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EXPERIMENTAL STUDY ON THE USE OF BITUMEN EMULSION IN THE STABLIZATION OF SUB-GRADE SOIL

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Abstract- Soil serves as the foundation for various construction projects, and its strength is a crucial factor in determining the stability and longevity of structures like roads. The subgrade, which is the natural soil or rock that lies below the pavement layers, plays a vital role in road pavement design. If the subgrade's strength is inadequate, stabilization techniques are often employed to enhance its properties.

Stabilization involves modifying the soil's properties to achieve better strength and durability. Common stabilizing agents include cement, fly ash, lime, and fibres. In this study, I am exploring the potential of using bitumen emulsion, specifically cationic bitumen emulsion (CMS), along with a small quantity of cement to improve the strength of gravel soil.

The California Bearing Ratio (CBR) is a standard test used to evaluate the mechanical strength of soils. A higher CBR value indicates better strength and load-bearing capacity. My study aims to enhance the CBR values of gravel soil by introducing bitumen emulsion and cement. This could lead to economic benefits by potentially reducing the required thickness of pavement layers.

The experimental process involves mixing the gravel soil with the bitumen emulsion and cement under specific conditions to optimize the resulting dry density and CBR value. These conditions are carefully chosen to assess the variations in strength properties and achieve the best possible outcomes for the gravel soil's strength.

Overall, my study highlights the importance of soil stabilization in construction, introduces the use of bitumen emulsion as a potential stabilizing agent, and emphasizes the significance of CBR values in evaluating soil strength. This research could contribute to more cost-effective and durable pavement designs.

Key words- Soil Stabilization, Dry density, California Bearing Ratio, Bitumen emulsion.

INTRODUCTION-

General

Soil plays a crucial role in construction and infrastructure development. The excerpt highlights the significance of soil in construction, particularly in terms of pavement structures. Here is a breakdown of the main points:[1]

1. Importance of Soil in Construction: Soil is a naturally abundant construction material that serves as a foundation for various construction projects. Almost all types of construction rely on or are built upon soil. This emphasizes the fundamental role soil plays in the built environment.

2. Impact on Pavement Performance: The long-term performance of pavement structures is heavily influenced by the strength and durability of the subgrade soils. The subgrade is the natural soil beneath a pavement structure that provides support. The quality of this subgrade soil has a direct impact on the performance of the pavement under the loads and stresses from traffic and environmental conditions.

3. Challenges with In-Situ Sub-Grades: Often, the natural in-situ subgrade soils do not possess the required strength and stability to ensure satisfactory performance under the anticipated traffic loads and changing environmental demands. This deficiency can lead to premature pavement deterioration, rutting, and other forms of distress.

4. Stabilization as a Solution: Stabilization is a recognized technique for enhancing the engineering properties of soil. It involves treating the soil with various stabilizers (such as lime, cement, or additives) to improve its strength, stability, and durability. This process aims to transform the subgrade soil into a more suitable material for supporting pavement structures.

5. Variability in Stabilization Results: However, the effectiveness of soil stabilization can vary significantly due to several factors. These include the natural variability in soil composition, differences in the micro and macro structures of different soils, variations in the geological deposits where soils are sourced, and the chemical interactions between the soil and the stabilizing agents.

6. Site-Specific Treatment: Given the variations mentioned above, the implementation of soil stabilization requires a site-specific approach. There is a need to carefully consider the specific conditions of the project site, including the type of soil, local geological characteristics, and the expected traffic and environmental loads.

7. Testing and Validation: Determining the appropriate treatment and stabilizers for a specific soil requires thorough testing. This involves creating soil-stabilizer mixtures and conducting laboratory tests to assess how the mixture's properties change. Through these tests, engineers can determine the most effective combination of stabilizers and treatment methods for achieving the desired engineering properties.

The subgrade refers to the compacted layer of soil beneath the pavement that serves as a foundation for the pavement structure. It plays a crucial role in distributing the loads from traffic and preventing pavement distress.[2]

The quality and characteristics of the subgrade soil are significant factors in determining the overall strength and stability of the pavement. If the subgrade soil is not adequately compacted or lacks the required strength, it can lead to pavement failures such as rutting, cracking, and settling. Therefore, ensuring the subgrade soil is of good quality and properly compacted is essential to maintain the longevity and performance of the pavement.[3]

Soil stabilization methods are used to improve the engineering properties of the subgrade soil, enhancing its strength and load-bearing capacity. There are two primary methods of soil stabilization:[4]

1. Mechanical Stabilization: This method involves physically altering the properties of the soil by mixing it with other materials to improve its strength and stability. Common techniques include adding aggregates (such as crushed stones) or geosynthetic materials to the soil to increase its load-bearing capacity.

2. Chemical or Additive Stabilization: Chemical methods involve introducing certain additives, such as cement, lime, or fly ash, into the soil to enhance its properties. These additives react with the soil particles to improve cohesion, reduce plasticity, and increase strength.

Both mechanical and chemical stabilization methods are employed based on the specific characteristics of the subgrade soil and the requirements of the pavement design. The goal is to create a subgrade that can better withstand the stresses imposed by traffic loads, thereby improving the overall performance and durability of the pavement structure.

The quality of the subgrade and the chosen stabilization method can impact the design of the pavement, influencing factors like pavement thickness and layer compositions. The aim is to create a pavement system that effectively distributes the traffic loads and ensures long-term functionality while minimizing maintenance and repair needs.[6]

Mechanical soil stabilization involves compaction of soil and the introduction of non-biodegradable reinforcements, while chemical methods involve adding substances like cement, lime, bitumen, etc. to improve soil properties.

About the project- research project related to pavement construction and soil stabilization using bitumen emulsion. This involves improving the properties of the soil and optimizing the strength and stability of the pavement layers. The Indian Road Congress outlines methodologies for pavement layers based on the quality of the subgrade, which is typically expressed in terms of California Bearing Ratio (CBR). CBR is a measure of the strength of subgrade soil under different conditions, often expressed as a percentage. Higher CBR values indicate better subgrade strength. The project utilizes locally available red-coloured laterite type gravel soil as the experimental material.

Laterite is a type of soil commonly found in tropical regions and can vary in its properties. Medium setting emulsion (MS) is used as a stabilizing agent in this study. Emulsions are mixtures of bitumen and water, and they are used to modify and improve the properties of soil. Bitumen sand stabilization is employed to enhance soil strength and resistance to water and frost. Bitumen is an effective stabilizing agent, particularly for sand, but it is noted that its use for soil stabilization can be costly. There is no standardized process or method for bitumen soil stabilization in Indian Standards. This means that this study is likely exploring a novel approach to this stabilization process.[4]

The project involves specific tests such as the Modified Compaction Test and the CBR Test. These tests are likely conducted to assess the changes in soil properties after the introduction of bitumen emulsion and to optimize the dry density of the stabilized soil. The main objective of the project seems to be focused on optimizing the stability of the soil and pavement layers. This might involve adjusting the mixing process with the bitumen emulsion to achieve the desired properties.

Objective and Scope of Research: -

The main objective of this experimental study is to enhance the properties of gravely soil by incorporating bitumen emulsion as a stabilizing agent and a small amount of cement as a filler. The purpose is to utilize emulsion to bolster the strength and geotechnical characteristics of gravel soil. Importantly, the use of bitumen emulsion is considered environmentally acceptable. The overarching goal of the project is to conduct a series of laboratory experiments to achieve these improvements.

The experiments include the following:

Specific Gravity: Determining the specific gravity of the soil sample. Specific gravity provides insight into the density and composition of the soil.

Grain Size Distribution: Analysing the distribution of grain sizes within the soil sample. This helps in understanding the soil's particle composition and its potential impact on stability.

Liquid Limit and Plastic Limit Tests: Conducting tests to determine the liquid limit and plastic limit of the soil. These tests help classify the soil and understand its plasticity and behaviour under different moisture conditions.

Standard Proctor Test: Performing a Standard Proctor compaction test to identify the maximum dry density and optimum moisture content of the soil sample. This information is crucial for designing stable structures on the soil.

CBR (California Bearing Ratio) Test: Carrying out CBR tests on soil samples mixed with both emulsion and cement. The CBR test assesses the load-bearing capacity of a soil under different conditions, simulating the soil's performance as a subgrade material. By using emulsion and cement, the aim is to increase the CBR value, indicating improved load-bearing capacity.

The ultimate objective of this innovation is to maximize the CBR value of the soil subgrade. This involves experimenting with various conditions, such as different ratios of bitumen emulsion and cement, to identify the combination that results in the highest CBR value. A higher CBR value implies that the soil can support heavier loads without significant deformation.

