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A Laboratory Investigation on the Application of Bitumen Emulsion in Gravel Road

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ABSTRACT- This paper investigates the potential of utilizing bitumen emulsion in gravel road construction, assessing its feasibility and efficacy through comprehensive laboratory analysis. Mechanical properties, longevity, and environmental impact are evaluated, focusing on rutting resistance, adhesion, cohesiveness, and moisture susceptibility of bitumen-treated gravel mixtures. Results demonstrate significant improvements in engineering characteristics, leading to heightened stability, reduced maintenance needs, and extended service life for gravel roads. Environmental assessments highlight potential sustainability benefits such as carbon emission reduction and natural resource conservation. The study employs medium setting emulsion (MSE) as a stabilizing agent on easily accessible laterite gravel soil. While bitumen's effectiveness for sand stabilization is acknowledged, its application on soil is constrained by cost and standardized protocol limitations. Various tests including the CBR Test and Modified Compaction Test were conducted to enhance soil strength and project stability. The research underscores bitumen emulsion's potential to enhance geotechnical properties while affirming its environmental safety. Crucial laboratory experiments such as the Standard Proctor test and tests for specific gravity, particle size distribution, and material identity were instrumental in optimizing the soil subgrade's CBR value for effective road construction.

KEYWORDS- Bitumen Emulsion, Gravel Roads, Stabilization, Laboratory Investigation

I. INTRODUCTION

An essential component of civil engineering and construction is soil stabilization, which aims to enhance the soil's engineering qualities and increase its suitability for a range of uses.The subgrade soil's strength and durability significantly impact the life span of pavement structures, necessitating the formulation of site-specific treatment options and testing of soil-stabilizer blends. Soil stabilization techniques focus on enhancing strength, load-bearing capacity, reducing permeability, enhancing durability, controlling swelling and shrinkage, and addressing environmental concerns. These methods include compaction, vibro-compaction, dynamic compaction, soil stabilization with geosynthetics, soil mixing, deep soil mixing, and soil replacement. Additionally, chemical-based methods involve the addition of materials like lime, cement, fly ash, bitumen, polymers, calcium chloride, sodium silicate, and potassium permanganate to chemically alter soil properties and improve stability.

Among chemical stabilization methods, soil stabilization using cement, lime, and fly ash has been extensively studied and implemented. Soil stabilization using cement involves mixing dry cement powder with native soil followed by hydration to form cementitious bonds, enhancing soil strength, cohesion, and durability. Lime stabilization alters soil characteristics through chemical reactions, producing cementitious compounds that bind soil particles together, improving strength, stability, and reducing plasticity. Fly ash, a byproduct of coal combustion, enhances soil properties through pozzolanic reactions, increasing strength, stability, and durability. Other chemical stabilization methods include bitumen stabilization, polymer stabilization, calcium chloride stabilization, sodium silicate stabilization, and potassium permanganate stabilization, offering versatile solutions for various engineering applications.

Bitumen soil stabilization, although less explored, offers promising benefits for road construction and maintenance due to bitumen's excellent bonding properties, water resistance. Incorporating bituminous materials into the soil enhances strength, durability, and water resistance, providing a cost-effective solution for soil stabilization projects. However, challenges such as handling and mixing bituminous materials, environmental concerns, and the need for further research into long-term performance and cost-effectiveness remain.

As the demand for sustainable and resilient infrastructure grows, there is increasing interest in exploring alternative soil stabilization methods, including those involving bitumen, to meet evolving construction needs. Continued research and development efforts in this area could lead to innovative approaches optimizing the use of bituminous materials for soil stabilization, ultimately advancing construction practices and creating more durable and environmentally friendly infrastructure.

II. OBJECTIVE

For the purpose of enhancing the geotechnical qualities of gravel soil, emulsion has been tried. Bitumen emulsion is generally recognized as safe for the ecosystem. There must be some laboratory experimentation in order to complete the

job.. The soil's maximum dry density and ideal moisture content are determined by the Standard Proctor test; its specific gravity, particle size distribution, and liquid content are determined by the Specific Gravity, Grain Size Distribution, and Liquid.
The substance is identified using the Limit Plastic Limit test. In order to do this, we must confirm a few factors to ensure that the soil subgrade's CBR value is as high as possible.

