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Stabilization of Pavement Subgrade Using Bio-Polymers

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ABSTRACT

The use of bio-polymers for stabilizing pavement subgrades has gained increasing attention in recent years due to their eco-friendliness and effectiveness in improving subgrade strength and stability. An overview of the idea of stabilising pavement subgrades using bio-polymers is provided in this study, along with information on the types and properties of bio-polymers, subgrade stabilisation mechanisms, and the effectiveness of bio-polymer-treated subgrades in laboratory and field tests. The findings point to bio-polymers as a potentially advantageous replacement for conventional chemical additives for subgrade stabilisation, with potential advantages in terms of cost-effectiveness, sustainability, and environmental impact.

Keywords: *Bio-polymer, Stabilization, soil subgrade, Xanthan gum, Guar gum, etc*

INTRODUCTION

A natural resource known as soil is created over a long period of time by the weathering and erosion of rocks, minerals, and organic material. It is a complex mixture of minerals, water, air, organic matter, and living things that supports the growth of plants, maintains the health of ecosystems, and serves as a habitat for a variety of creatures. Yet not all soils are created equal, and some soils might not be appropriate for particular kinds of construction or development. For instance, massive structures or heavy traffic may not be able to be supported by soils with poor bearing capacity or high compressibility, whereas soils with high water content may be prone to erosion or instability. Soil stabilization is the process of improving the physical and mechanical properties of soil to make it more suitable for specific uses, such as construction, infrastructure development, or agriculture. The goal of soil stabilization is to increase the soil's strength, durability, and resistance to deformation and degradation, and to minimize the potential for settlement, erosion, or other types of soil failure. Some of the renewable technologies are enzymes, surfactants, biopolymers, synthetic polymers and more. Bitumen, tar emulsions, asphalt, cement, lime can be used as binding agents for producing a road base. While using such products, issues such as safety, health and the environmental effects must be considered. So using biopolymers in soil stabilization is an alternate method to reduce the environment effects. Bio-polymers are a type of natural polymer that are derived from renewable resources, such as plants, animals, and microorganisms. They have gained significant attention in recent years due to their environmentally-friendly and sustainable nature. One potential application of bio-polymers is in the stabilization of pavement subgrades. Bio-polymers, on the other hand, offer a natural and sustainable alternative for subgrade stabilization. They can be used in two ways: as a soil additive or as a soil binder. As a soil additive, bio-polymers can improve the engineering properties of subgrade soil, such as its strength and stiffness. As a soil binder, bio-polymers can be used to stabilize loose or sandy soils by binding the soil particles together and creating a more stable subgrade.

LITERATURE REVIEW

Mir Aamir Fayaz. The soil over which the construction is to be carried out should have enough strength to carry the design load, neither should failure occur. This problem mainly occurs when construction is to be done on clayey soil. The main focus of this research was to improve the strength of clayey soil & to obtain a optimum amount of soil- fibers of geosynthetics mix. The objective of study was to increase the strength of clayey soil using fibers of geosynthetics fiber.As we know fibers of geosynthetics act as a reinforcing material. As clay shows high shrinkage, swell characteristics & low bearing capacity especially under sub-grade, Therefore, there is a need to improve the strength characteristics of soil. So, the main focus of this research was to increase the strength characteristics of soil. The tests performed in laboratory was Pycnometer test for specific gravity, Casagrande’s test for liquid limit, plastic limit test, Standard proctor test for determination of OMC & MDD & modified proctor test.

Ashwin Balaji. Examined how bio polymers effects the soil stabilization. Soil is a very important material for civil engineering because its often used in various construction purposes. Stabilization of a soil is the process of improving the strength parameters of the soil. There are different soil stabilization process are available for enhance the strength of the soil. Bio-polymers also used for soil stabilization, which is sustainable and eco-friendly. Bio-polymers provides more strength compare than other stabilization process.