RESULTS AND DISCUSSION

Water content test by oven drying method: - Red-coloured laterite type gravel soil collected in the closed container from the field. Following readings have been taken-
Weight of empty container(W1) = 20gm
Weight the container with the soil(W2) =127gm
Weight the container with the dried soil(W3) =106gm
Weight of moist soil = W2-W1 = 157-50= 107gm
Weight of dry soil = W3-W1 = 136-50 = 86gm
Weight of water = Weight of moist soil- weight of dry soil= 107-86= 21gm
Water content= (Weight of water/Weight of dry soil) x100
= (21/ 86) x100 = 24.41%
The water content of red-coloured laterite type gravel soil is **24.41%**

Specific gravity test: - Specific gravity of soil is very important property to understand the soil condition. As previously discussed 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 1: Results of Specific gravity test

S. No.	Observation Number	1	2	3
1	Mass of Empty Pycnometer (M1 gm)	653gm	653gm	653gm
2	Mass of Pycnometer + dry soil (M2 gm)	853gm	880gm	872gm
3	Mass of Pycnometer + dry soil + water at temperature T 26^{0}C (M3 gm)	1682gm	1700gm	1692gm
4	Mass of Pycnometer + water (M4 gm) at temperature T 26^0 C	1558gm	1558gm	1558gm
5	Specific gravity G at T 26^0 C = (M2 - M1) / [(M4 - M1) - (M3 – M2)]	2.63	2.67	2.58
6	Average specific gravity at T 26^0 C	**2.62**		

Liquid limit plasticity limit test: - The gravel soil used in this study was course grained soil obtained from local road routes in Udaipur, Rajasthan. The soil was tested for water content, specific gravity, liquid limit, plastic limit, and grain size distribution as to be well known about physical properties of this soil material. From these experimental results a proper idea about the type of soil has been found.
Liquid Limit (WL): **25.41%**
Plastic Limit (WP): **18.37%**
Plasticity Index (IP): **7.04%**

Grain size distribution test: -
In this test the sample of 2000 gm of soil was taken and dried in oven for 24 hours.
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 results

Sieve Size	Mass of Soil Retained in each sieve (gm)	Percent Retained (%)	Cumulative Retained (%)	Percent Finer (%)
12.5mm	0	0	0	100
9.5mm	88	4.4	4.4	95.6
6.3mm	290	14.5	18.9	81.1
4.75mm	313	15.65	34.55	65.45
2.36mm	560	28.0	62.55	37.45
1.18mm	240	12.0	74.55	25.45
600micron	187	9.35	83.9	16.1
300micron	140	7.0	90.9	9.1
150micron	90	4.5	95.4	4.6
Pan	92	-----	------	-----

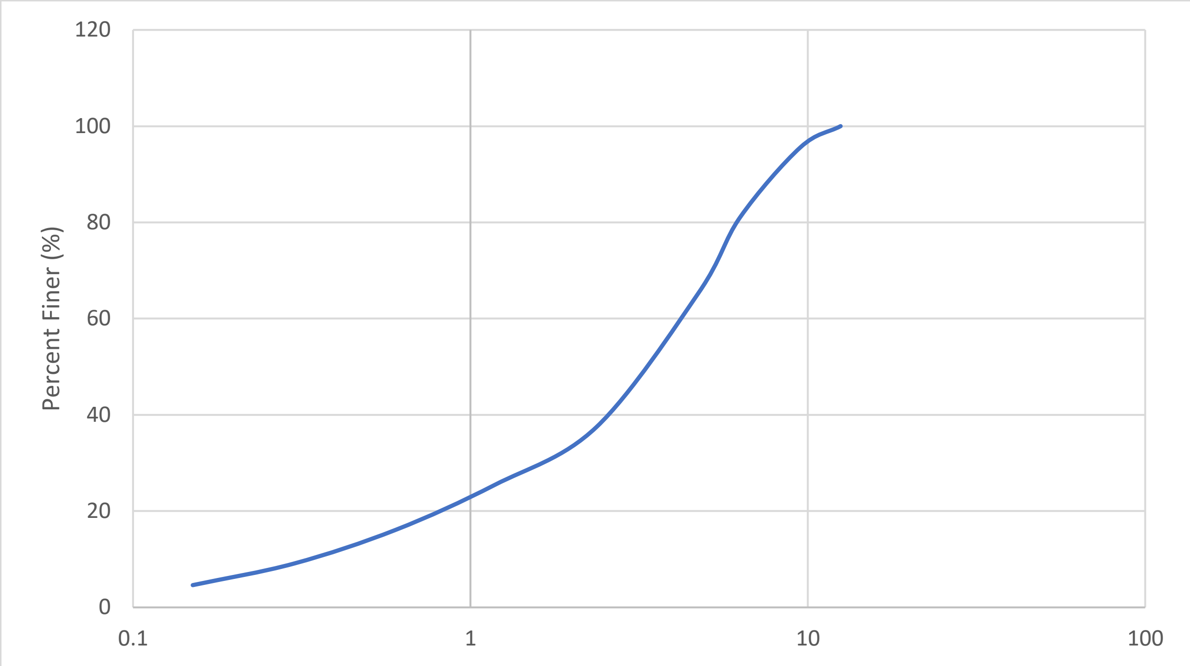

Fig. 1 Grain size distribution graph

After plotting the graph of grain size distribution, the available soil is well graded soil.

Compaction test: - Therefore four conditions for testing are used here to check the variation of maximum dry density of this gravel soil mixing with emulsion.

Case A: Locally available soil is used for testing.

Case B: Locally available soil tested with 4% MS emulsion added.

Case C: Locally available soil with 4% MS emulsion and 2% cement added.

Case D: Locally available soil with 6% of emulsion and 2% of cement added.

In these four conditions modified proctor test is performed and plotted with moisture content percentage in X axis and corresponding dry density value in Y axis. From carves the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) was noted.

Case A: Locally available soil is used for testing: - In this case the sample is prepared from local available red-coloured laterite soil and the standard proctor test was performed at different water content.

OBSERVATIONS:

Table 3 Observation table of standard Proctor test of Case- A (Locally available soil is used for testing)

Mould Diameter -10cm, Heigh- 12.73cm, Volume- 1000 cc, Weight- 3568gm						
Determination No.	1	2	3	4	5	6
Weight of mould + compacted soil (gm)	5384	5480	5623	5832	5754	5534
Weight of compacted soil, W (gm)	1816	1912	2055	2284	2186	1966
Average moisture content, w %	3.6%	5.1%	7.2%	9.7%	11.1%	13.3%
Bulk density (gm /cc) = W / (Mould volume)	1.816	1.912	2.055	2.264	2.186	1.966
Dry density (gm/cc) = Bulk density/(1+w)	1.75	1.81	1.91	2.06	1.96	1.73

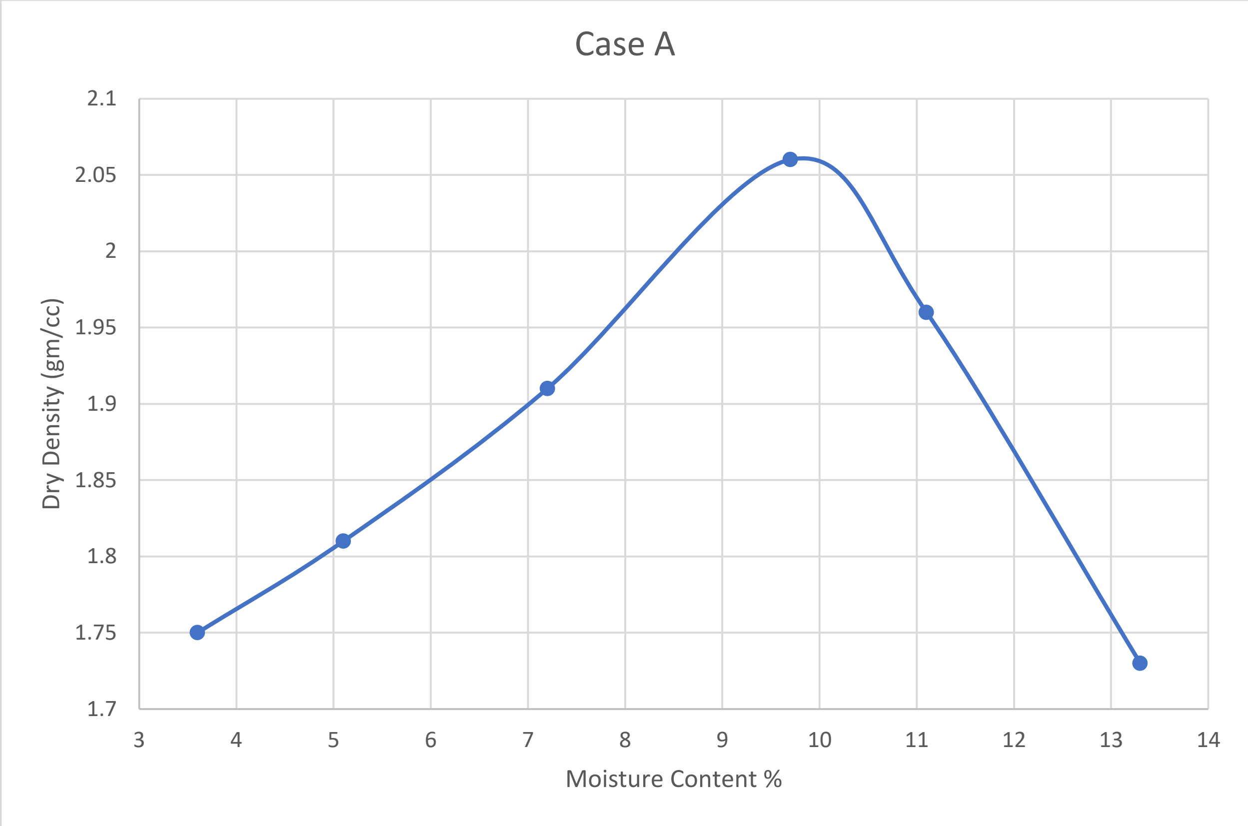

Fig. 5.2 Graph of Standard Proctor test of Case- A (Locally available soil is used for testing)