III. LITERATURE REVIEW

Baloochi H. [1] In order to stabilize soil, using waste paper fly ash (WPFA) as a binder is a sustainable method that has drawn interest in a number of building applications. According to their research, WPFA has cementitious phases and free lime, which could cause it to expand in stabilized soil. The expansion was minimized by adding a 30-minute delay after mixing and lowering the water content. Additionally, lowering the water content strengthened the soil; some samples' strength values were comparable to those of control samples that had been cured for seven days. In general, WPFA exhibits potential as a soil stabilizer when used with appropriate measures to prevent its expanding nature.

Per Lindh [2] When the five possible binders—lime, energy fly ash, bio fly ash, slag, and cement—were examined for effectiveness, waste paper fly ash (WPFA) stood out as a viable choice with potential advantages for resource conservation and the environment. as supplements to enhance the criteria of soil strength. On the 28th day, strength differences in soil specimens stabilized by various binder combinations were evaluated using P-wave velocity measurements. In this investigation, the combinations that showed the best fixation and chemical bonding with soil particles were emphasized. This work adds knowledge on industrial soil strength testing for building roadbeds.

Firoozi, A.A., [3] draws attention to the difficulties that come with clayey soils, including their tendency to become stiff while dry and lose it when wet, which can cause settling and a decrease in compressive strength. The substantial harm that expansive soils inflict highlight the need of putting into practice efficient soil development techniques. Utilizing additions like lime, cement, fly ash, and slag to stabilize the soil is one method. There are still difficulties, though, since sulfate-rich soils stabilized with cement or lime can heave significantly and cause pavement failure. In order to improve geotechnical qualities, the study discusses basic civil engineering soil improvement procedures as well as contemporary scientific soil stabilization approaches.

Siham Farrag [4], explains soil stabilizing strategies in detail, including concepts, uses, benefits, and drawbacks of both established and new procedures. Researchers, engineers, and practitioners working on soil stabilization projects with the goal of advancing civil engineering knowledge and practices found the provided review to be a useful resource.

Akash A D [5], investigates the use of geosynthetic materials for soil stabilization in order to improve the engineering properties and load-bearing capacity of subgrade soil. The study assesses the effect of geotextiles on reinforced granular soils using laboratory testing, such as CBR tests. The results are intended to provide guidance for the efficient application of geotextile reinforcement to enhance soil stability and bearing capacity in infrastructure projects, especially in the building of roads.

Jayanthi, P. [6], examines techniques for stabilizing soil, including as mechanical and chemical procedures, to enhance the strength and density of the soil. In order to solve issues such as environmental damage and soil cracking, the study promotes the use of sustainable materials such as industrial waste. The promise of these materials and the need for additional study to improve their application in soil stabilization techniques are highlighted by a critical assessment of the literature.

Andavan, S., [7], highlights the importance of soil characteristics and soil stabilization methods in guaranteeing sturdy foundations for building projects. In particular, the construction of pavements requires an understanding of the characteristics and interactions of materials such as aggregates and soil. The study focuses on bitumen's application as a soil stabilizer, emphasizing both its financial and mechanical advantages..

Matthew, A. G. [8], examined the impact of employing various mixes of bitumen emulsion and cement to stabilize lateritic soil. Samples of soil were taken from borrow pits in the Kwali Area Council of Abuja, and between 4% and 8% of chemicals were added. For both stabilized and unstabilized soils, different ratios of bitumen emulsion and cement were used, and geotechnical characteristics like UCS and CBR were evaluated.

Maheshwari G.Bisana [9], sought to use bitumen emulsion and seashells to stabilize the soil in black cotton fields. Calcium carbonate-rich seashells function similarly to lime. As a binder, bitumen emulsion keeps water from penetrating the soil.

Danu, R. [10], provides an overview of novel soil stabilizing methods used in civil engineering with a particular emphasis on geosynthetics. Benefits of geosynthetics include enhanced drainage, reduced erosion, higher bearing capacity, and soil reinforcement. Geotextiles, geogrids, and geocells are a few examples of these geosynthetic materials. These materials can be applied to a variety of soil stabilization applications because of their versatility.

IV. METHODOLOGY

A. Specific Gravity

Specific Gravity is a Property of Soil.When evaluating soils, density is calculated as the proportion of soil solids mass to the mass of water in a given volume of soil. Therefore, it may be thought of as the factor by which dirt weighs more than water. The soil types have varying specific gravities. The temperature should be carefully adjusted, and pure water should be used so that there are no gas bubbles, One important physical parameter is specific gravity. Soil types often have their own unique specific gravities, which fall into one of four broad ranges given in table 1.

