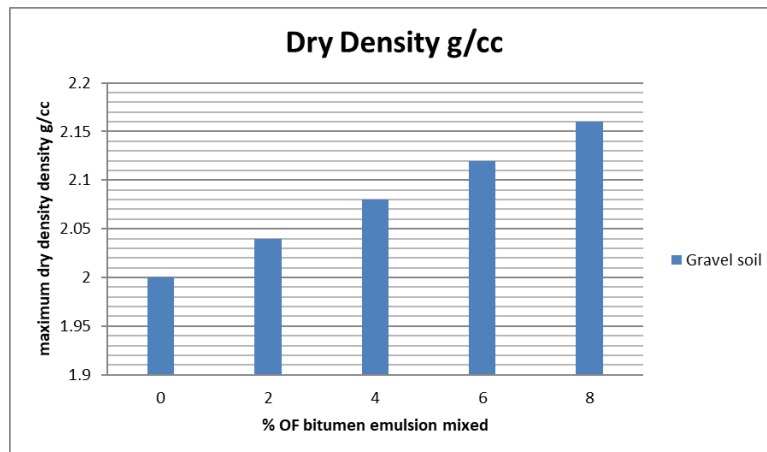


Fig 7: variation of Maximum Dry Density value

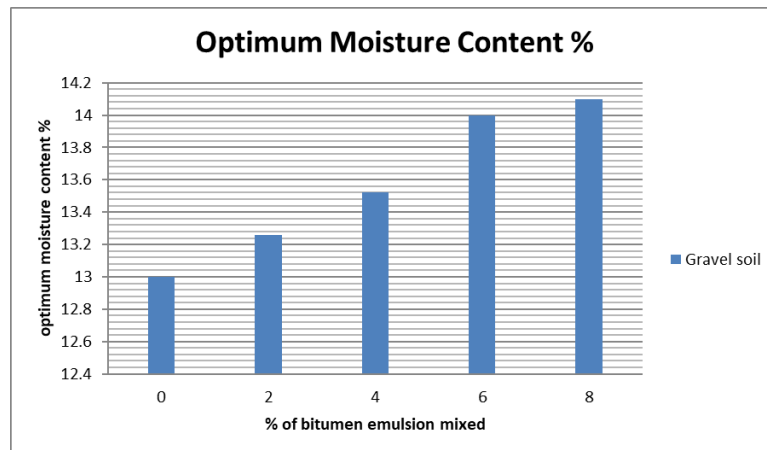


Fig 8: variation of Optimum Moisture Content value

**4.5 California bearing ratio test**

The data collected for the determination of California bearing ratio of soil with different percentages of bitumen emulsion are tabulated below:

MDD g/cc = 2

OMC % = 13

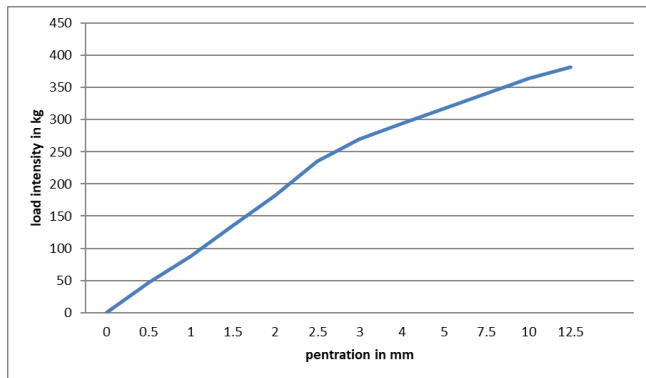
Weight of original sample = 6.800 kg

Surcharge = 5kg

Soaking hours = 96hrs

**Table 6:** Soaked and unsoaked values for CBR test

	Before soaking			After soaking		
	10	20	30	10	20	30
No. of blows	10	20	30	10	20	30
Mould no.	01	02	03	01	02	03
Volume of mould in cc (v)	2250	2250	2250	2250	2250	2250
Weight of mould W1 (gm)	6455	6480	6825	6455	6480	6825
Weight of mould + compacted soil W2 (gm)	10790	10350	11890	10970	11515	11990
Weight of compacted soil W3=W2-W1 (gm)	4335	3870	5065	4515	5035	5165
Wet density of soil Dw= W3/V	1.93	1.72	2.25	2.01	2.24	2.30