Case B: Locally available soil tested with 4% MS emulsion added: - In this case 4% MS emulsion were added in red-coloured laterite soil and standard proctor test at different water content was performed.

OBSERVATIONS:

Table 5.4 Observation table of Standard Proctor test of Case- B (Locally available soil tested with 4% MS emulsion added)

Mould Diameter- 10cm, Heigh- 12.73cm, Volume -1000 cc, Weight -3568gm						
Determination No.	1	2	3	4	5	6
Weight of mould + compacted soil (gm)	5401	5492	5743	5870	5824	5614
Weight of compacted soil, W (gm)	1833	1924	2175	2302	2265	2046
Average moisture content, w %	3.3%	5.2%	7.1%	9.9%	11.3%	13.5%
Bulk density (gm /cc) = W / (Mould volume)	1.833	1.924	2.175	2.343	2.265	2.046
Dry density (gm/cc) = Bulk density/(1+w)	1.77	1.83	2.03	2.09	2.03	1.80

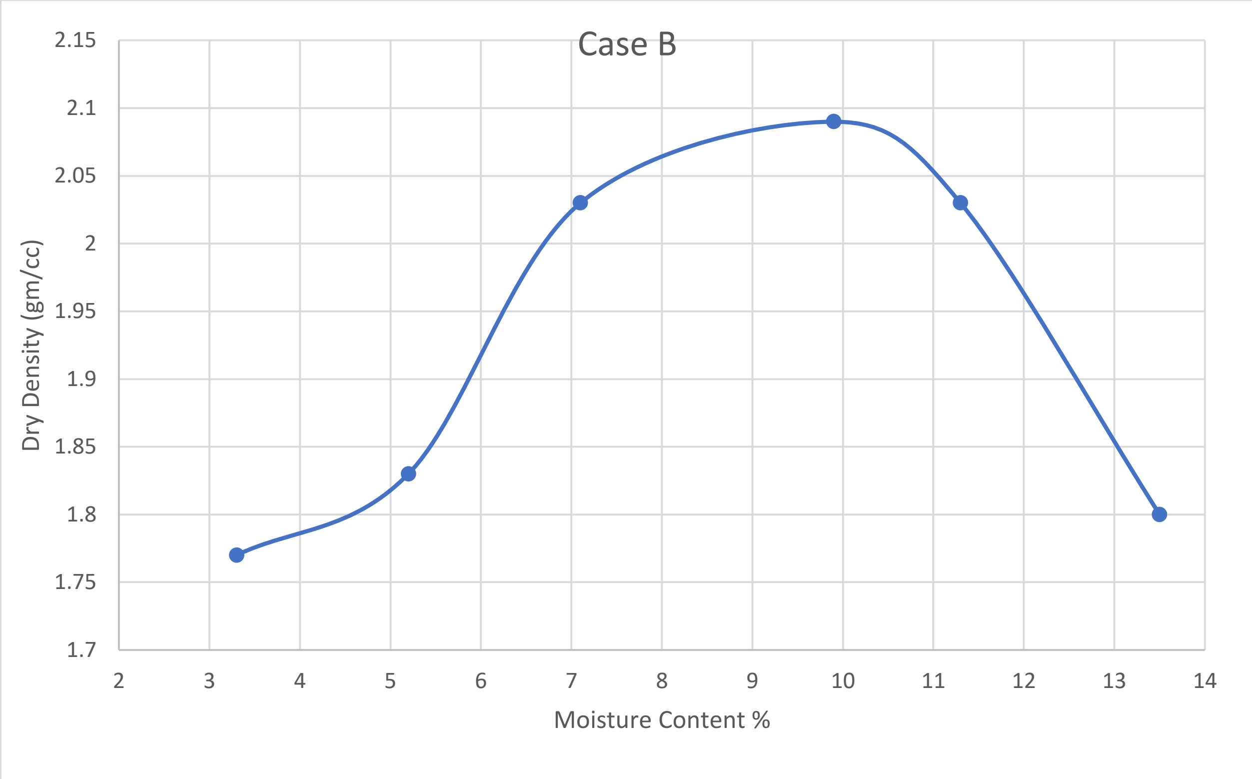

Fig. 3 Graph of Standard Proctor test of Case- B (Locally available soil tested with 4% MS emulsion added)

Case C: Locally available soil with 4% MS emulsion and 2% cement added: - In this case 4% MS emulsion were added along with 2% cement in red-coloured laterite soil and standard proctor test at different water content was performed.

OBSERVATIONS:

Table 5 Observation table of Standard Proctor test of Case- C (Locally available soil with 4% MS emulsion and 2% cement added)

Mould Diameter- 10cm, Heigh- 12.73cm, Volume -1000 cc, Weight- 3568gm						
Determination No.	1	2	3	4	5	6
Weight of mould + compacted soil (gm)	5451	5594	5764	5934	5814	5744
Weight of compacted soil, W (gm)	1883	2026	2196	2366	2246	2176
Average moisture content, w %	3.1%	5.4%	7.5%	9.8%	11.5%	13.7%
Bulk density (gm /cc) = W / (Mould volume)	1.883	2.026	2.196	2.366	2.246	2.176
Dry density (gm/cc) = Bulk density/(1+w)	1.82	1.92	2.04	2.15	2.01	1.91