Habiba afrin. Examined the physical and chemical properties of soil in different types of stabilization methods. It looks at how these methods can affect the shear strength, shrink-swell properties, permeability and compressibility of a soil mass. The paper also examines how these changes can improve the load bearing capacity for pavements and foundations.

Jianxin Huang. Provides a review of the research on use of polymers for soil stabilization in pavement and geotechnical engineering. It looks at different properties that impact the effectiveness of various polymer classes, such as geopolymer, biopolymer, and synthetic organic polymer. It also examines the mechanisms governing stabilization with these polymers and how they interact with soils composed predominantly of sand or clay particles. Finally it discusses some advantages to using these polymers for soil stabilization as well as challenges that need to be addressed before wider use can occur.

S. Sugandini. presents soil geosynthetic interaction properties for different types of samples of clayey soil were used with geocomposite reinforced materials for conducting CBR test to finding the density of soil samples and mechanical strength of sub grade soil.

EXPERIMENTAL MATERIALS

Soil

The soil used in the study is collected from a field in a village near to Rajam town.

Figure 1: Crumb rubber

Xanthan gum

Xanthan gum is a high molecular weight polysaccharide that is produced by the fermentation of carbohydrates by the bacterium Xanthomonas campestris. It is commonly used as a food additive, particularly as a thickening and stabilizing agent in a wide variety of food products, such as sauces, dressings, and baked goods. Xanthan gum is an effective thickening agent because it forms a gel-like substance when mixed with water, and it has the ability to suspend particles in liquids. This makes it useful in a range of food products where a stable texture and appearance are important**.** The chemical formula for Xanthan is C34H49O29 ((monomer).

