International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

Laboratory Investigation on Strength Behavior of Gravel Soil Stabilized with Bitumen Emulsion and Cement

[1]Shraddha Singh, [2]Akhand Pratap Singh, [3]Prof. R.R.L. Birali

[1]M.Tech. Scholar, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India
[2]Assistant Professor, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India
[3]Professor, Department of Civil Engineering, Shri Rawatpura Sarkar University, Raipur, India

***Abstract* - Soil is a fundamental material in all types of civil engineering construction, particularly in road infrastructure where the strength and durability of the subgrade soil are critical. When the natural subgrade does not meet the required strength criteria, stabilization becomes necessary to improve its engineering properties. This study focuses on enhancing the strength characteristics of gravelly soil using Medium Setting (MS) cationic bitumen emulsion, with Ordinary Portland Cement (OPC) as a secondary stabilizing agent. The experimental program involves a series of laboratory tests including specific gravity, grain size distribution, Atterberg limits, Modified Proctor Compaction, and California Bearing Ratio (CBR) tests under various conditions. Four distinct mixing scenarios were evaluated, varying the proportions of bitumen emulsion and cement, as well as curing durations. The influence of these parameters on the maximum dry density and CBR values of the stabilized soil was analyzed. Results indicate that the inclusion of 3% bitumen emulsion along with 2% cement, followed by a curing period of 5 hours, yields the most significant improvement in strength. This combination resulted in a notable increase in maximum dry density and up to a 50% improvement in CBR value compared to untreated soil. These findings confirm that the combined use of bitumen emulsion and cement can effectively enhance the load-bearing capacity of gravel subgrade, offering a cost-effective and sustainable solution for road construction**.

Keywords: Bitumen Emulsion, Soil Stabilization, CBR, Gravel Soil, Cement, Subgrade Improvement.

I. INTRODUCTION

Soil is one of nature's most plentiful building resources, forming the foundation for almost every type of construction. The strength and endurance of subgrade soils significantly impact the long-term performance of pavement structures. However, in-situ subgrades often lack the necessary support to provide acceptable performance under increasing traffic loads and environmental demands. Stabilization is a well-established method for enhancing soil engineering properties, but the effectiveness of stabilization varies widely due to the heterogeneous nature of soil formation, differences in soil micro and macro structures, geological variability, and chemical interactions between the soil and stabilizers. These variabilities necessitate site-specific treatment options that must be validated through thorough testing of soil-stabilizer mixtures. Given the increasing demands on infrastructure due to urbanization and climate change, innovative and cost-effective stabilization techniques are crucial. One promising approach is the use of bitumen emulsion in gravel road stabilization. This method has the potential to improve the strength and durability of subgrade soils, making it a valuable solution for modern pavement engineering challenges.

The primary objective of this experimental study is to explore the effectiveness of adding bitumen emulsion to gravel soil to enhance its properties. The study focuses on improving the California Bearing Ratio (CBR) values of gravel soil, thereby increasing its strength and potentially reducing the overall structural thickness of pavements. This could lead to significant cost savings in road construction and maintenance. Laboratory experiments will investigate the basic characteristics of the soil and its strength, particularly in terms of CBR values, with the addition of a small amount of cement to further stabilize the soil.

By identifying the optimal conditions for mixing cationic bitumen emulsion (CMS) with gravelly soil, the study aims to determine the best combination of materials to achieve superior gravel soil strength properties. This research is timely and relevant, addressing the current needs for sustainable and resilient infrastructure development.

This experimental study aims to investigate the use of bitumen emulsion in enhancing the properties of gravel soil. By improving the CBR values, the study seeks to increase the strength and durability of subgrade soils, potentially reducing pavement thickness and construction costs. Laboratory experiments will focus on the basic characteristics of the soil and its strength, measured through CBR values, with a small amount of cement added for further stabilization. The research aims to identify the optimal conditions for mixing cationic bitumen emulsion (CMS) with gravelly soil to achieve

ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

superior gravel soil strength properties, addressing the current needs for sustainable and resilient infrastructure development.

1.1 Objective and Scope of Work

The primary goal of this experimental investigation is to enhance the properties of gravelly soil by adding bitumen emulsion as a stabilizing agent and a small amount of cement as filler. The use of emulsion aims to improve the geotechnical stability and strength of the gravel soil. Bitumen emulsion is generally considered environmentally friendly. Several laboratory experiments are required to achieve the project's objectives. These experiments include:

- Determination of the specific gravity of the soil sample
- Grain size distribution analysis of the soil sample
- Liquid limit and plastic limit tests to identify the material properties
- Standard Proctor Test to obtain the maximum dry density and optimal moisture content of the soil sample
- CBR Test of soil sample mixed with emulsion and cement

The main objective is to enhance the CBR value of the soil subgrade by validating a few key factors. This study seeks to provide insights into the optimal mixing conditions and material combinations to achieve superior strength properties in gravelly soil, ultimately contributing to more resilient and cost-effective road construction practices.

II. REVIEW OF LITERATURE

2.1 General

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.