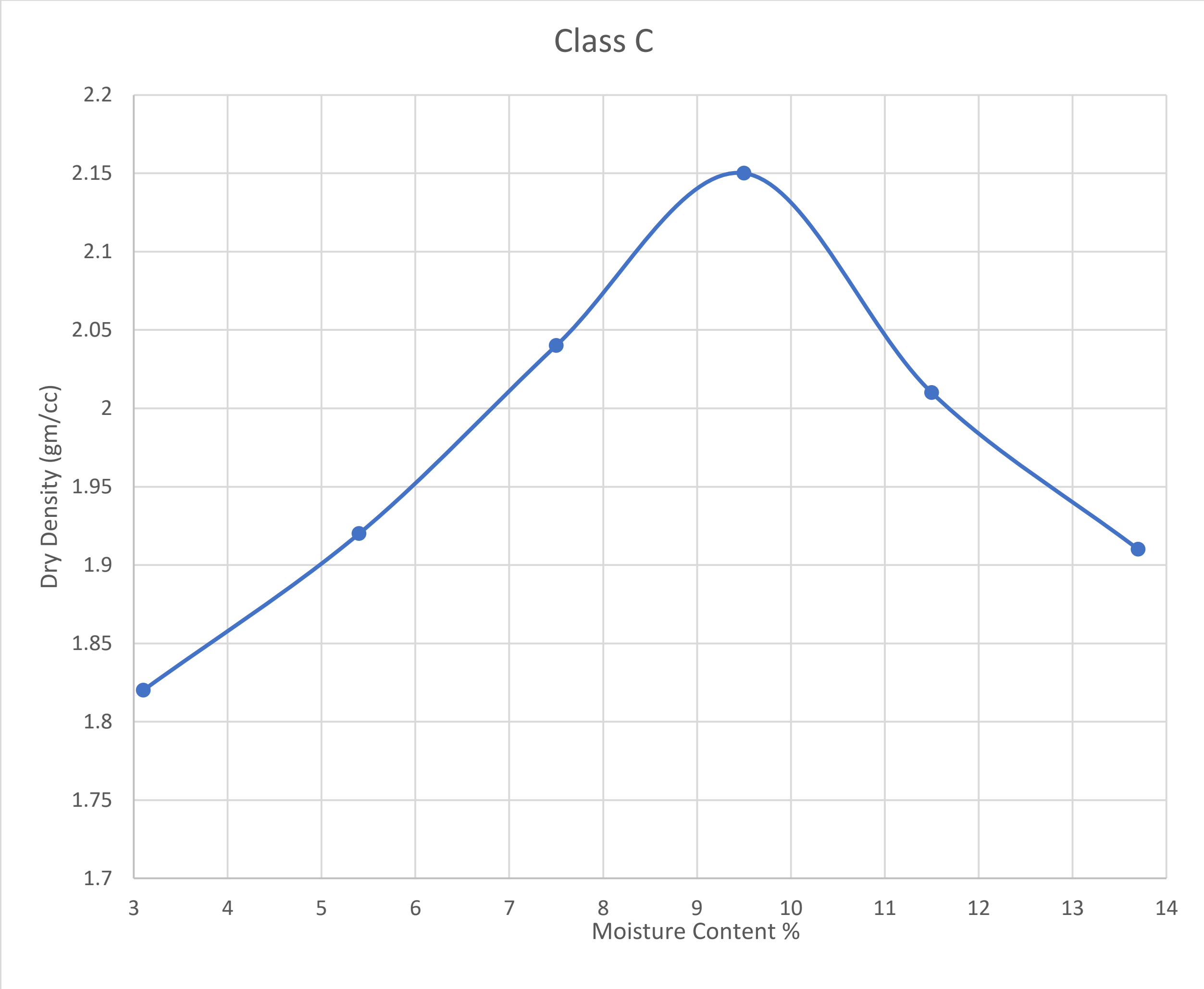

Fig. 4 Graph of Standard Proctor test of Case- C (Locally available soil with 4% MS emulsion and 2% cement added)

Case D: Locally available soil with 6% of emulsion and 2% of cement added: - In this case 6% MS emulsion were added along with 2% cement in red-coloured laterite soil and standard proctor test at different water content was performed.

OBSERVATIONS:

Table 6 Observation table of Standard Proctor test of Case- D (Locally available soil with 6% of emulsion and 2% of cement added)

Mould Diameter- 10cm, Heigh- 12.73cm, Volume -1000 cc, Weight -3568gm						
Determination No.	1	2	3	4	5	6
Weight of mould + compacted soil (gm)	5471	5597	5813	6033	5942	5722
Weight of compacted soil, W (gm)	1903	2029	2245	2465	2374	2154
Average moisture content, w %	3.5%	5.8%	7.6%	9.7%	11.3%	13.5%
Bulk density (gm /cc) = W / (Mould volume)	1.903	2.029	2.245	2.465	2.374	2.154
Dry density (gm/cc) = Bulk density/(1+w)	1.83	1.91	2.08	2.24	2.13	1.89

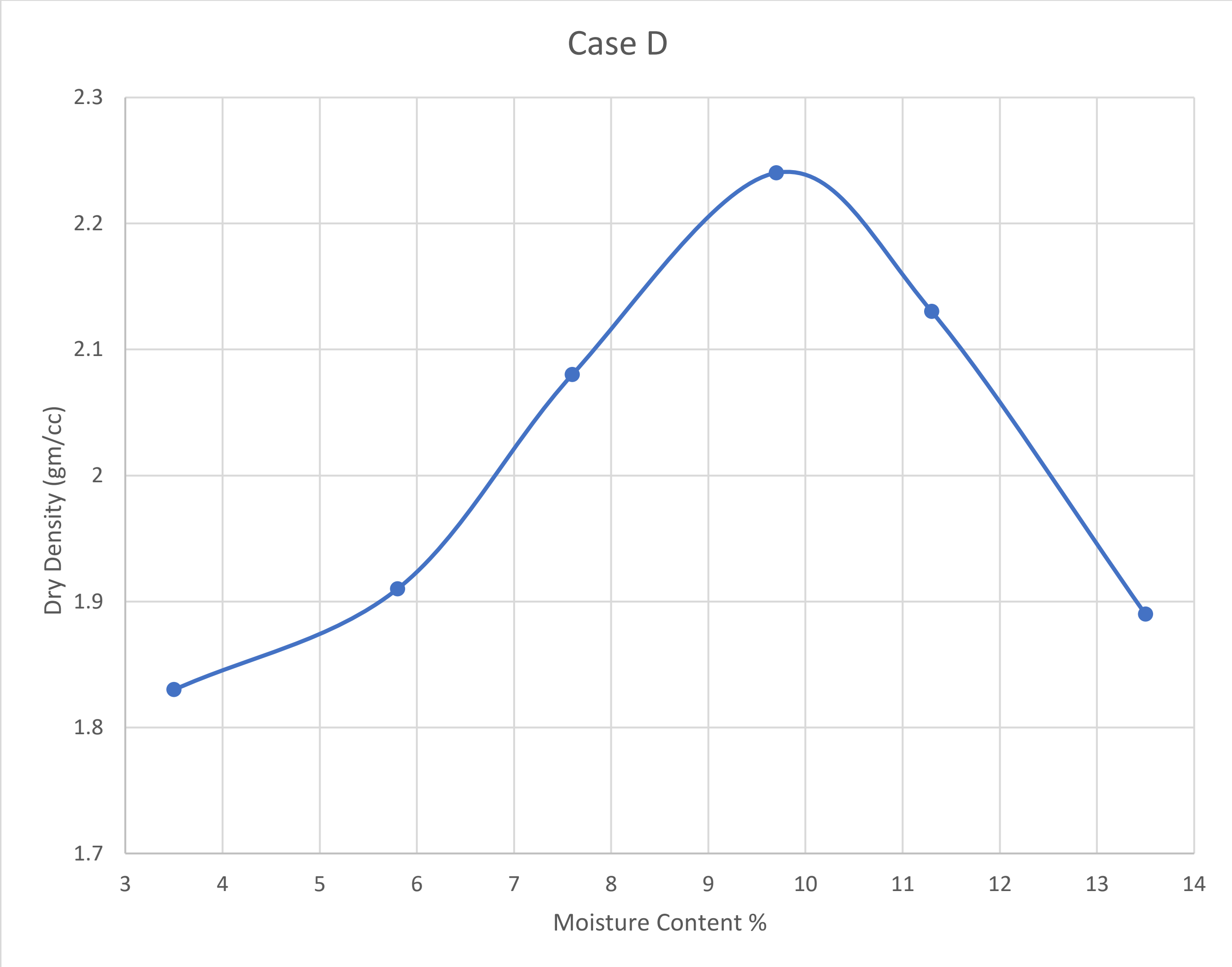

Fig. 5 Graph of Standard Proctor test of Case- D (Locally available soil with 6% of emulsion and 2% of cement added)

Summary of Standard Proctor Test-

Table 7 Summary of Standard Proctor Test

Case	Optimum Moisture Content (OMC)	Maximum Dry Density (MDD)
Case A	9.7	2.06
Case B	9.9	2.09
Case C	9.8	2.15
Case D	9.7	2.24

CBR test: - The CBR is the performed to measure the resistance of a material to penetration of a standard plunger under controlled density and moisture conditions. This is an normal test to find the subgrade strength before construction of road pavement. 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 is 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 reported for each specimen from the corresponding graphs and tables which are shown below. Generally, the CBR value at 2.5mm penetration is normally 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 types of specimens 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. Table of CBR value and the CBR graph is case wise shown below.

Case A: Locally available soil is used for testing: -

Size of mould: 2250 cc
Results of Standard proctor test of Case A.
Maximum Dry Density value: 2.06 gm./cc
Optimum Moisture Content: 9.7%
CBR test is done in two conditions. First one is in un-soaked condition and secondly in two days of soaking in water condition. CBR value at 2.5mm penetration and 5mm penetration are calculated.