Table 1: Specific Gravity, Standard

Types of Soil	Specific Gravity
Sand	3.63 to 3.66
Silt	2.65 to 2.7
Clay and Silty soil	2.66 to 2.9
Organic soil	1+ to 2.5

The volume of the soil is determined in an experimental setting using a volumetric flask, and the soil's mass is calculated by dividing its weight by the mass of water with the same volume. The letter "G" stands for the soil's specific gravity. To determine the void ratio, density, porosity, and saturation state in soil engineering. The values for calculation of G are mentioned below in the table no 2.

G is Specific Gravity
G = (M2-M1) / (M3-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 2: Calculated Specific Gravity Value

Sample No	M1- (gm)	M2- (gm)	M3- (gm)	M4- (gm)	Sp. Gravity
1.	112.3766	161.3766	375.8888	344.8326	2.6754
2.	111.4848	160.4848	376.7218	345.8028	2.6558
3.	113.0332	162.0332	377.9762	346.8612	2.6852

B. Size Variation of Particles

Some particles in the soil sample are only a few microns in size, while others are several centimeters in length. The size and form of the particles in a soil sample have a significant impact on many of the soil's physical qualities.There are two ways to determine particle size distribution: sieve analysis, which is performed solely on coarse grained soils, and sedimentation analysis, which is performed on fine grained soil samples. Index properties refer to the many physical and technical characteristics that aid in correctly identifying soil. The quality of soil relies on the characteristics of each individual grain rather than on the physical condition in which the soil occurs naturally.Here, we dried a 2000-gram soil sample in the oven for 12 hours. Sieve analysis is the standard method for determining the overall particle size distribution. There were 10 sieves involved as shown in table.

Table 3: Sieve Analysis Result

Sr. No.	Sieve Size in mm (D)	Weight of the soil retained(g)	Percentage of weight retained	Cumulative percentage of Wt retained	Percentage finer (N) (100-cumulative%)
1	80	0	-----	0	100
2	40	97.118	4.851	4.851	93.149
3	20	312.424	15.6212	20.4232	77.5768
4	4.75	389.55	19.4824	39.9546	58.1434
5	2	499.996	24.9998	64.9544	33.0456
6	1	249.998	12.4558	77.4494	20.5506
7	0.6	162.876	8.1438	85.5932	12.4068
8	0.425	129.458	6.4778	92.071	5.929
9	0.150	47.726	2.3912	94.4622	3.5378
10	Pan	70.854	3.528	98	0

A semi-log graph is then used to display the findings, with the ordinate representing the % finer and the abscissa representing the particle diameter, or logarithmic sieve sizes. Coarse grained dirt has been sieved and the results are in figure 1.

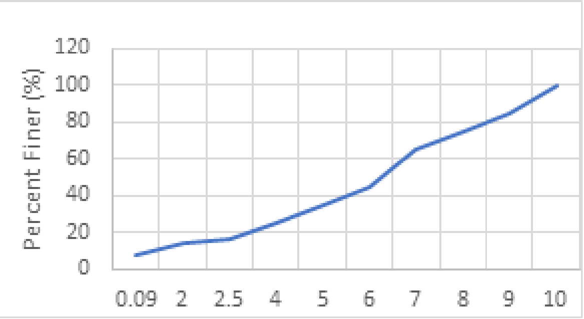

Figure 1: Graph showing the range of Grain Sizes

Soil is often well graded or badly graded. Soils with an excellent gradation have a variety of particle sizes and shapes. Instead, poorly or evenly graded soil contains more or less particles of certain sizes than others.
The particle size distribution is shown clearly in this semi-log graph. D10 and D60 are firm thanks to the guidance of this curve.
The soil's particle diameter, as measured by the sieve size, is displayed on the X axis of the semi-log graph, while the percentage of finer particles is shown on the Y axis in the figure no 1 placed above.