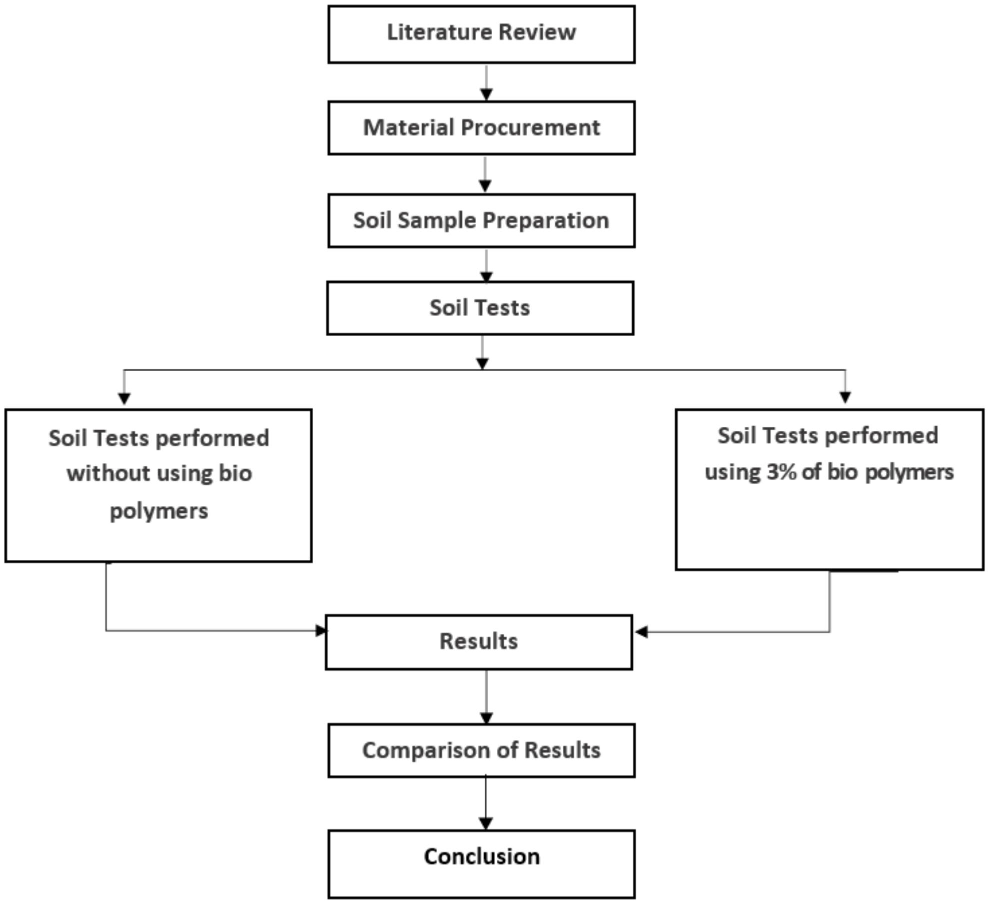
Guar gum

Guar gum is a type of natural polysaccharide, which is derived from the seeds of the guar plant (Cyamopsis tetragonolobus). It is a white powder that is commonly used as a thickening and stabilizing agent in a wide range of food products, including baked goods, dairy products, and sauces.

Guar gum is also used in various industries, such as the textile, pharmaceutical, and paper industries, due to its ability to thicken and increase viscosity. It is considered a high-performance additive and is often used as a substitute for synthetic thickeners.

EXPERIMENTAL METHODOLOGY

In this chapter, the methodology adopted for the work has been explained. The detailed laboratory experiments conducted to determine the properties of the soil. The methodology proposed for determination of finding optimum amount of fiber content by mixing percentages of bio-polymer at 3%. The soil was collected from Rajam area, near balini and then placed the collected soil in oven for 24 hours. Then performed the basic tests like specific gravity, liquid limits, plastic limit test, CBR test, UCS test, compaction test in order to find the soil properties. Now conduct the above same tests by adding bio polymers and find out the result.



EXPERIMENTAL INVESTIGATION

Experiments that are to be carried out: -

1. Specific gravity by density bottle method
2. Liquid limit by Casagrande liquid limit apparatus
3. Plastic limit
4. Compaction test
5. Unconfined compression test
6. California bearing ratio test

1. Specific gravity by density bottle method

The steps involved in the determination of specific gravity in this method are schematically shown in Fig

Procedure

- The weight of the clean and dry Pycnometer is taken to the nearest 0.01g (W1).
- About 300 g of oven dried soil sample passing through 425 IS Sieve is taken for the test. The soil sample is placed in it. The pycnometer with soil is weighed to the nearest 0.01g(W2)
- Sufficient water is added to the pycnometer such that the soil is just covered. The entrapped air may be removed by shaking accompanied by occasional stirring.
- Water is added in increments, accompanied by occasional stirring until the pycnometer is full. The pycnometer is weighed to the nearest 0.01g(W3)
- The pycnometer is emptied, washed with water thoroughly and rinsed with water and then filled with water completely. The pycnometer is then weighed to the nearest 0.001g (W4).

Reference

IS 2720: Part 3: Sec 1: 1980 Methods of test for soils: Part 3 Determination of specific gravity Section 1 fine grained soils.

2. Liquid limit by Casagrande liquid limit apparatus

Liquid limit is the water content at which a soil changes from liquid state to plastic state. It is the minimum water content at which the soil is still in liquid state but possesses small shear strength against flow.

As per IS 2729 (Part 5)-1985, liquid limit is defined as the water content at which, the soil placed in the brass cup of Casagrande's liquid limit apparatus and cut into a groove of standard dimensions, will flow together for a distance of 12 mm at the bottom of the groove under 25 blows.

Procedure

- A clean sharp groove of standard dimensions is made in the soil paste using a grooving tool. This is done by keeping the grooving tool in touch with and normal to the surface of the brass cup at the top and rotating it along the diameter of the cup through the centre line of the cam follower
- The water content of the soil is determined (w1) by collecting a sample of soil.
- The soil paste is removed from the brass cup and placed into the evaporating dish and the equipment is cleaned.

- More water is added to the soil in the evaporating dish and mixed thoroughly.
- Steps are repeated to get 3 more readings of water content (w2, w3, w4) and blow count (N2, N3, N4), each with higher water content.