OBSERVATIONS

Table 8 Case A: CBR Values in unsoaked condition

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	120	-----	-----
2	1.0	250	-----	-----
3	1.5	340	-----	-----
4	2.0	420	-----	-----
5	2.5	500	1370	36.49
6	3.0	550	-----	-----
7	3.5	600	-----	-----
8	4.0	650	-----	-----
9	4.5	700	-----	-----
10	5.0	750	2055	36.49
11	5.5	790	-----	-----
12	6.0	830	-----	-----
13	6.5	860	-----	-----
14	7.0	890	-----	-----
15	7.5	915	2630	-----
16	8.0	940	-----	-----
17	8.5	965	-----	-----
18	9.0	985	-----	-----
19	9.5	1005	-----	-----
20	10.0	1020	3180	-----
21	10.5	1035	-----	-----
22	11.0	1045	-----	-----
23	11.5	1055	-----	-----
24	12.0	1060	-----	-----
25	12.5	1065	-----	-----
26	13.0	1070	-----	-----

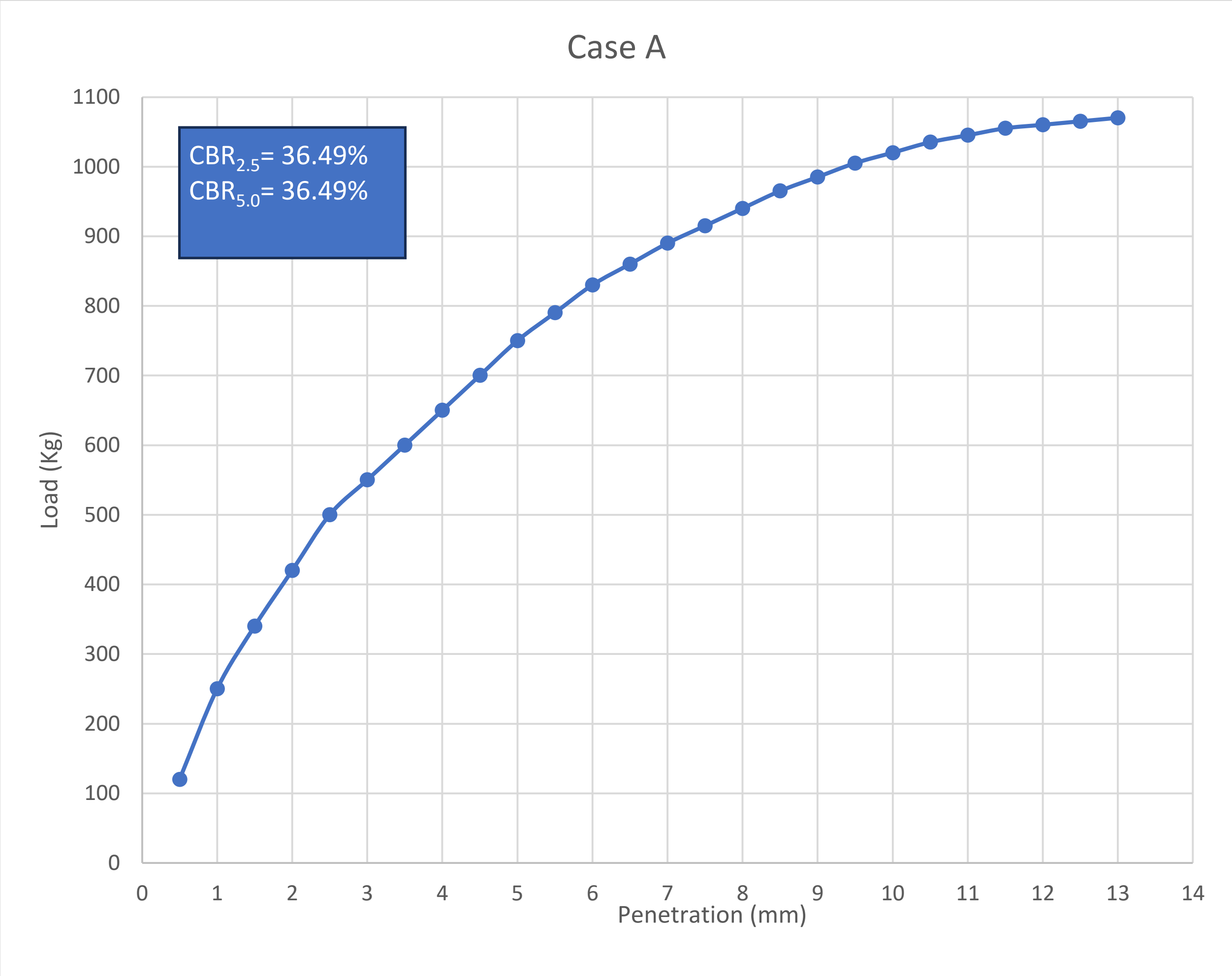

Fig. 6 Case A: CBR Values in unsoaked condition

Table 9 Case A: CBR Values for two days of soaking in water

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	20	-----	-----
2	1.0	55	-----	-----
3	1.5	82	-----	-----
4	2.0	110	-----	-----
5	2.5	133	1370	9.70
6	3.0	151	-----	-----
7	3.5	165	-----	-----
8	4.0	180	-----	-----
9	4.5	190	-----	-----
10	5.0	199	2055	9.68
11	5.5	220	-----	-----
12	6.0	230	-----	-----
13	6.5	239	-----	-----
14	7.0	248	-----	-----
15	7.5	257	2630	-----
16	8.0	265	-----	-----
17	8.5	273	-----	-----
18	9.0	280	-----	-----
19	9.5	286	-----	-----
20	10.0	291	3180	-----
21	10.5	295	-----	-----

22	11.0	298	-----	-----
23	11.5	301	-----	-----
24	12.0	303	-----	-----
25	12.5	304	-----	-----
26	13.0	305	-----	-----

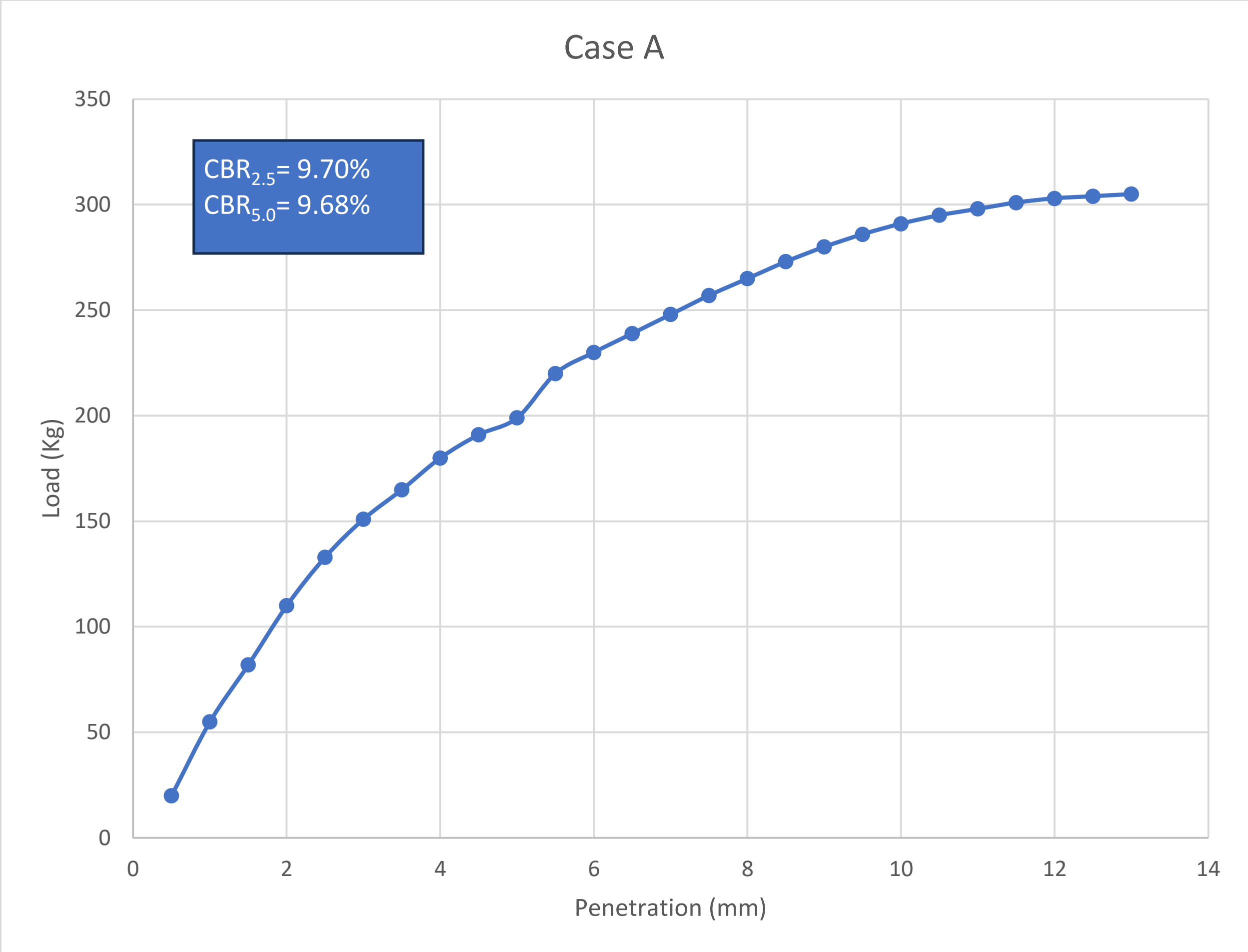

Fig. 7 Case A: CBR Values for two days of soaking in water

Case B: Locally available soil with 4% MS emulsion: -

Size of mould: 2250 cc
Results of Standard proctor test of Case B.
Maximum Dry Density value: 2.09 gm./cc
Optimum Moisture Content: 9.9 %
CBR test is done in two conditions. First one is in un-soaked condition and secondly in two days of soaking in water condition. CBR value at 2.5mm penetration and 5mm penetration are calculated.

