Experimental Study on Improving Subgrade Properties with Bitumen Emulsion

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Abstract*— Subgrade soil significantly influences the performance and durability of flexible pavements, and weak or moisture-susceptible soils often lead to settlement and premature failures. This study evaluates the effectiveness of bitumen emulsion as a stabilizing agent to improve subgrade properties through laboratory investigations. Various proportions of bitumen emulsion were blended with locally available soil and tested for changes in Atterberg limits, compaction characteristics, California Bearing Ratio (CBR), and unconfined compressive strength (UCS). The results showed reduced plasticity, improved compaction behavior, enhanced bearing capacity, and better resistance to moisture, with an optimum emulsion content yielding maximum strength improvement. The findings demonstrate that bitumen emulsion stabilization is a practical, economical, and sustainable method for enhancing subgrade performance and extending the service life of flexible pavements.

Index Terms*— Subgrade Soil, Bitumen Emulsion, Soil Stabilization, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), Atterberg Limits, Compaction Characteristics, Flexible Pavement.

I. INTRODUCTION

Starting from the base, soil is a standout amongst the most abundant construction materials of nature. Just about all kind of construction is based with or upon the soil. Long term performance of pavement structures is altogether affected by the strength and durability of the subgrade soils. In-situ sub-grades frequently don't provide the support required to achieve acceptable performance under the traffic loading with increasing environmental demands. Despite the fact that stabilization is a well-known option for improving soil engineering properties yet the properties determined from stabilization shift broadly because of heterogeneity in soil creation, contrasts in micro and macro structure among soils, heterogeneity of geologic stores, and because of chemical contrasts in concoction interactions between the soil and utilized stabilizers. These properties require the thought of site-specific treatment alternatives which must be accepted through testing of soil-stabilizer mixtures. Whether the pavement is flexible or rigid, it rests on a soil foundation on an embankment or cutting, normally that is known as subgrade. It may be defined as a compacted layer, generally occurring local soil just beneath the pavement crust, providing a suitable foundation for the pavement. The soil in subgrade is normally stressed to certain minimum level of stresses due to the traffic loads. Subgrade soil should be of good quality and appropriately compacted so as to utilize its full strength to withstand the stresses due to traffic loads for a particular pavement. This leads the economic condition for overall pavement thickness. On the other hand the subgrade soil is characterized for its strength for the purpose of design of any pavement.

Improvement of soil engineering properties is referred to soil stabilization. There are two primary methods of soil stabilization. One is mechanical method and the other one is chemical or additive methods. Soil is a gathering or store of earth material, determined regularly from the breakdown of rocks or rot of undergrowth that could be uncovered promptly with force supplies in the field or disintegrated by delicate reflex means in the lab. The supporting soil beneath pavement and its exceptional under course is called sub grade soil. Without interruption soil underneath the pavement is called regular sub grade. Compacted sub grade is the soil compacted by inhibited development of distinctive sorts of substantial compactors. Presently every road construction project will use one or both of these stabilization strategies. The most well-known type of mechanical soil stabilization is compaction of the soil, while the addition of cement, lime, bituminous or alternate executors is alluded to as a synthetic or added substance strategy for stabilization of soil. American Association of State Highway and Transportation Officials (AASHTO) classification system is a soil classification system specially designed for the construction of roads and highways used by transportation engineers. The system uses the grain-size distribution and Atterberg limits, such as Liquid Limits and Plasticity Index to classify the soil properties. There are different types of additives available. Not all additives work for all soil types. Generally, an additive may be used to act as a binder, after the effect of moisture, increase the soil density. Following are some most widely used additives: Portland cement, Quicklime or Hydrated Lime, Fly Ash, Calcium Chloride, Bitumen etc. But, mechanical soil stabilization alludes to either compaction or the introduction of sinewy and other non-biodegradable reinforcement of soil. This practice does not oblige compound change of the soil and it is regular to utilize both mechanical and concoction intends to attain detailed stabilization. There are a few routines used to accomplish mechanical stabilization like compaction, combining, soil reinforcement, expansion of graded aggregate materials and mechanical remediation.

II. LITERATURE REVIEW

Bitumen emulsion is used as chemical stabilizer. Cement is used here as a binder only to improve strength of road. Previously lots of work was done on sand bitumen stabilization and gravel soil bitumen stabilization in different places. This study is being inspired from those researches. Here gravel red coloured soil is used, as it is available in many states of India. Some similar works, done before, is discussed below.

Chinkulkijniwat and Man-Koksung (2010) Ref 1 They directed a test research on compaction aspects of non-gravel and gravelly Soils using a little compaction device. The standard delegate test has been broadly utilized and acknowledged for characterizing soil similarity for field compaction control. Here additionally indicates about the influence of gravel size and gravel content on standard delegate test results. In this study a relationship developed between the summed up optimum water substance of the fine division in the gravelly soil and the gravel content in standard molds using compaction results from the proposed little device.