Michael (1993) conducted a bench-scale evaluation of asphalt emulsion stabilization on contaminated soils. The study highlighted the use of ambient temperature asphalt emulsion stabilization technology for environmental remediation of soils polluted by organic contaminants.

Razouki et al. (2002) performed an experimental investigation on granular stabilized roads. Bitumen was used as a stabilizer acting either as a binder or a waterproofing material, with applications mainly in road bases and surfaces.

Cokca et al. (2003) explored the impact of compaction moisture content on the shear strength of unsaturated clay. The study concluded that shear strength is influenced significantly by moisture content, with the peak strength typically occurring around the optimum moisture content.

A. P. Chritz (2006) evaluated the performance of in-place mixed bituminous stabilized shoulder gravel. This study addressed maintenance challenges of gravel shoulders faced by highway agencies and presented a cost-effective stabilization method.

Hussain (2008) established a correlation between CBR value and undrained shear strength obtained from vane shear tests. The findings showed that both shear strength and CBR value increase with the plasticity index and decrease with higher water content.

Chinkulkijniwat and Man-Koksung (2010) studied the compaction behavior of non-gravel and gravelly soils using a mini compaction apparatus. They investigated the effects of gravel size and content, developing a correlation between optimum water content and gravel fraction.

Yuehuan et al. (2010) investigated foamed bitumen stabilization for flexible pavement subgrades in Western Australia. The study emphasized the use of foamed bitumen as an innovative alternative to soil cement stabilization, showing its adaptability and performance under varying conditions.

Paul et al. (2011) introduced the concept of soil stabilization using a mix of bitumen and well-graded gravel or crushed aggregates. The study emphasized the waterproofing and adhesion mechanisms of asphalt stabilization, enhancing durability and reducing the negative effects of water on fine-grained soils.

L. Lauren (2011) conducted experimental research on polymer emulsions as soil stabilization agents. The CBR tests showed that polymer emulsions can significantly improve the strength of subgrade, sub-base, and base course materials, suggesting their potential as future stabilizers.

Martin et al. (2011) worked on foam bitumen stabilization using 2% cement and 3.5% bitumen foam. The study demonstrated the method's success due to its speed of construction, material compatibility, and resilience to weather conditions.

Jones et al. (2012) carried out laboratory tests on bitumen soil stabilization using asphalt emulsion a blend of binder, water, and emulsifier. Through ITS, UCS, and Marshall tests, it was shown that asphalt emulsion enhances early strength and handling efficiency during curing.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 9, Issue 6, pp 184-194, June-2025

https://doi.org/10.47001/IRJIET/2025.906025

Marandi and Safapour (2012) focused on base course modification using cement and bitumen. Their findings showed that bitumen stabilization functions differently from cement stabilization, primarily through waterproofing. The study proposed this method as a replacement in areas with low-quality materials.

2.1 Study Framework

Selection of Material and Methodology

Selection of material and methodology is crucial for any experimental investigation. To determine the soil's physical properties, the following tests are conducted:

- Specific Gravity Test
- Grain Size Distribution Test by Sieve Analysis
- Plastic Limit and Liquid Limit Tests

Next, the mixing procedure and different test conditions are chosen. The Modified Proctor Test is conducted to determine the maximum dry density. The primary goal is to increase the soil's strength, so CBR tests are performed under various conditions to compare and maximize the CBR value.

1. Methodology Chart

2. Material Selection

a. Red-colored laterite gravel soil
b. Medium setting emulsion (MS)
c. Cement as filler

3. Initial Soil Tests

a. Specific Gravity
b. Grain Size Distribution
c. Plastic Limit and Liquid Limit

4. Mixing Procedure

a. Determine optimal conditions for mixing soil, emulsion, and cement
b. Vary proportions to find the best combination

5. Compaction Test

a. Modified Proctor Test for Maximum Dry Density and Optimal Moisture Content

6. Strength Tests

a. CBR tests under different conditions (soil alone, soil with emulsion, soil with emulsion and cement)