C. Liquid Limit and Plastic Limit Test

The liquid limit of the soil is the point at which the soil stops being a liquid and shifts from a liquid to a plastic condition that corresponds to the minimal water content. The soil's liquid limit is measured using the Casagrande apparatus. In this case, the soil was gathered from nearby roads, and the results of this investigation have given us a good understanding of the type of soil. The plastic limit is the point at which the soil stops acting as plastic soil, shifting from a plastic to a semi-solid form in accordance with the minimum water content. To put it simply, the water content at the location where the soil begins to crumble when rolled into
Plasticity Index (IP) = Liquid Limit (WL) - Plastic Limit (WP)
Liquid Limit = 29.71
Plastic Limit = 21.98
Plasticity Index = 7.73

D. Compaction Test (Modified Proctor Test)

The moisture content as well as the Dry Density is determined by performing this test under standard conditions as it establish a connection between these two properties by plotting a graph on Y and x axis respectively. The values so obtained first increases and attain a maximum value and then decreases in same order and acquire a parabolic shape. The max point is denoted as Yd(max) and the respective moisture content as O.M.C The Maximum dry density is calculated as under:
Dry density Yd (max) (gm/cc) = wet density/ 1 + moisture content/100
Under four particular conditions testing done on gravel soil mixing with emulsion to compare the variation of maximum dry density.
Situation-1 Normal available tested soil is used for testing-S1
Situation -2 Normal available soil tested with 4% MS emulsion added-S2
Situation -3 Normal available soil tested with 4% MS emulsion and 3% of cement added-S3

Situation-4 Normal available soil tested with 4% MS emulsion and 3% of cement added and wait five hours before testing S- S4

Modified proctor test is performed under these four conditions and plotted with dry density in the bar chat below figure no 2.

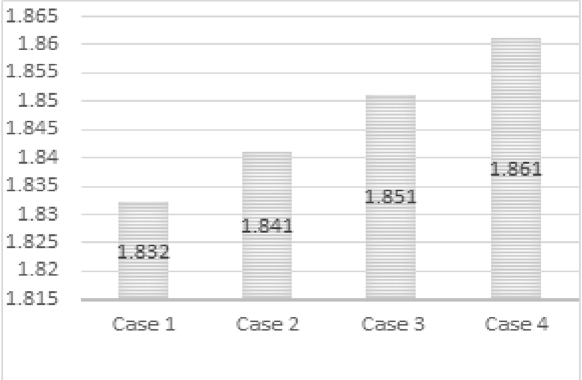

Figure 2: Variation in the Highest Possible Dry Density

It is clear in the above bar charts that the dry density values increase from situation 1 to situation 4. In case 1 our dry density increases 1.832 which indicates that yd max value determines the stability of subsoil and in case 2 our dry density value increases from situation 1 to situation 2 that is 1.832 to 1.841 which also indicate the yd max value determines the more stability of subsoil as compared to case1. The dry density value in case 3 increases from situation 2 to situation 3 that is 1.841 to 1.851 which indicates that yd max value determines the much more stability as compared to case 1 and case2 of subsoil. The last case 4 dry density value increases from rest of all that is 1.861 which indicates that yd value determines the good stability of subsoil.

E. California Bearing Ratio

It is a penetration test which is calculated as the amount of force required to penetrate the given soil sample and the standard loads given at various point of penetration i.e. 2.5,3,3.5,4, 4.5 and 5 mm by using a cylindrical plunger of 50 mm diameter. Stability of a subgrade soil is described in terms of values of CBR Standard loads in Kgs at different depth of penetration in mm as shown in table 4.

Table 4: The Load Standard for Various Penetrations

Sr. No.	Penetration ofPlunger (mm)	Standard Load(Kgs)
1.	2.5	1370
2.	5	2055
3.	7.5	2630
4.	10	3180

CBR Test is done for above four cases under three conditions. First under unsoaked condition and second under 2 days and third under four days of soaking. The situations which we discussed earlier (Proctor test) from S1 to S4 again used to determine CBR at 2.5 mm and 5 mm of penetration as given under. Here the standard mould size, volume we will take 2250 cc and from the table no 5 given below CBR is calculated for each conditions.

Table 5: Optimum moisture content and yd (max)

Exp- No.	$\gamma_{d(max)}$ (g/cc)	OMC (%)
1.	1.832	10.52
2.	1.841	10.52
3.	1.851	10.52
4.	1.861	10.52

Case 1:

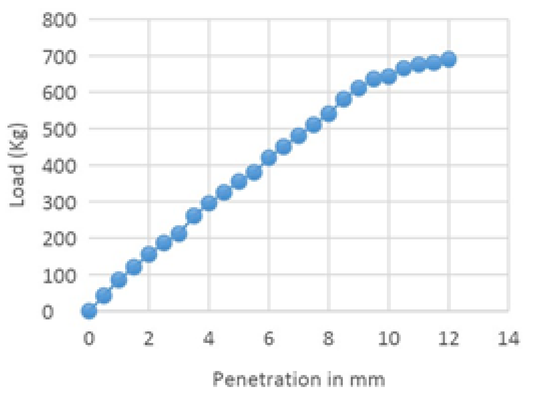

Figure 3: Unsoaked condition

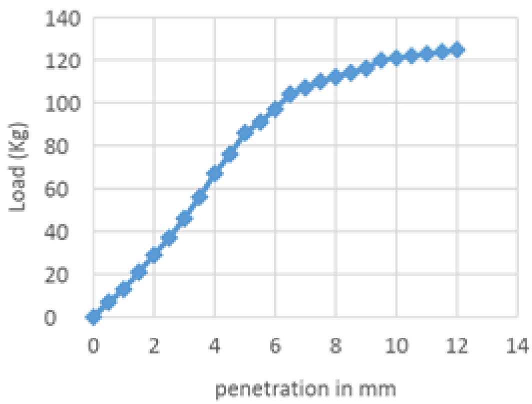

Figure 4: 4 Days Soaked Condition

The above two graphs in figure 3 and figure 4 is placed between the load and penetration. The mould size is the industry-standard 2250 cc and the Standard Available Soil Test Is Used for This Case Max. dry density was determined with the use of a proctor test and found to be 1.832g/cc. Moisture Levels That Are Just Right 10.52% of the total. There are two distinct environments in which a CBR test may be conducted. The first is dry, the second has been drenched for four days. The CBR is computed at two different penetration depths of 2.5mm and 5mm.For unsoaked CBR at 2.5mm is 13.9% and at 5mm is 15.99%. For four days soaked CBR at 2.5mm is 2.93% and at 5mm is 3.71%

Case 2:

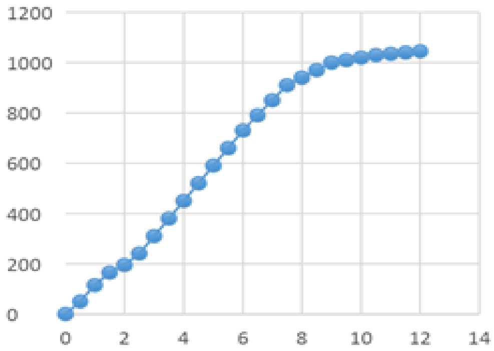

Figure 5: (Unsoaked condition)

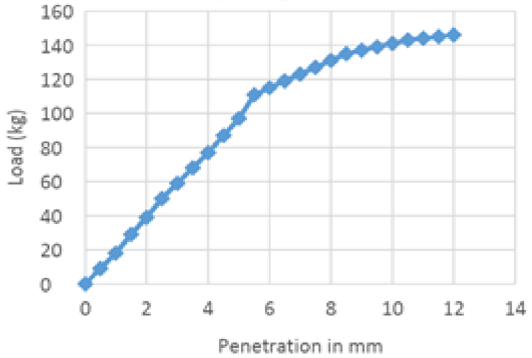

Figure 6: 4 Days Soaked Condition

The above two graphs in figere5 and figure 6 is placed between the load and penetration. The Mold size is the industry-standard 2250 cc and the Standard Available Soil Test Is Used for This Case Max. dry density was determined with the use of a proctor test and found to be 1.841 g/cc. Moisture Levels That Are Just Right 10.52% of the total. There are two distinct environments in which a CBR test may be conducted. The first is dry, the second has been drenched for four days. The CBR is computed at two different penetration depths of 2.5mm and 5mm.For unsoaked CBR at 2.5mm is 17.33% and at 5mm is 25.2%. For four days soaked CBR at 2.5mm is 3.80% and at 5mm is 4.55%