**Fig 9:** plot for CBR data for normal available soil (un soaked)

$$\text{CBR at 2.5mm} = \frac{235}{1270} \times 100 = 17.15\%$$

$$\text{CBR at 5.0mm} = \frac{317.25}{2055} \times 100 = 15.43\%$$

**Case A**

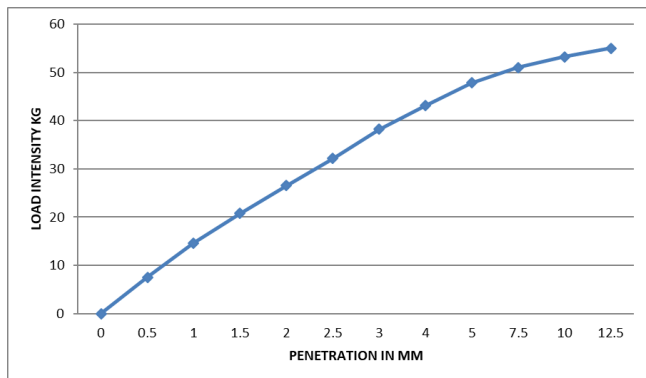
**Mould size:** standard volume 2250cc

Normal available soil tested with 2% of bitumen emulsion (soaked)

MDD = 2g/cc

OMC = 13%

CBR values at 2.5mm penetration and 5.0mm penetration is calculated



**Fig 10:** Plot for CBR of soil with 2% bitumen emulsion

1. soaked CBR value of soil with 2% B.E at 2.5mm penetration is 2.35%
2. soaked CBR value of soil with 2% B.E at 5.0mm penetration is 2.33%

**Case B**

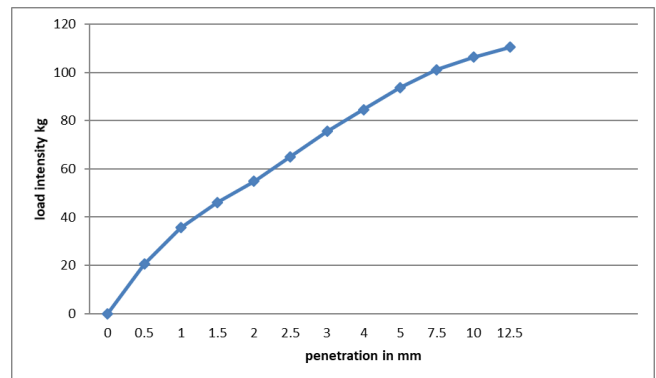
**Mould size:** standard volume 2250cc

Normal available soil tested with 4% of bitumen emulsion (soaked)

MDD = 2g/cc

OMC = 13%

CBR values at 2.5mm penetration and 5.0mm penetration is calculated



**Fig 11:** plot for CBR of soil with 4% bitumen emulsion

1. soaked CBR value of soil with 4% B.E at 2.5mm penetration is 4.74%
2. soaked CBR value of soil with 4% B.E at 5.0mm penetration is 4.55%

**Case C:**

**Mould size:** standard volume 2250cc

Normal available soil tested with 6% of bitumen emulsion (soaked)