7. Analysis

a. Compare CBR values
b. Optimize mixing procedure for maximum strength

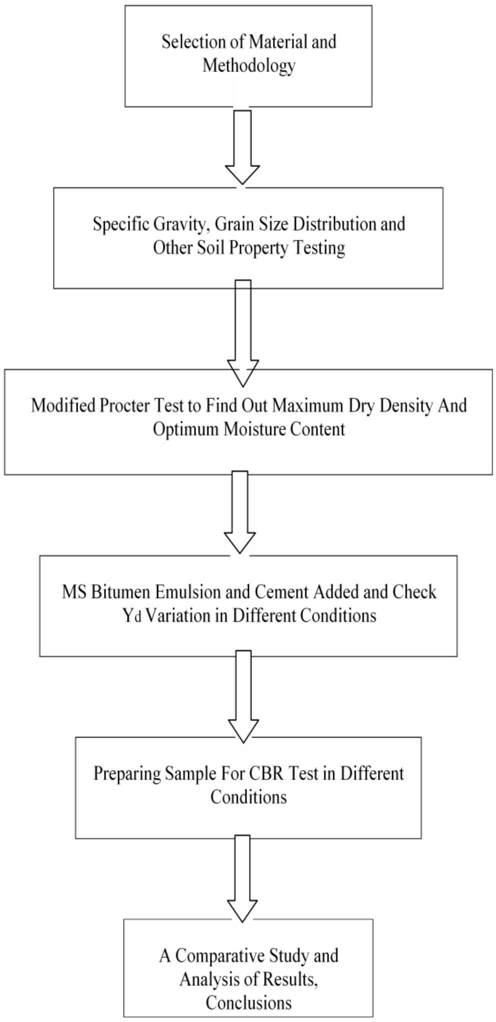


Figure 2.1: Methodology Flow Chart

III. EXPERIMENT PROGRAMME

3.1 Specific Gravity of Soil

Specific gravity is defined as the ratio between the mass of a substance and the mass of an equal volume of water. For soils, it represents how many times soil solids are heavier compared to an equal volume of water. This property is denoted by 'G'. Specific gravities vary for different soil types. During experiments, it is important to account for temperature correction and to use gas-free distilled water.

Specific gravity is a crucial physical property used to calculate other soil engineering properties such as void ratio, density, porosity, and saturation condition.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

To measure specific gravity, a volumetric flask is used. The procedure involves determining the volume of the soil, measuring its weight, and then dividing it by the weight of an equal volume of water. This measurement provides essential data for understanding and predicting the behavior of soils in engineering applications.

G is Specific Gravity

$$G = (M2-M1)/((M4-M1)-(M3-M2))$$

Here,

M1=Weight of bottle
M2=Weight of bottle and Dry soil
M3=Weight of bottle, Dry soil and Water
M4= Weight of bottle and water

Table 3.1: Standard Specific Gravity

Type of Soil	Specific Gravity
Sand	2.63-2.67
Silt	2.65-2.7
Clay and Silty Soil	2.67-2.9
Organic Soil	1+ to 2.6

3.2 Particle Size Distribution

Soil particles vary widely in size and shape, ranging from a few microns to several centimeters. The size and shape of these particles significantly influence the soil's physical properties, such as strength, permeability, and density. Particle size distribution is determined using two primary methods: sieve analysis for coarse-grained soils and sedimentation analysis for fine-grained soils. The results from these methods are plotted on a semi-logarithmic graph, where the ordinate represents the percentage finer and the abscissa represents the particle diameter or sieve sizes on a logarithmic scale.

For this study, sieve analysis was conducted on coarse-grained soil samples. This analysis helps to determine the distribution of particle sizes in the gravel soil, which is essential for understanding its suitability for bitumen emulsion stabilization and overall performance in road construction. Soils are categorized as well-graded or poorly graded based on the distribution of particle sizes. Well-graded soils contain a variety of particle sizes and shapes, ensuring a good distribution across the spectrum. Conversely, poorly graded soils exhibit an excess of certain particle sizes and a deficiency in others, leading to a less uniform distribution. To analyze particle size distribution, sieve analysis results are plotted on a semi-logarithmic graph. In this graph, the particle diameter or sieve size (in millimeters) is plotted on the X-axis using a logarithmic scale, while the percentage finer is plotted on the Y-axis. This graph provides a clear depiction of the particle size distribution.

From the resulting curve, key parameters such as D10 and D60 are determined. D10 is the diameter at which 10% of the soil particles are finer, while D60 is the diameter at which 60% of the particles are finer. The uniformity coefficient (Cu) is calculated as the ratio of D60 to D10. The uniformity coefficient provides a measure of the soil's particle size range and helps in assessing the soil's grading quality.

3.3 Liquid Limit and Plastic Limit Test

The liquid limit (WL) of a soil is the moisture content at which the soil transitions from a liquid to a plastic state. At this limit, the soil has shear strength of 17.6 g/cm² and flows to standard dimensions for a groove when jarred 25 times using the Casagrande apparatus. The liquid limit is determined as the water content at which 25 drops of the cup cause the groove to close.

The plastic limit (PL) is the moisture content at which the soil transitions from a plastic to a semi-solid state. It is defined as the water content at which the soil begins to crumble when rolled into a 3 mm diameter thread.

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

In summary, the liquid limit (WL) marks the transition from a liquid to a plastic state with minimal shear strength, while the plastic limit (PL) marks the transition from plastic to semi-solid state.

3.4 Compaction Test (Modified Proctor Test)

The Proctor Test is used to determine the relationship between moisture content and dry density of soils. This test involves compacting soil in a standard mold using a rammer dropped from a specified height. The objective is to find the optimum moisture content (OMC) at which the soil achieves its maximum dry density (Yd). The Proctor Test was first developed by R.R. Proctor in 1933, who demonstrated that the dry density of soil under compaction depends on the amount of water the soil contains. The standard Proctor compaction test, named in his honor, has been updated to include variations such as the Modified Proctor Test.

In the Modified Proctor Test, the procedures are similar to the standard test but with some key differences. Notably, the compaction effort is greater: the rammer weighs 4.5 kg and is dropped from a height of 18 inches. This increased compactive effort results in a higher degree of soil compaction.