Razouki et al. Ref 2 He propose an experimental study on Granular Stabilized Roads. Bitumen was used as a stabilizing agent may act as a binder or as a water-proofing material. Soil-bitumen systems had found the greatest used in road bases and surfaces.

III. EXPERIMENT PROGRAMME

3. 1 Materials used
1. Bitumen emulsion
2. Soil

3.1.1 Bitumen Emulsion Emulsified Bitumen usually consists of bitumen droplets suspended in water. Most emulsions are used for surface treatments. Because of low viscosity of the Emulsion as compared to hot applied Bitumen, The Emulsion has a good penetration and spreading capacity. The type of emulsifying agent used in the bituminous emulsion determines whether the emulsion will be anionic or cationic. In case of cationic emulsions there are bituminous droplets which carry a positive charge and Anionic emulsions have negatively charged bituminous droplets. Based on their setting rate or setting time, which indicates how quickly the water separates from the emulsion or settle down, both anionic and cationic emulsions are further classified into three different types. Those are rapid setting (RS), medium setting (MS), and slow setting (SS). Among them rapid setting emulsion is very risky to work with as there is very little time remains before setting. The setting time of MS emulsion is nearly 6 hours. So, work with medium setting emulsion is very easy and there is sufficient time to place the material in proper place before setting. The setting rate is basically controlled by the type and amount of the emulsifying agent. The principal difference between anionic and cationic emulsions is that the cationic emulsion gives up water faster than the anionic emulsion. Over a time of time, which may of years, the asphalt stage will in the long run separate from the water. Asphalt is insoluble in water, and breakdown of the emulsion includes the combination of droplets. The asphalt droplets in the emulsion have a little charge. The wellspring of the charge is the emulsifier, and ionisable segments in the asphalt itself. However when two droplets do attain enough vitality to defeat this hindrance and approach nearly then they hold fast to one another. Over a time of time, the water layer between droplets in floccules will thin and the droplets will combine. Components which constrain the droplets together, for example, settlement under gravity, dissipation of the water, shear or solidifying will quicken the flocculation and mixture process.

3.2 Tests conducted on soil

3.2.1 Specific Gravity The ratio between the mass of any substance of a definite volume divided by mass of equal volume of water is defined as Specific Gravity. For soils, it is the number of times the soil solids are heavier in the assessment to the equal volume of water present. So it is basically the number of times that soil is heavier than water. Specific gravities for different type of soils are not same. In the time of experiment it should be cared about the temperature correction and water should be gas-free distilled water. This specific gravity of soil is denoted by 'G'. Specific gravity is very a very important physical property used to calculate other soil engineering properties like void ratio, density, porosity and saturation condition.

Proctor Test is essentially for determination of the relationship between the moisture substance and dry density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a stature of 30 cm. It is a research center test system for experimentally deciding the optimum moisture content (OMC) at which a given soil sorts will get most thick and accomplish its maximum dry density (Yd). The name Proctor is given out of appreciation for R. R. Proctor for demonstrating that the dry density of soil for a compactive exertion relies on upon the measure of water the soil holds throughout soil compaction in 1933. His unique test is most generally alluded to as the standard Proctor compaction test, which recently was overhauled to make the new compaction test. That is Modified Proctor Test.

Fig 3.1. Modified Proctor test apparatus

The soil that is normally compacted into the mold to a certain measure of equivalent layers, each one receiving a number blows from a standard weighted sledge at a standard height. This methodology is then rehashed for distinctive qualities of dampness substance and the dry densities are determined for each one case. In this case materials are filled in five equivalent layers with 25 blows in each one layer. The hammer and the mould for modified proctor test are shown below the entire project work can be divided by the following cases:

CASE A: Normal available soil is used for testing.

CASE B: Normal available soil tested with 3% emulsion.

CASE C: Normal available soil tested with 3% emulsion & 2% cement wait for 30mins before testing.

CASE D: Normal available soil tested with 3% emulsion & 2%cement and wait for 10 hrs before testing

BITUMEN EMULSION

- Emulsified bitumen usually consists of bitumen droplets suspended in water .
- Most emulsions are used for surface treatments because of low viscosity as compared to bitumen.
- The emulsions has a good penetration and spreading capacity.