OBSERVATIONS

Table 10 Case B: CBR Values in unsoaked condition

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	150	-----	-----
2	1.0	275	-----	-----
3	1.5	390	-----	-----
4	2.0	500	-----	-----
5	2.5	605	1370	44.16
6	3.0	690	-----	-----
7	3.5	760	-----	-----
8	4.0	820	-----	-----
9	4.5	870	-----	-----
10	5.0	907	2055	44.13
11	5.5	945	-----	-----
12	6.0	980	-----	-----
13	6.5	1015	-----	-----
14	7.0	1045	-----	-----
15	7.5	1073	2630	-----
16	8.0	1095	-----	-----
17	8.5	1116	-----	-----
18	9.0	1136	-----	-----
19	9.5	1155	-----	-----
20	10.0	1170	3180	-----
21	10.5	1182	-----	-----
22	11.0	1191	-----	-----
23	11.5	1197	-----	-----
24	12.0	1202	-----	-----
25	12.5	1207	-----	-----
26	13.0	1210	-----	-----

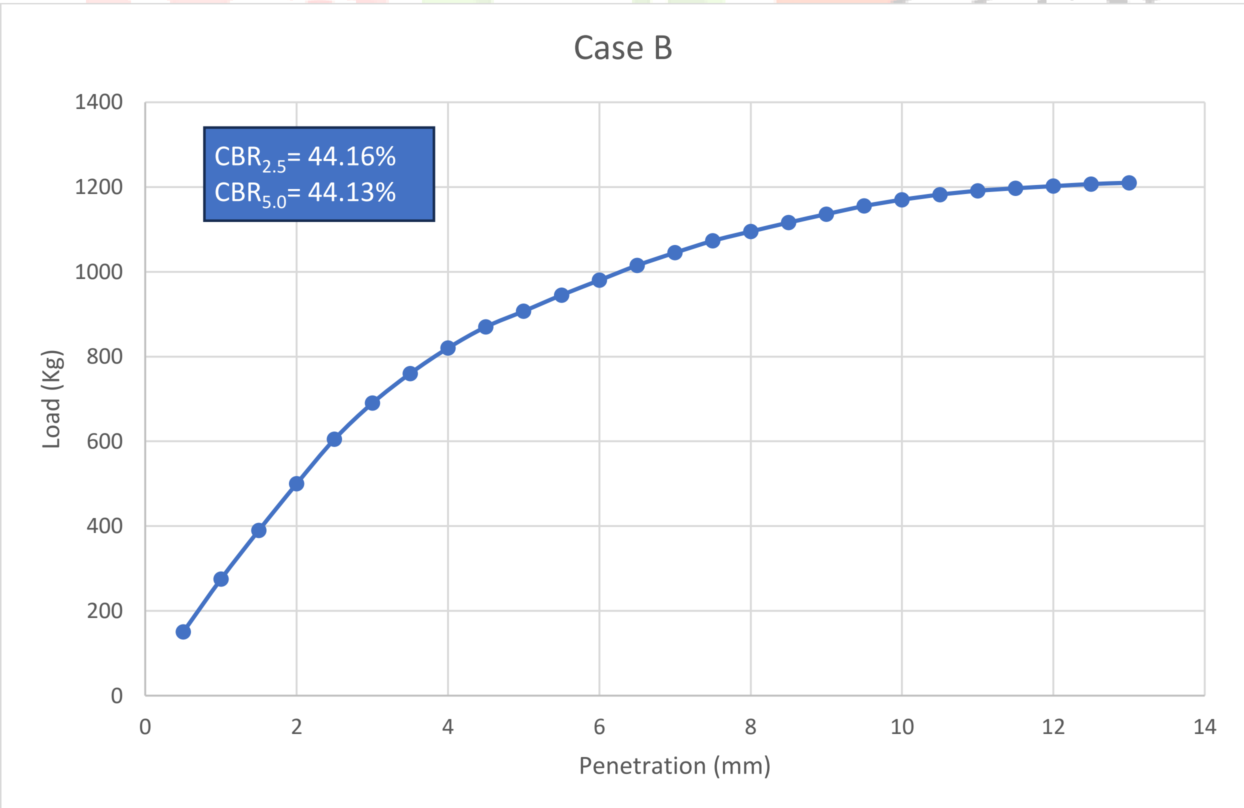

Fig. 8 Case B: CBR Values in unsoaked condition

Table 11 Case B: CBR Values for two days of soaking in water

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	35	-----	-----
2	1.0	75	-----	-----
3	1.5	120	-----	-----
4	2.0	155	-----	-----
5	2.5	203	1370	14.81
6	3.0	230	-----	-----
7	3.5	250	-----	-----
8	4.0	268	-----	-----
9	4.5	285	-----	-----
10	5.0	302	2055	14.69
11	5.5	316	-----	-----
12	6.0	330	-----	-----
13	6.5	343	-----	-----
14	7.0	355	-----	-----
15	7.5	366	2630	-----
16	8.0	377	-----	-----
17	8.5	387	-----	-----
18	9.0	397	-----	-----
19	9.5	406	-----	-----
20	10.0	415	3180	-----
21	10.5	424	-----	-----
22	11.0	432	-----	-----
23	11.5	440	-----	-----
24	12.0	447	-----	-----
25	12.5	454	-----	-----
26	13.0	460	-----	-----

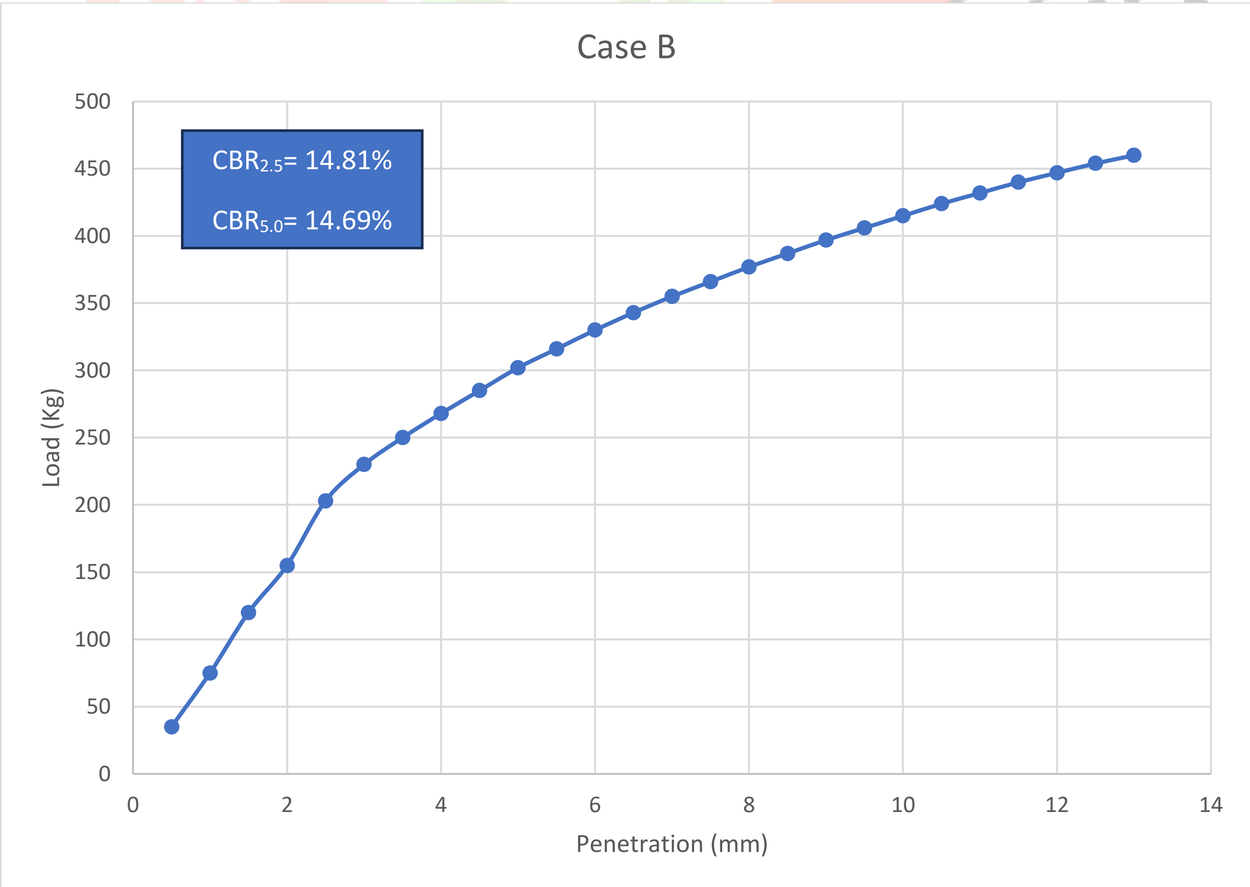

Fig. 9 Case B: CBR Values for two days of soaking in water

Case C: Locally available soil with 4% MS emulsion and 2% cement added: -
Size of mould: 2250 cc
Results of Standard proctor test of Case C.
Maximum Dry Density value: 2.15 gm./cc
Optimum Moisture Content: 9.8 %
CBR test is done in two conditions. First one is in un-soaked condition and secondly in two days of soaking in water condition. CBR value at 2.5mm penetration and 5mm penetration are calculated.

