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A comparative study on effect of bitumen emulsion, cement and lime on soil stabilization

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Abstract: Soil is the basic foundation for any civil engineering structures and is one of nature's most abundant construction materials for base. The most important part of a road pavement is subgrade soil and its strength. It is required to bear the loads without failure. If strength of soil is poor, then stabilization is normally needed. Subgrade is sometimes stabilized or replaced with stronger soil material so as to improve the strength. Numerous methods are available in the literature for soil stabilization but sometimes, some of the methods like chemical stabilization, lime stabilization, cement stabilization, fly ash stabilization adversely affect the chemical composition of the soil. In this study bitumen emulsion, cement and lime were mixed with dredged soil to investigate the relative strength of gravel soil in terms of Unconfined Compression Test (UCC), Bearing Capacity and California Bearing Ratio (CBR). The effect of bitumen emulsion, Cement and Lime on the geotechnical characteristics of cement and lime mixtures was investigated by conducting various tests like CBR and UCC. A little cement added to provide better soil strength. It is observed that excellent soil strength results by using cationic bitumen emulsion (CMS) with little quantity of cement used as filler. The appropriate mixing conditions for gravelly soil with CMS Bitumen emulsion have been first attempted. This is followed by deciding four particular material conditions to show the variation in dry density and CBR value to achieve the best possible strength properties of gravel soil. However, in this study, without additives soil was tested to find the Optimum Moisture Content (OMC), CBR value, Plasticity Index and Unconfined Compression Strength.

Keywords: Soil Stabilization, Bitumen emulsion, Lime, Cement, Fillers, Soil strength

1. Introduction

Soil stabilization is a process by which a soils physical property are transformed to provide long-term permanent strength gains. Stabilization is accomplished by increasing the shear strength and the overall bearing capacity of a soil. Once stabilized, a solid monolith is formed that decreases the permeability, which in turn reduces the shrink/swell potential and harmful effects of freeze/thaw cycles. The shrink/swell potential of a soil is the amount that a soil can change in volume depending on the moisture content. Some expansive soils can expand as much as ten percent! This drastic change in volume can easily produce enough force to cause serious damage to a home, building or roadway. Soil stabilization can improve in-situ, or natural state, soils eliminating the need for expensive remove-and-replace operations. Often soils that provide the structural base for roads, building pads or parking lots are chemically treated to control engineering properties of a soil, such as moisture content. Soil stabilization is accomplished by using lime, lime-based products or other chemicals such as Portland cement. These chemicals rely on pozzolanic reactions to form permanent bonds between soil particles. Pre-project testing is essential to be sure that enough material is present to permanently stabilize the soil.

If the stabilized soil layer is incorporated into the structural design of the pavement, the subsequent layers will be thinner resulting in sizable cost savings. Lime Stabilized soils over perform non-stabilized soils when materials, design, and construction are properly considered. Soil is the foundation for any civil engineering structures and is one of nature's most abundant construction materials for base. The most important part of a road pavement is subgrade soil and its strength. It is required to bear the loads without failure. If strength of soil is poor, then stabilization is normally needed. Subgrade is sometimes stabilized or replaced with stronger soil material so as to improve the strength. Numerous methods are available in the literature for soil stabilization but sometimes, some of the methods like chemical stabilization, lime stabilization, cement stabilization, fly ash stabilization adversely affect the chemical composition of the soil.

In this study bitumen emulsion, cement and lime were mixed with dredged soil to investigate the relative strength of gravel soil in terms of Unconfined Compression Test (UCC), Bearing Capacity and California Bearing

Ratio (CBR). The effect of bitumen emulsion, Cement and Lime on the geotechnical characteristics of cement and lime mixtures was investigated by conducting various tests like CBR and UCC. A little cement added to provide better soil strength. It is observed that excellent soil strength results by using cationic bitumen emulsion (CMS) with little quantity of cement used as filler. The appropriate mixing conditions for gravelly soil with CMS Bitumen emulsion have been first attempted. This is followed by deciding four particular material conditions to show the variation in dry density and CBR value to achieve the best possible strength properties of gravel soil. However, in this study, without additives soil was tested to find the Optimum Moisture Content (OMC), CBR value, Plasticity Index and Unconfined Compression Strength. Stabilization is a process of improving subsoil engineering properties prior to construction. There are many techniques of stabilization, including preloading the ground with high energy impacts, using sand drains and sand filters, prefabricated wick drains, and adding chemical additives.

2. Materials and Methods

Selection of material and methodology those are the first criteria for any type of experimental investigation. To know the soil physical properties following tests are conducted like specific gravity test, grain size distribution test by sieve analysis and plastic limit and liquid limit test. After that the important part is to choose mixing procedure and the cases or different conditions for conducting the next tests. To determine the maximum dry density of the material modified proctor test has been conducted. But the actual goal is to increase the strength. So CBR test are conducted in different cases and conditions and make a comparative experimental study. So the methodology is how to achieve maximum bearing capacity or maximize the CBR value. In the next page Methodology part is in chart form.