GRAVEL SOIL

- The soil used for this study is a gravel soil which is collected from the surroundings visvodaya engineering college
- To find out the physical properties of the soil sample collected from the following tests are carried out

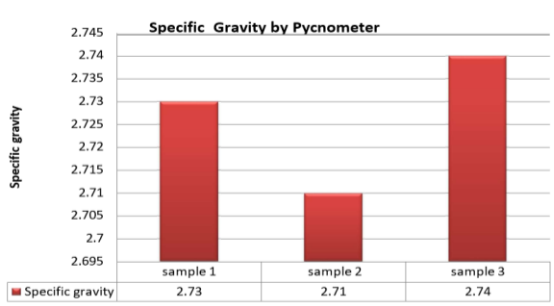
➢ Specific gravity
➢ Particle size distribution
➢ Compaction test (modified)
➢ California Bearing Ratio (CBR)

IV RESULTS AND DISCUSSION

SPECIFIC GRAVITY TEST: Specific gravity of soil is very important property to understand the soil condition. As previously discussed here

➢ M1 = weight of empty pycnometer
➢ M2 = weight of pycnometer + soil
➢ M3 = weight of pycnometer + soil +water
➢ M4 = weight of pycnometer + water
➢ G = (W2-W1)/(W2-W1) -(W3-W4)

Sample No	M1(gm)	M2(gm)	M3(gm)	M4(gm)	Sp.Gravity
1	114.67	164.67	383.56	351.87	2.73
2	113.76	163.76	384.41	352.56	2.71
3	115.34	165.34	385.69	353.94	2.74



Particle size distribution (Dry sieve analysis)

Sieve No	Sieve Size	Mass of soil in retained in each sieve (gm)	Percent retained (%)	Cumulative retained (%)	Passing through sieve (%)
1	4.75 mm	230	23	23	77
2	2.36 mm	145	14.5	37.5	62.85
3	2.00 mm	108	10.8	48.3	51.7
4	1.18 mm	103	10.3	58.6	41.4
5	1.00 mm	100	10	68.6	31.4
6	600 micron	92	9.2	7.8	22.2
7	300 micron	126	12.6	90.4	9.6
8	150 micron	53	5.3	95.7	4.3
9	90 micron	17	1.7	97.4	2.6
10	75 micron	17	1.7	99	0.9
11	Pan	9	0.9	100	0

COMPACTION TEST

- About 6kgs of soil is taken passing through IS 4.75mm
- Water is added to it and mixed properly and soil is compacted in 5 layers each layer with 56 blows of rammer 4.5kg falling from 45cm.
- The collar was removed and excess soil is trimmed using straight edge and cleaned outside and weighed.
- The process is repeated for different moisture content percentages.

V CBR TEST

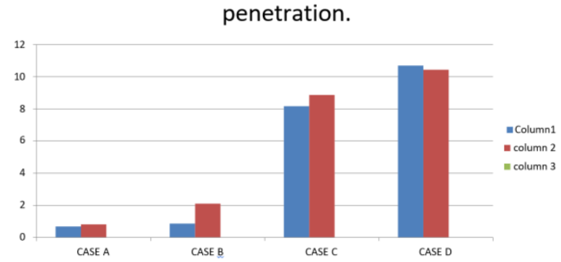
- Arrange the mould on the base plate with distance piece and assemble the extension collor.
- Take 6 kgs of soil passing through IS 4.75mm sieve.
- Mix the soil with optimum moisture content (8%) and compact the soil in 5 layers each layer with 55 blows by 4.8kg rammer falling from 45cm height.

- Trim the soil and add a min of 4.5kg surcharge load in the of disc weights.
- Keep the entire mould under loading frame and set the proving ring dial and penetration dial to zero and rotate the loading handle at a steady rate of 0.05inch per min note the proving ring readings corresponding to penetrations of 25,50,75,100,125,150,175,200,250,300,400,500.

S.NO	Penetration dial gauge		Load dial gauge	
	Dial gauge Reading	Penetration Reading	Proving ring reading	load in kg
1	0	0	0	0
2	25	0.25	1.3	1.5
3	50	0.50	2.1	2.43
4	75	0.75	2.25	2.61
5	100	1.0	2.3	2.66
6	125	1.25	3.2	3.712
7	150	1.50	3.9	4.52
8	175	1.75	4.7	5.452
9	200	2.00	5.1	5.91
10	250	2.50	7.9	9.16
11	300	3.00	9.7	11.25
12	400	4.00	12.3	14.26
13	500	5.00	14.2	16.47

Results and Discussions about Case A, Case B, Case C, Case D: From the previous modified proctor results 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 2.2 gm/cc. Little bit of fluctuation in optimum moisture content value in different cases. This dry density value is a very important physical property in case of stability of subgrade soil. Bellow the variation of maximum dry density in those special cases are shown bar wise.

CBR RESUTLS for CASE A,B,C& DFOR 2.5mm&5mm penetration.



VI CONCLUSION

The study demonstrates that stabilizing subgrade soil with bitumen emulsion significantly improves its engineering properties and suitability for use in flexible pavement foundations. Laboratory evaluations confirmed reductions in plasticity, improvements in compaction behavior, and notable increases in California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) with the addition of optimum emulsion content. The treated soil also showed enhanced resistance to moisture and better durability compared to untreated samples. These improvements indicate that bitumen emulsion is an effective, economical, and practical stabilizing agent for weak and moisture-sensitive subgrades. Adopting this method in pavement construction can enhance load-bearing capacity, reduce maintenance needs, and extend pavement service life, making it a sustainable solution for subgrade improvement.

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