Case 3

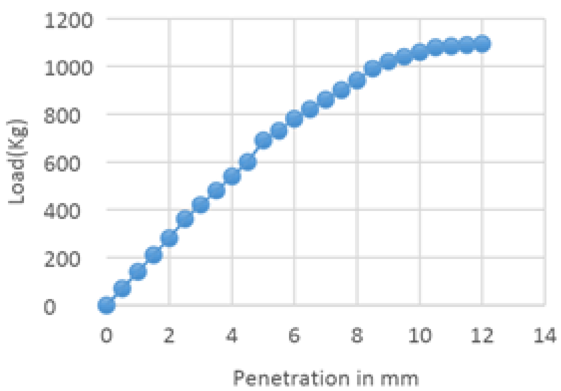

Figure 7: Unsoaked condition

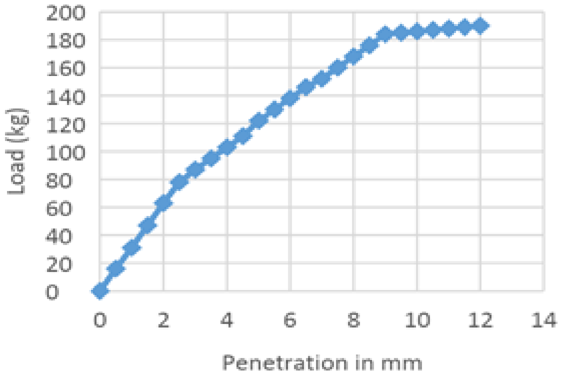

Figure 8: Soaked condition

Case 4:

The above two graphs in figure 7 and figure 8 is placed between the load and penetration. The Mold size is the industry-standard 2250 cc and the Standard Available Soil Test Is Used for This Case Max. dry density was determined with the use of a proctor test and found to be 1.851 g/cc. Moisture Levels That Are Just Right 10.52% of the total. There are two distinct environments in which a CBR test may be conducted. The first is dry, the second has been drenched for four days. The CBR is computed at two different penetration depths of 2.5mm and 5mm.For unsoaked CBR at 2.5mm is 25.13% and at 5mm is 29.5%. For soaked CBR at 2.5mm is 4.50% and at 5mm is 4.93%

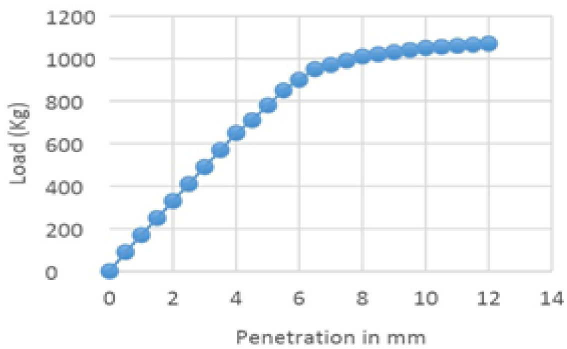

Figure 9: Unsoaked Condition

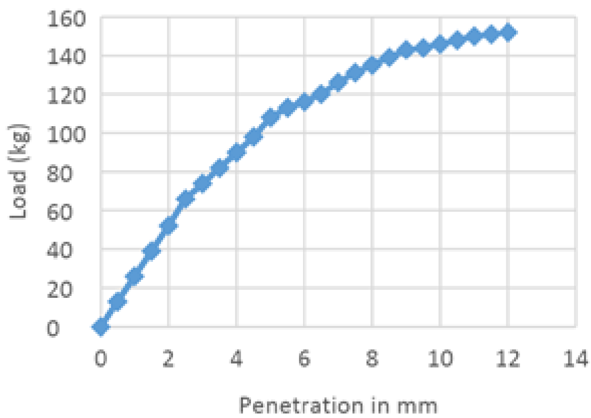

Figure 10: Soaked Condition

The above two graphs in figure 9 and figure 10 is placed between the load and penetration. The Mold size is the industry-standard 2250 cc and the Standard Available Soil

Test Is Used for This Case Max. dry density was determined with the use of a proctor test and found to be 1.861 g/cc. Moisture Levels That Are Just Right 10.52% of the total. There are two distinct environments in which a CBR test may be conducted. The first is dry, the second has been drenched for four days, . The CBR is computed at two different penetration depths of 2.5mm and 5mm.For unsoaked CBR at 2.5mm is 29.5% and at 5mm is 33.3%. For soaked CBR at 2.5mm is 5.80% and at 5 mm is 5.6%

V. CONCLUSION

Subgrade is the compacted soil layer directly below the pavement crust; it is often composed of native soil in the area. It's an excellent base for the asphalt. It is crucial, then, to strengthen the subgrade soil, either by replacing the excellent soil with new soil or by stabilizing the present soil. The CBR test is widely used to evaluate the stability of the subgrade soil. Our study in this paper clearly shows there is a considerable improvement in CBR of subgrade soil due to the use of bitumen emulsion if proper mixing is done. Every state of condition it was found that CBR value has increased consecutively from case 1 to case 4. Its economical in cost and quality of stabilization improvement as we can see in the above work. This type of stabilization is applicable in gravel soil road. This is acceptable application from subgrade soil.4% emulsion is taken. There is not significance change as above their %age in the dry density because being a stabilizing agent.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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