International Research Journal of Innovations in Engineering and Technology (IRJIET)
ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

Figure 3.1: Modified Proctor Test Apparatus

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.

3.6 California Bearing Ratio Test

The California Bearing Ratio (CBR) is a measure of the strength of soil, reflecting the resistance of the soil to penetration by a standard loading device. It is defined as the ratio of the force per unit area required to penetrate a soil mass with a standard load at a rate of 1.25 mm/min, compared to the force required for the same penetration of a standard material, typically limestone.

The CBR value is expressed as a percentage, with a standard material (limestone) used as the reference. The standard loads for various penetrations for this reference material are as follows:

- **At 2.5 mm penetration:** The standard load for limestone corresponds to a CBR value of 100%.
- **At 5 mm penetration:** The standard load for limestone corresponds to a CBR value of 100%.
- **At 7.5 mm penetration:** The standard load for limestone corresponds to a CBR value of 100%.
- **At 10 mm penetration:** The standard load for limestone corresponds to a CBR value of 100%.

By comparing the load required to achieve specific penetrations in the soil sample with the standard loads for limestone, the CBR value of the soil can be determined. This value helps in assessing the suitability of the soil for various construction purposes, including road and pavement design.

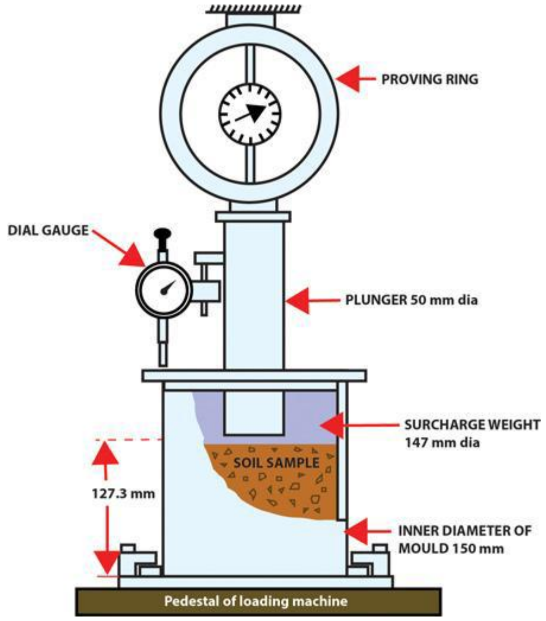


Figure 3.2: California Bearing Ratio Testing Machine

CBR value is calculated by this formula:

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

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

Table 3.2: Standard Load in Different Penetration

Penetration of Plunger (mm)	Standard Load (Kg)
2.5	1370
5	2055
7.5	2630
10	3180

IV. RESULT AND DISCUSSION

4.1 Specific Gravity Test

Specific gravity of soil is very important property to understand the soil condition. As previously discussed here M1 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.

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 9, Issue 6, pp 184-194, June-2025

https://doi.org/10.47001/IRJIET/2025.906025

Table 4.1: Specific Gravity Test Result

Sample No.	M1 (gm)	M2 (gm)	M3 (gm)	M4 (gm)	Specific Gravity
1	114.66	164.66	383.55	351.85	2.73
2	113.75	163.75	384.40	352.85	2.71
3	115.33	165.34	385.67	353.92	2.7

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 Raipur 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 (W_L): 28.91%

Plastic Limit (W_P): 21.67%

Plasticity Index (IP): 7.24%

4.3 Grain Size Distribution (Sieve Analysis)

Index properties are essential physical and engineering characteristics used to identify and classify soil. These properties are intrinsic to the soil grains themselves and remain consistent regardless of the soil's state in nature.

To determine the grain size distribution, a sample of 2000 grams of soil was dried in an oven for 12 hours. The sieve analysis is the most commonly used test for this purpose. In this analysis, soil is passed through a series of sieves with progressively smaller mesh sizes.

For the analysis, eleven sieves were utilized. The results from the sieve analysis are then plotted on a semi-logarithmic graph. In this graph:

- The X-axis represents the particle diameter or sieve size on a logarithmic scale.
- The Y-axis represents the percentage finer, indicating the cumulative percentage of soil particles that are smaller than the corresponding sieve size.

This graphical representation provides a clear picture of the soil's grain size distribution, which is critical for understanding the soil's behavior and suitability for various engineering applications.