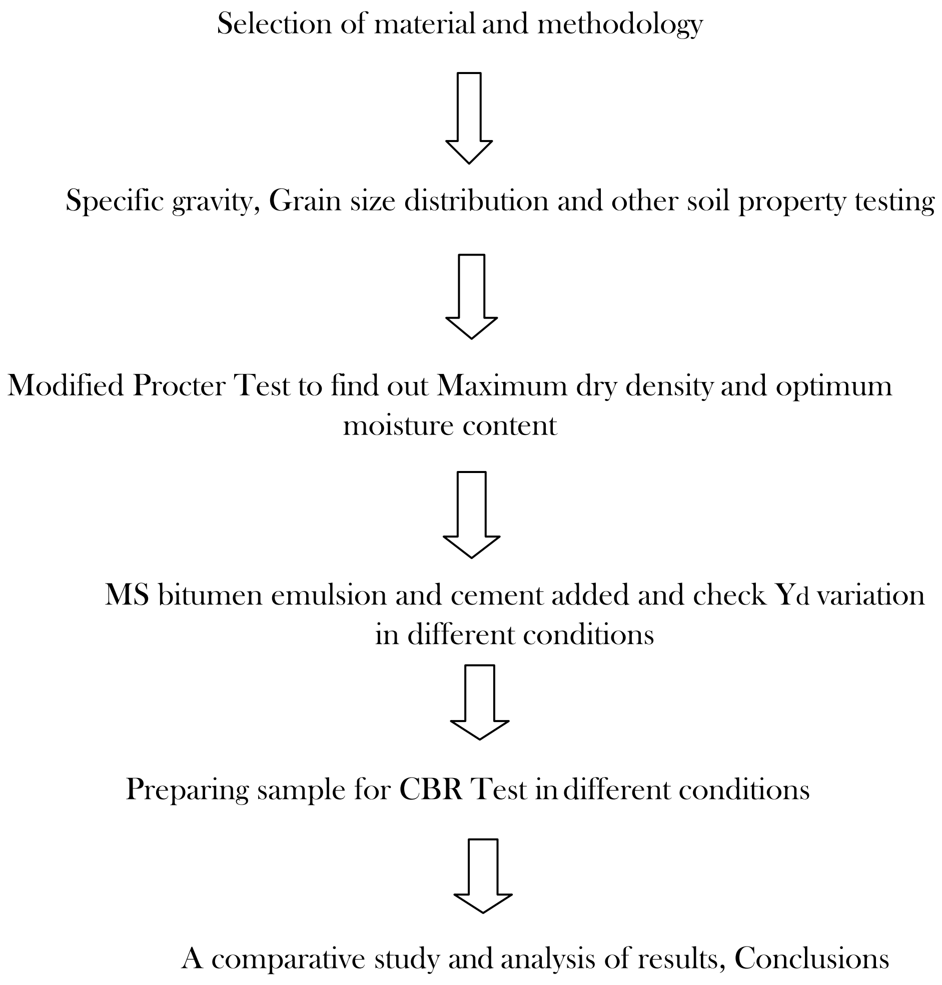

Fig.1: Selection of material and methodology

3. Results

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.

As it is discussed, the ratio between the weight of the soil solids and weight of an equal volume of water is termed as Specific Gravity. The measurement is done in a volumetric flask in an experimental setup where the volume of the soil is found out and its weight is then further divided by the weight of equal volume of water.

Table 1: Properties

Type of soil	**Specific gravity**
Sand	2.63 to 2.67
Silt	2.65 to 2.7
Clay and Silty soil	2.67 to 2.9
Organic soil	1+ to 2.6

California Bearing Ratio 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 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 calculated for each specimen from the corresponding graphs which is shown below. Generally, the CBR value at 2.5mm penetration is 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 specimen 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. CBR value and the CBR graph is case wise shown below.

Case A: Normal available tested soil is used for testing in this case.

Case B: Normal available soil tested with 3% MS emulsion added.

Case C: Normal available soil tested with 3% MS emulsion and 2% OPC cement added

Case D: Normal available soil tested mixing with 3% of emulsion and 2% of OPC cement added and after 5-hour testing started.