OBSERVATIONS

Table 12 Case C: CBR Values in unsoaked condition

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value at 2.5mm and 5.0mm penetration
1	0.5	160	-----	-----
2	1.0	300	-----	-----
3	1.5	415	-----	-----
4	2.0	550	-----	-----
5	2.5	647	1370	47.22
6	3.0	710	-----	-----
7	3.5	780	-----	-----
8	4.0	845	-----	-----
9	4.5	905	-----	-----
10	5.0	968	2055	47.10
11	5.5	1025	-----	-----
12	6.0	1080	-----	-----
13	6.5	1130	-----	-----
14	7.0	1170	-----	-----
15	7.5	1195	2630	-----
16	8.0	1210	-----	-----
17	8.5	1220	-----	-----
18	9.0	1225	-----	-----
19	9.5	1229	-----	-----
20	10.0	1233	3180	-----
21	10.5	1236	-----	-----
22	11.0	1239	-----	-----
23	11.5	1241	-----	-----
24	12.0	1243	-----	-----
25	12.5	1244	-----	-----
26	13.0	1245	-----	-----

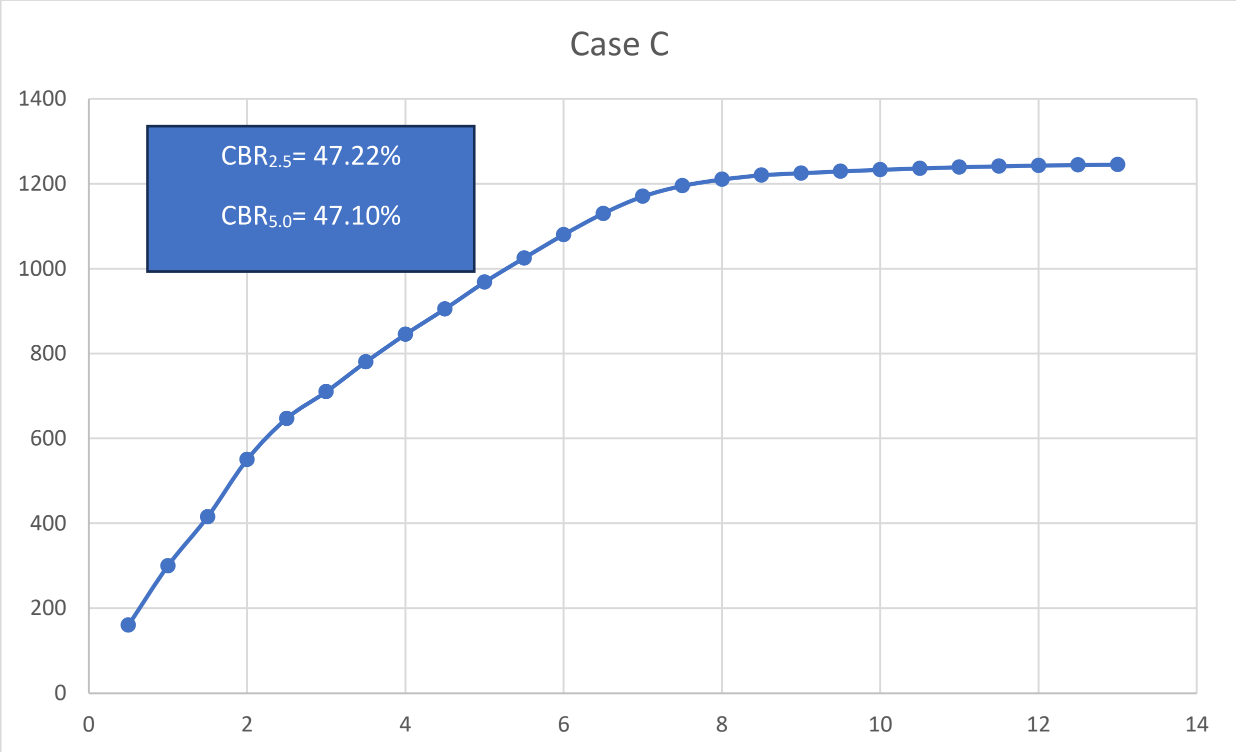

Fig. 10 Case C: CBR Values in unsoaked condition

Table 13 Case C: CBR Values for two days of soaking in water

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	38	-----	-----
2	1.0	85	-----	-----
3	1.5	145	-----	-----
4	2.0	196	-----	-----
5	2.5	251	1370	18.32
6	3.0	285	-----	-----
7	3.5	310	-----	-----
8	4.0	332	-----	-----
9	4.5	355	-----	-----
10	5.0	372	2055	18.10
11	5.5	387	-----	-----
12	6.0	402	-----	-----
13	6.5	416	-----	-----
14	7.0	429	-----	-----
15	7.5	442	2630	-----
16	8.0	454	-----	-----
17	8.5	465	-----	-----
18	9.0	476	-----	-----
19	9.5	485	-----	-----
20	10.0	494	3180	-----
21	10.5	502	-----	-----
22	11.0	510	-----	-----
23	11.5	518	-----	-----
24	12.0	525	-----	-----
25	12.5	532	-----	-----
26	13.0	538	-----	-----

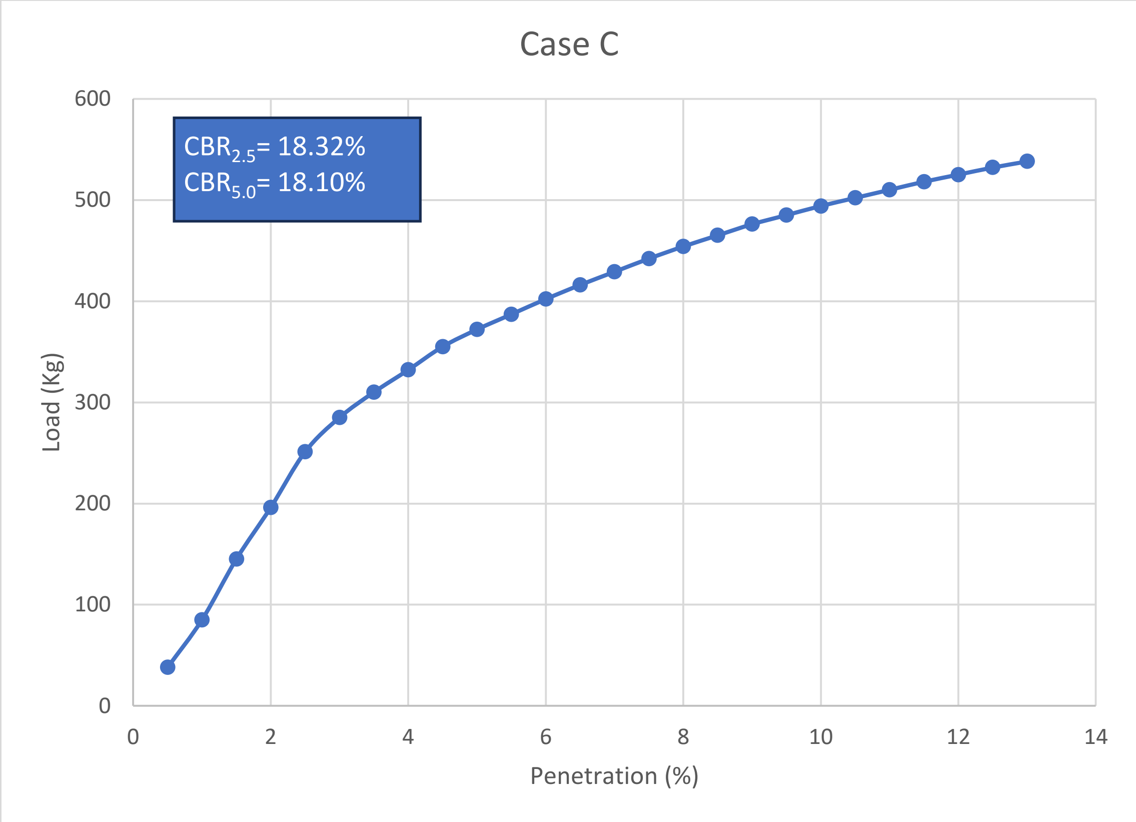

Fig. 11 Case C: CBR Values for two days of soaking in water

Case D: Locally available soil with 6% of emulsion and 2% of cement added: -

Size of mould: 2250 cc

Results of Standard proctor test of Case D.