Table 4.2: 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

International Research Journal of Innovations in Engineering and Technology (IRJIET)
ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

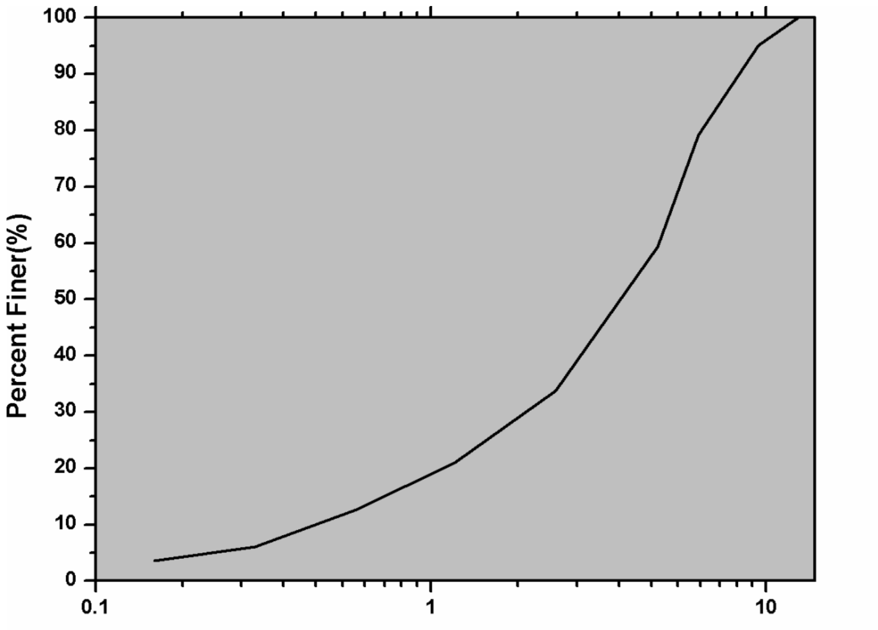


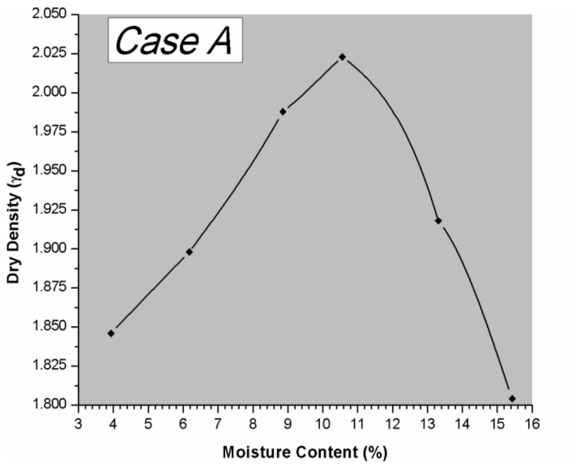
Figure 4.1: Grain Size Distribution Graph

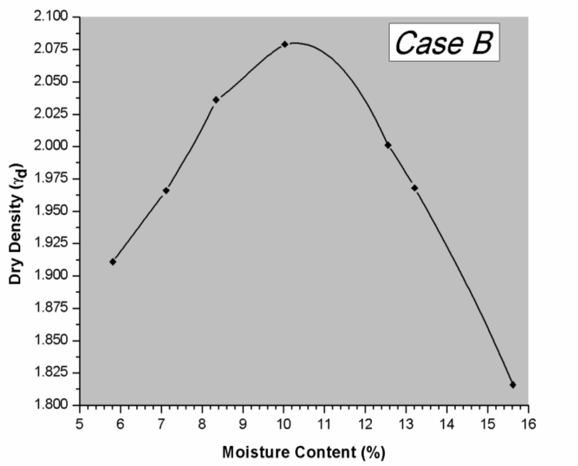
4.4 Compaction Test

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%.

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 density is 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.





ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

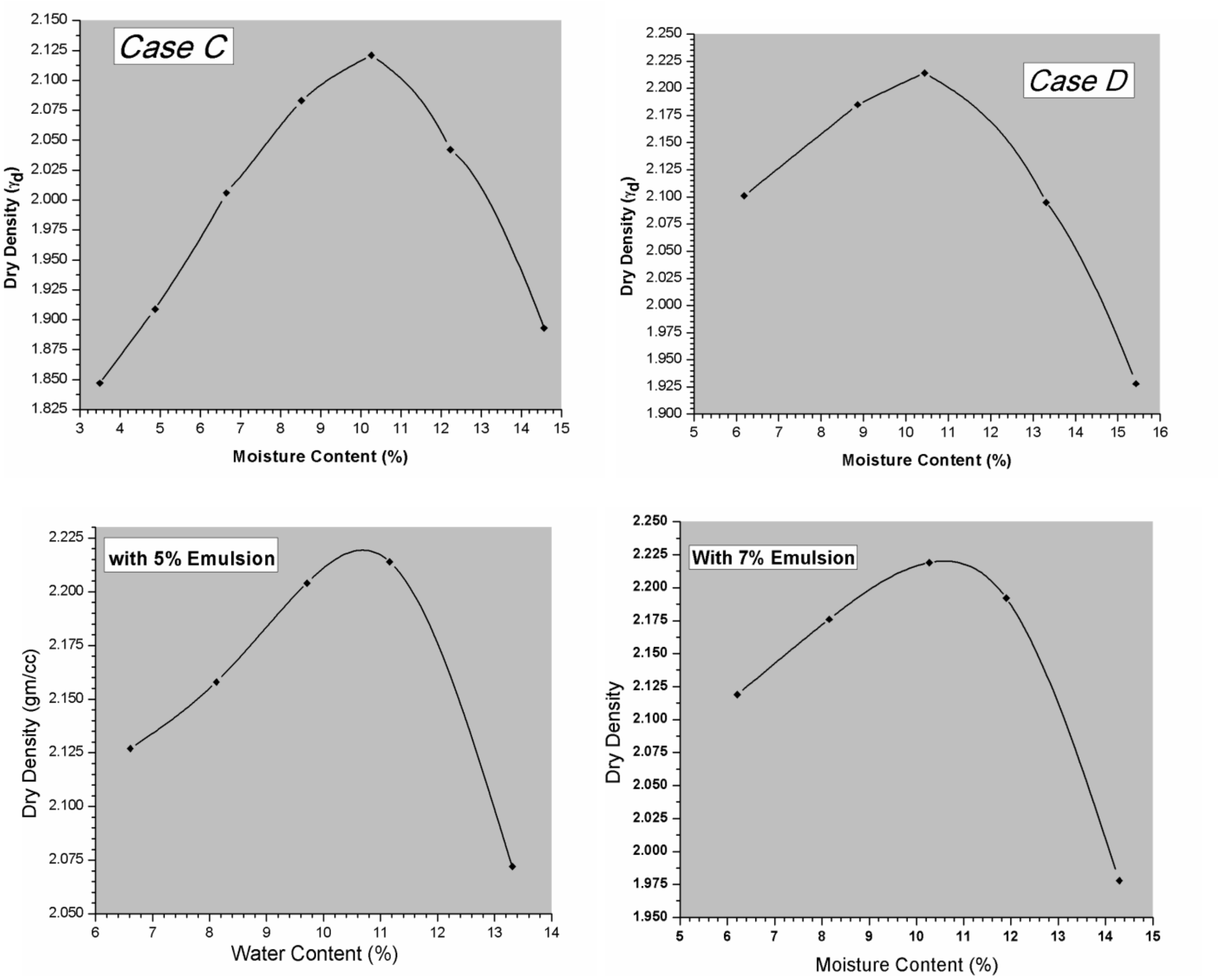


Figure 4.2: Modified Proctor Test Graphs

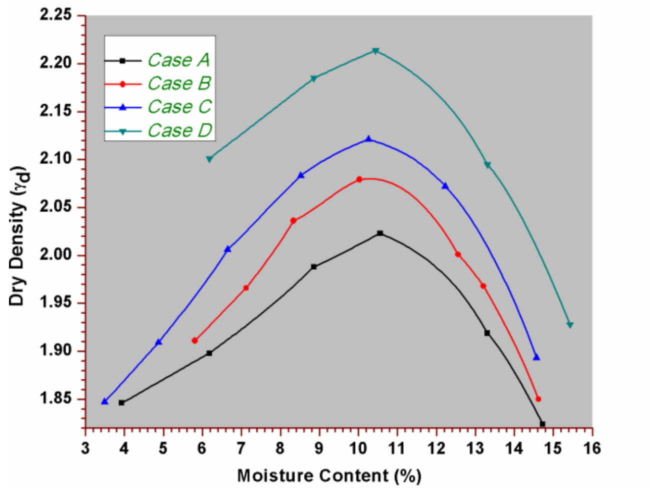


Figure 4.3: Modified Proctor Test Comparison Graph

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 Yd value is a very important physical property in case of stability of sub-grade soil. Bellow the variation of maximum dry density in those special cases are shown bar wise.

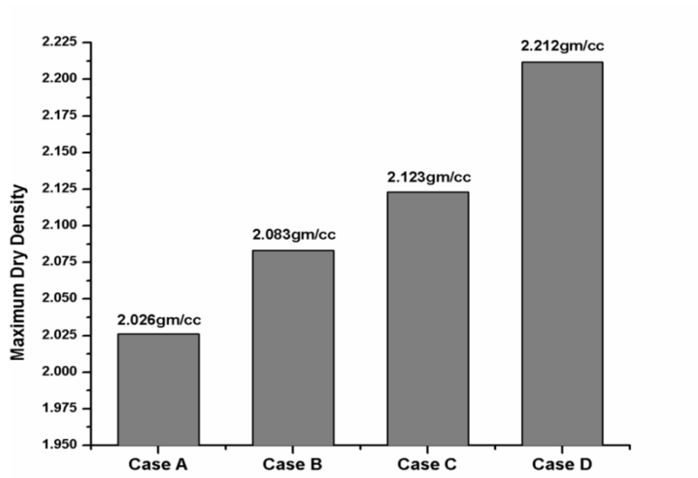


Figure 4.4: Variation of Maximum Dry Density Value

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 9, Issue 6, pp 184-194, June-2025

https://doi.org/10.47001/IRJIET/2025.906025

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.