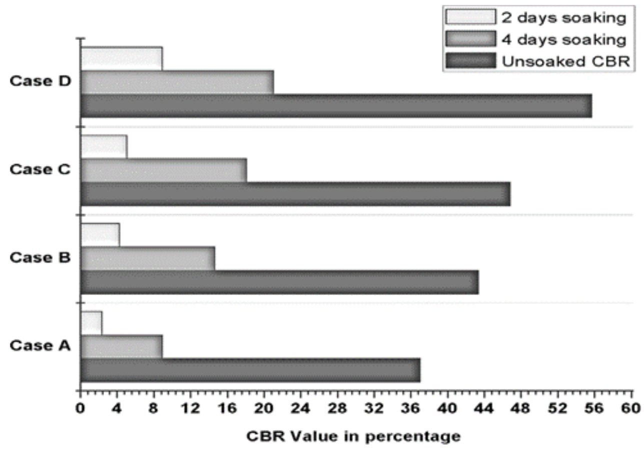

Fig. 2: CBR Values

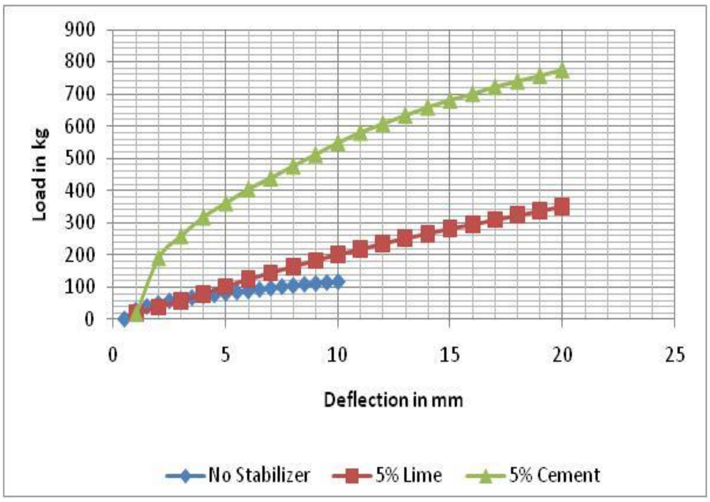

Fig. 3: Load results

Unconfined Compression Test: The Unconfined Compression Test is a laboratory test used to derive the Unconfirmed Compressive Strength (UCS) of a rock specimen. Unconfirmed Compressive Strength (UCS) stands for the maximum axial compressive stress that a specimen can bear under zero confining stress. Due to the fact that stress is applied along the longitudinal axis, the Unconfined Compression Test is also known as Uniaxial Compression Test. UCS is a parameter widely used in geotechnical design, but may not represent the strength in-situ. On a large scale, the rock mass properties are highly affected by other factors including discontinuities, faults and weathering. During the test, apart from the axial load, axial and lateral deformation are commonly measured to derive the sample's elastic modulus and Poisson's ratio.

Samples are retrieved by drill cores and are selected cautiously in order be representative of the original rock formation. The minimum diameter of a specimen must be at least 47 millimeters and 10 times larger than the size of the largest mineral grain (or 6 times larger for weaker rocks e.g. sandstones, marlstones).

The samples' length to diameter ratio (L/D) must be between 2.0 and 2.5, according to ASTM (American Society for Testing and Materials) and 2.5-3.0 according to ISRM (International Society for Rock Mechanics). The cylindrical surfaces are prepared in order to be flat and smooth. In particular, the sample's ends must be levelled within a 0.02 millimeters tolerance and they should not depart from perpendicular by more than 0.06 degrees. The purpose of the procedure is to preserve the in-situ properties of the sample until the test is conducted. Therefore, moisture recorded in the field should also be preserved until testing. At least 5 samples are required to achieve a reliable value of the UCS

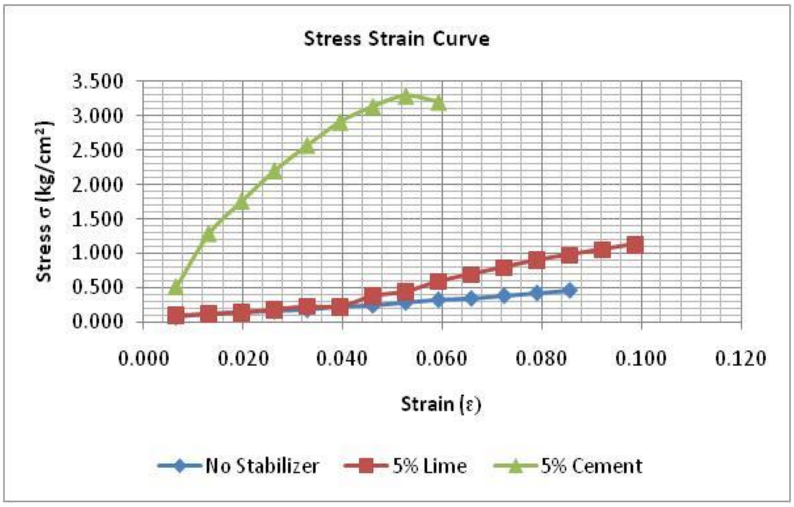

Fig. 4: Stress results

4. Conclusions

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

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