MDD = 2g/cc

OMC = 13%

CBR values at 2.5mm penetration and 5.0mm penetration is calculated

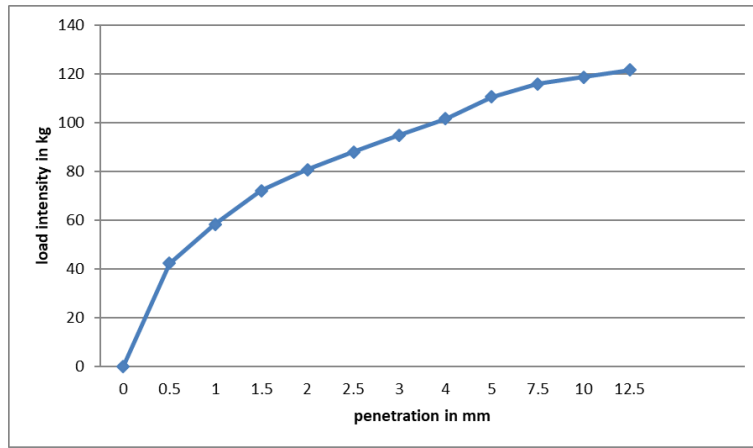


Fig 12: plot for CBR of soil with 6% bitumen emulsion

1. soaked CBR value of soil with 6% B.E at 2.5mm penetration is 6.4%
2. soaked CBR value of soil with 6% B.E at 5.0mm penetration is 5.4%

**Case D:**

3. **Mould size:** standard volume 2250cc
4. Normal available soil tested with 8% of bitumen emulsion (soaked)
5. MDD = 2g/cc
6. OMC = 13%
7. CBR values at 2.5mm penetration and 5.0mm penetration is calculated

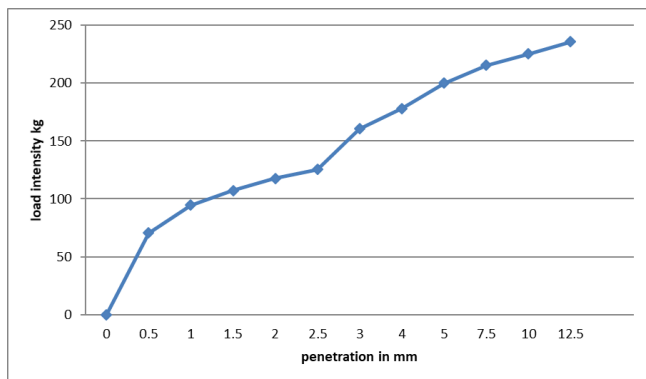


Fig 13: Plot for CBR of soil with 8% bitumen emulsion

1. soaked CBR value of soil with 8% B.E at 2.5mm penetration is 9.14%
2. soaked CBR value of soil with 8% B.E at 5.0mm penetration is 9.01%

**Conclusions**

Based on analysis and interpretation of experimental investigation following conclusions are drawn

**1. Maximum dry density and Optimum moisture content**  
 To study the effect of addition of bitumen emulsion in soil on MDD and OMC relationship different percentages of bitumen emulsion is added and optimised. It is interpreted that there is increase in MDD and OMC with addition of bitumen emulsion. The maximum dry density is occurred at 13% optimum moisture content from compaction test.

**2. California bearing ratio (soaked)**

1. The addition of 2% bitumen emulsion gives CBR

- values as 2.35% and 2.33% for soaked tests at 2.5mm and 5.0mm penetration respectively.
2. The addition of 4% bitumen emulsion gives CBR values as 4.74% and 4.55% for soaked tests at 2.5mm and 5.0mm penetration respectively.
3. The addition of 6% bitumen emulsion gives CBR values as 6.4% and 5.4% for soaked tests at 2.5mm and 5.0mm penetration respectively.
4. The addition of 8% bitumen emulsion gives CBR values as 9.14% and 9.01% for soaked tests at 2.5mm and 5.0mm penetration respectively.

The best results are obtained when the soil is left for soaking after mixing with bitumen. The soaked CBR values of soil samples increases considerably with addition of bitumen emulsion as compared to the normal soil. The stabilization of gravel soil with bitumen emulsion gives better strength to subgrade soil in pavement design.

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