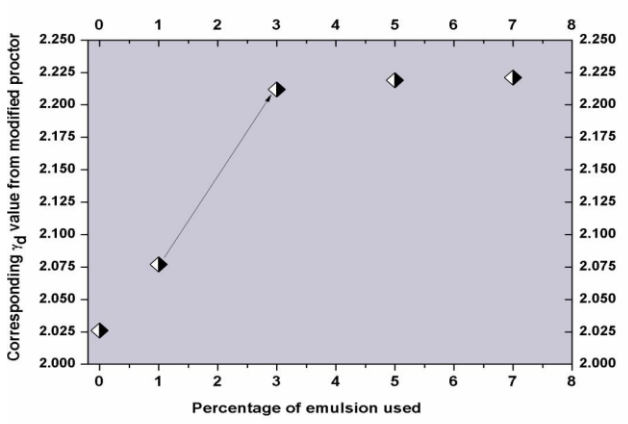


Figure 4.5: Variation of MDD with Emulsion Quantity

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.

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.

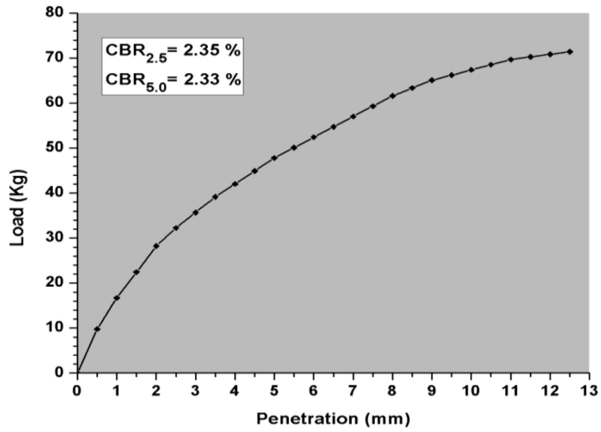


Figure 4.6: CBR Test Result, Case A (4 days of soaking)

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 5 mm penetration is calculated.

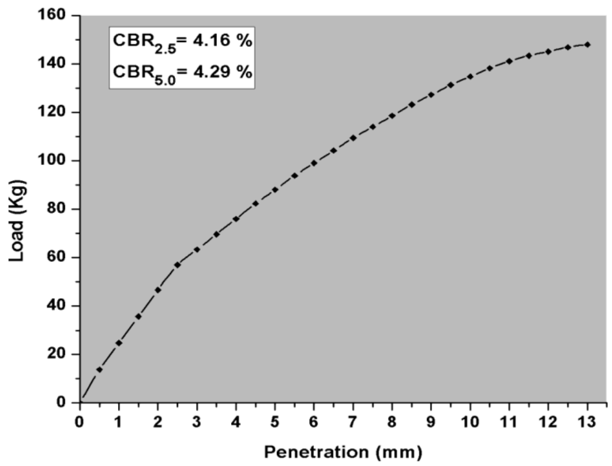


Figure 4.7: CBR Test Result, Case B (4 days of soaking)

4.6 Discussion

A subgrade is a layer of compacted soil situated directly beneath the pavement crust, typically constructed from locally available soil. This layer, generally assumed to be 300 mm thick, provides a foundational support for the pavement. Enhancing the strength of the subgrade is crucial, as it directly impacts the overall performance and durability of the

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 9, Issue 6, pp 184-194, June-2025

https://doi.org/10.47001/IRJIET/2025.906025

pavement. This can be achieved either by replacing the existing soil with higher-quality material or by stabilizing the existing soil.

The California Bearing Ratio (CBR) test is a widely used method for evaluating the stability and load-bearing capacity of subgrade soil. The CBR test measures the soil's resistance to penetration under standard load conditions, providing an indication of its strength and suitability for supporting pavement structures.

The results of the CBR test are typically presented in a bar chart. This chart allows for a clear comparison of CBR values under different conditions, showing whether improvements in CBR have been achieved. The bar chart helps to identify the optimal conditions for maximizing the CBR value, which is essential for ensuring the stability and performance of the subgrade. The following bar chart provides a detailed view of the CBR values and highlights the effectiveness of various soil stabilization techniques or treatments applied.