Maximum Dry Density value: 2.24 gm./cc

Optimum Moisture Content: 9.7 %

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

OBSERVATIONS

Table 14 Case D: CBR Values in unsoaked condition

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	230	-----	-----
2	1.0	425	-----	-----
3	1.5	580	-----	-----
4	2.0	705	-----	-----
5	2.5	813	1370	59.34
6	3.0	914	-----	-----
7	3.5	1000	-----	-----
8	4.0	1080	-----	-----
9	4.5	1150	-----	-----
10	5.0	1214	2055	59.07
11	5.5	1264	-----	-----
12	6.0	1304	-----	-----
13	6.5	1336	-----	-----
14	7.0	1364	-----	-----
15	7.5	1389	2630	-----
16	8.0	1410	-----	-----
17	8.5	1425	-----	-----
18	9.0	1438	-----	-----
19	9.5	1450	-----	-----
20	10.0	1460	3180	-----
21	10.5	1467	-----	-----

22	11.0	1473	-----	-----
23	11.5	1480	-----	-----
24	12.0	1486	-----	-----
25	12.5	1491	-----	-----
26	13.0	1495	-----	-----

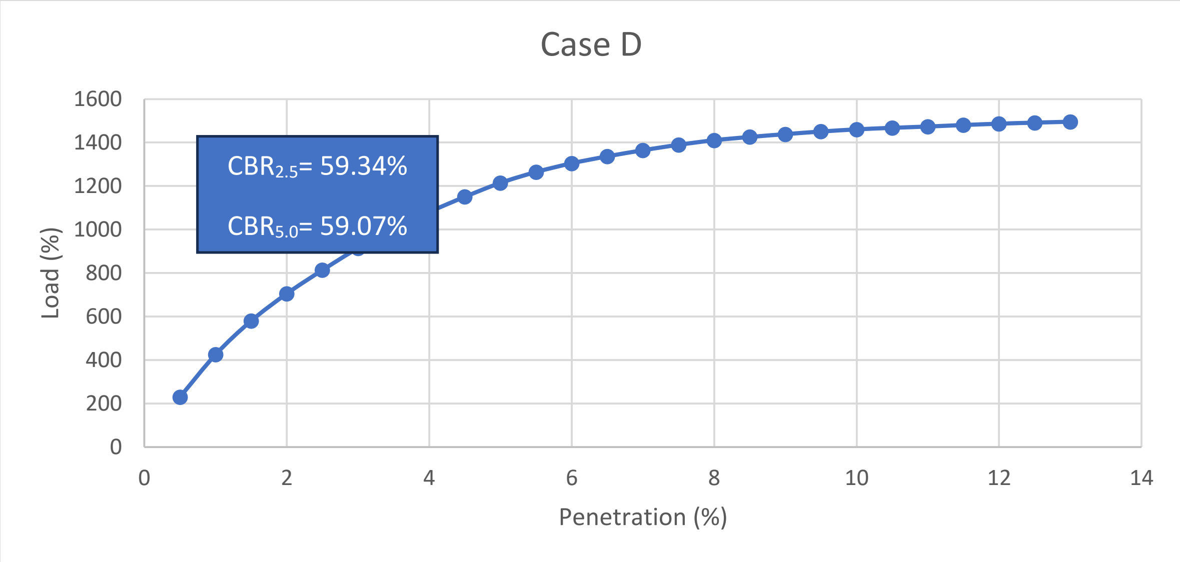

Fig. 12 Case D: CBR Values in unsoaked condition

Table 15 Case D: CBR Values for two days of soaking in water

S. No.	Penetration depth (mm)	Load (Kg)	Standard load (Kg)	CBR Value (%) at 2.5mm and 5.0mm penetration
1	0.5	70	-----	-----
2	1.0	150	-----	-----
3	1.5	220	-----	-----
4	2.0	275	-----	-----
5	2.5	330	1370	24.08
6	3.0	375	-----	-----
7	3.5	408	-----	-----
8	4.0	434	-----	-----
9	4.5	460	-----	-----
10	5.0	485	2055	23.60
11	5.5	507	-----	-----
12	6.0	527	-----	-----
13	6.5	545	-----	-----
14	7.0	560	-----	-----
15	7.5	572	2630	-----
16	8.0	582	-----	-----
17	8.5	590	-----	-----
18	9.0	597	-----	-----
19	9.5	603	-----	-----
20	10.0	608	3180	-----
21	10.5	613	-----	-----
22	11.0	617	-----	-----
23	11.5	620	-----	-----
24	12.0	622	-----	-----
25	12.5	623	-----	-----
26	13.0	624	-----	-----

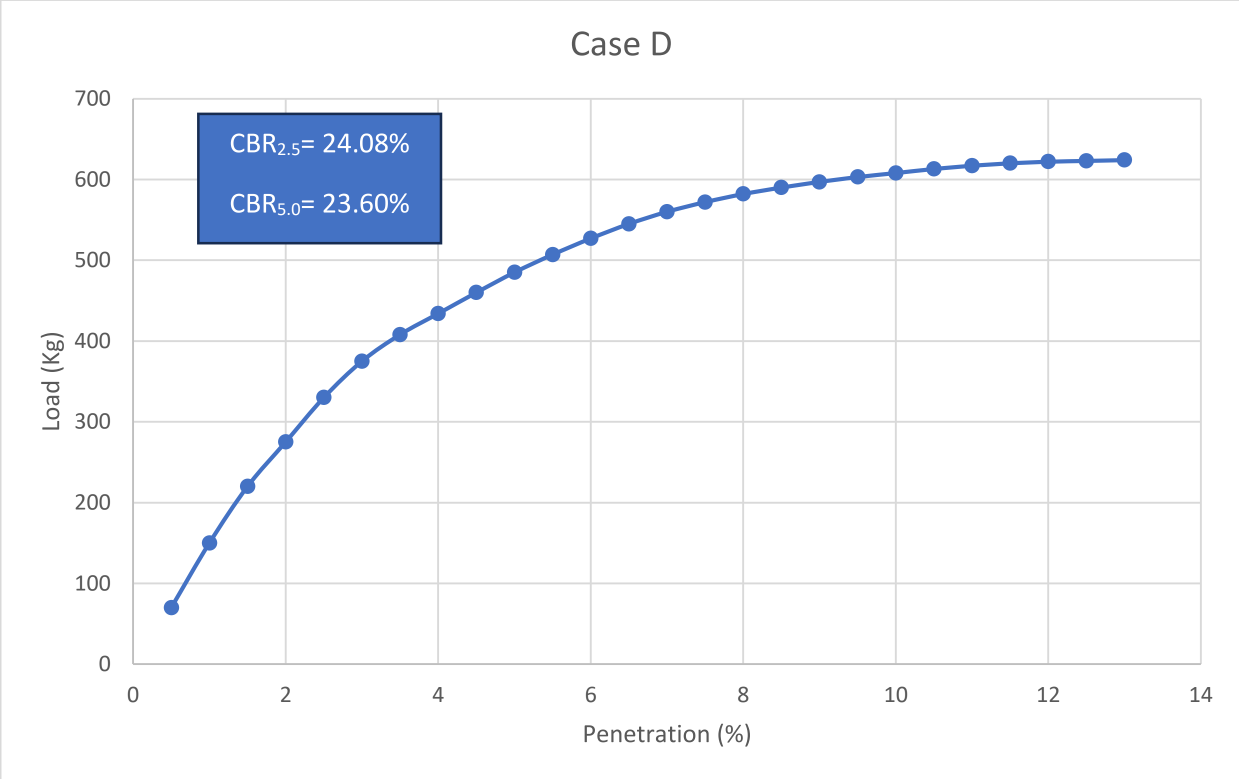

Fig. 13 Case D: CBR Values for two days of soaking in water

Discussion: - Subgrade may be defined as a compacted soil layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness, which supports the pavement layers. It provides a suitable foundation for the road pavement. So, it is very important to improve the 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.

CONCLUSION: - From this experimental study there is a considerable improvement in the value of California Bearing Ratio (CBR) of sub grade soil due to use of MS bitumen emulsion and cement if proper mixing is done. It is seen that it best results are obtained if the soil emulsion mix is left for about six hours after mixing. In each state of condition, it was found that CBR value has increased considerably from Case A to Case D. In this experimental study CBR value has increased up to 45 % of the unmodified soil CBR. Observing its economic cost and quality of stabilization improvement, this type of stabilization may be applicable in gravel soil road or in shoulder portion of highways.

From this experimental study it is also seen that the dry density of the sub grade soil is increases considerably from Case A to Case D.

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