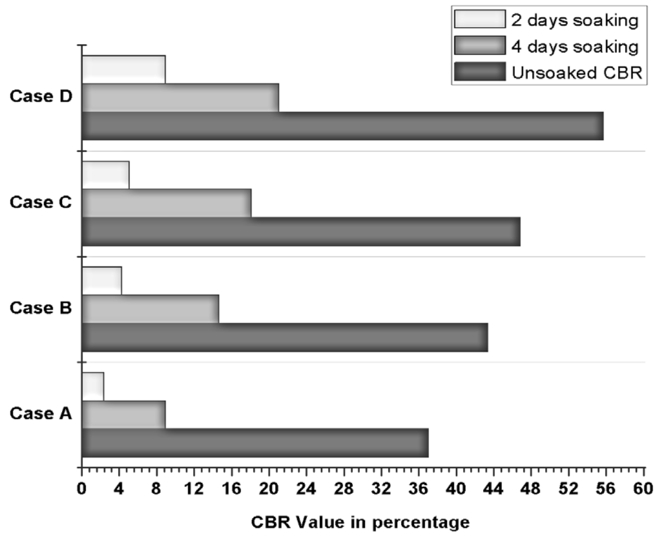


Figure 4.8: CBR Value Comparison Bar Chart

V. CONCLUSION AND FUTURE SCOPE

5.1 Conclusions

Based on the laboratory investigation on the strength behavior of gravel soil stabilized with bitumen emulsion and cement, it is evident that the combined use of these stabilizers significantly improves the engineering properties of gravel soil. The treated soil demonstrates enhanced strength, stability, and durability, making it more suitable for use in road construction, especially in low-volume traffic areas and rural regions. The experimental results indicate that an optimal dosage of 2-3% bitumen emulsion by weight of aggregate, along with 4-6% cement by weight of soil, yields the most favorable outcomes in terms of unconfined compressive strength and overall soil performance. This combination alters the soil structure, reduces voids, and enhances cohesion, contributing to improved load-bearing capacity and resistance to moisture. Controlled and uniform mixing of both stabilizers is essential to achieve consistent results and ensure the effectiveness of the stabilization process. Furthermore, the stabilized gravel soil exhibits lower maintenance requirements over time, making this technique economically viable and sustainable for long-term applications. Overall, the study confirms that bitumen emulsion and cement, when used together in appropriate proportions, offer a practical and efficient method for stabilizing gravel soils and improving the performance and lifespan of gravel roads.

5.2 Future Scope of Works

The experimental study on the strength behavior of gravel soil stabilized with bitumen emulsion and cement has demonstrated promising potential for enhancing road infrastructure. To build on these findings, several areas warrant further research. Long-term performance evaluation is essential to understand how the stabilized gravel soil behaves under varying traffic loads, moisture conditions, and climatic influences over extended periods. Comparative studies on different types and grades of bitumen emulsions and cementitious materials can provide deeper insight into their individual and combined effects on soil strength and durability. Investigating the impact of stabilization on surface characteristics such as skid resistance is also crucial for ensuring road safety, particularly in wet or high-speed conditions. In addition, an economic and environmental assessment should be conducted to quantify the cost savings, material efficiency, and ecological benefits of using bitumen emulsion and cement together. Such studies would support the development of more sustainable construction practices. Finally, the formulation of standardized guidelines and specifications for the design, mixing, application, and maintenance of stabilized gravel roads can ensure uniform quality and performance across projects. These future research directions will help optimize the use of bitumen emulsion and cement in gravel soil stabilization, leading to more durable, safe, and cost-effective road infrastructure.

REFERENCES

[1] Alayaki, F. M., Bajomo, O. S. (2011), Effect of Moisture Variation on the Strength Characteristics of Laterite soil. Proceedings of the Environmental Management Conference, Federal University of Agriculture, Abeokuta, Nigeria.

[2] Hodgkinson., A.T. Visser (2004), University of Pretoria and Concor Roads (Pty) Ltd, The role of fillers

ISSN (online): 2581-3048
Volume 9, Issue 6, pp 184-194, June-2025
https://doi.org/10.47001/IRJIET/2025.906025

and cementitious binders when recycling with foamed bitumen or bitumen emulsion.

[3] Cokca. E., Erol,O., Armangil. (2004), "Effects of compaction moisture content on the shear strength of an unsaturated clay", Geotechnical and Geological Engineering.

[4] Chauhan.(2010)," a laboratory study on effect of test conditions on subgrade strength". Unpublished B.Tech Thesis, N.I.T Rourkela.

[5] Consoli, N. C., Prietto, P. D. M., Carroro, J. A. H., and Heineck, K. S. (2001). "Behavior of compacted soil-fly ash-carbide lime mixture."J. Geotech. Geoenviron. Eng., 127(9), 774–782.

[6] D. Jones., A. Rahim., S. Saadeh., and J.T. Harvey (2012), Guide lines for the Stabilization of Subgrade Soils in California, Guideline: UCPRC-GL-2010-01.

[7] Gregory Paul Makusa. (2012), Department of Civil, Environmental and Natural resources engineering, Luleå University of Technology, Sweden.

[8] Jaleel, Z.T.(2011), Effect of Soaking on the CBR-Value of Subbase Soil. Eng. and Tech. journal, vol.29.

[9] Mouratidis A. (2004), Stabilization of pavements with fly-ash, Proceedings of the Conference on Use of industrial by-products in road construction, Thessaloniki, 47-57.

[10] Nugroho, S.A., Hendri,A., Ningsih, S.R.(2012), Correlation between index properties and california bearing ratio test of pekanbaru soils with and without soaked. Canadian Journal on Environmental, Construction and Civil Engineering Vol. 3, Indonesia.

[11] Punmia B.C., Jain A.K, Jain A.K (2004), Soil Mechanics and Foundation, Laxmi Publications, New Delhi 16th edition.

Citation of this Article:

Shraddha Singh, Akhand Pratap Singh, & Prof. R.R.L. Birali. (2025). Laboratory Investigation on Strength Behavior of Gravel Soil Stabilized with Bitumen Emulsion and Cement. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 9(6), 184-194. Article DOI https://doi.org/10.47001/IRJIET/2025.906025

****