Reference

IS 2720: Part 5: 1985 Method of Test for Soils - Part 5: Determination of Liquid and Plastic Limit

3. Plastic limit

Plastic limit is the water content at which a soil changes from plastic state to semi-solid state. It is the minimum water content at which soil remains in plastic state and can be moulded to any shape without rupture.

IS:2720 (Part 5) - 1985 describes the procedure for determination of plastic limit. Experimentally, the plastic limit is defined as the water content at which a soil begins to crumble (forms cracks) when rolled into a thread of 3 mm diameter.

Procedure:

- About 60 g of air-dried soil passing through 425µ IS Sieve is taken and mixed with sufficient water such that its water content is more than the estimated plastic limit and such that soil becomes plastic enough to be easily molded with fingers.
- About 20 g of the thoroughly mixed soil is taken. A ball is made with about 8g of this soil and rolled on the glass plate with fingers with just sufficient pressure to roll the mass into a thread of uniform diameter, throughout its length.
- The rate of rolling with fingers shall be at rate of 80 to 90 strokes per minute, counting a stroke as one complete forward and backward motion of the fingers.
- When the diameter of the soil thread reaches 3 mm, the soil thread is worked back to form a ball.
- The procedure of rolling into thread of uniform diameter of 3 mm and kneading back into a ball is repeated until cracks appear on the surface of the soil thread, which begins to crumble. When this condition is reached, the water content of the piec es of soil thread is determined.
- The test is repeated taking another portion of the soil paste and a total of 3 trials are made and the corresponding water contents are determined. The average water content out of three trials to the nearest whole number is reported as the plastic limit.

References:

IS 2720: Part 5 : 1985 Method of Test for Soils - Part 5 : Determination of Liquid and Plastic Limit

4. Compaction test

The soil is compacted using standard compaction specifications at different moisture contents and the corresponding dry density of compacted soil is determined. The water content corresponding to maximum dry density, known as Optimum Moisture Content (OMC) is obtained by plotting a graph with water content on X-axis and Dry density on Y- Axis.

Procedure

- Aggregations of soil particles shall be broken and the soil is mixed with a suitable amount of water. The amount of water to be added initially for the first trial is 4 to 6 percent for sandy or gravelly soil and 8 to 10 percent below plastic limit (PL-8 or PL10) of the soil for cohesive soils.
- The soil and water should be mixed thoroughly and it is required to store mixed sample in a sealed container for about 16 hours in case of high plastic clays for uniform distribution of moisture throughout the volume of the soil
- The compaction mould with the base plate attached is weighed to the nearest 1 g using a balance of capacity 10 kgf (W1)
- The mould with base plate is placed on a solid base, such as concrete floor. About 2.5 kgf of the wet soil is taken and divided approximately in to 3 parts. One part of the wet soil is placed in the mould and compacted by applying 25 blows with the 2.6 kgf rammer, falling through exactly 31cm on the soil for each blow. The blows should be uniformly distributed over the entire area of the mould
- The reminder of the compacted soil specimen is broken up to individual particle level by hand knife and by rubbing through the 20 mm IS sieve, and then mixed with the remainder of the original sample
- The inside surface of compaction mould collar and rammer are cleaned of soil Suitable amount of water is now added to the wet soil, 1 to 2 percent for sandy or gravelly soils and 2 to 4 percent for cohesive soil.
- The procedure in steps 2 to 11 is repeated to get at least 5 trials, so that the weights W1, W2, W3, W4 and W5 as well as the water contents w1, w2, w3, w4 and w5 are obtained.

References:

1. IS 2720 : Part VII : 1980 Methods of Test for Soils - Part VII : Determination of Water Content-Dry Density Relation Using Compaction

2. IS:10074-1982 specification for compaction mould assembly.

5. Unconfined Compression Test

The Unconfined Compression test is a special case of a triaxial compression test, in which the confining (cell) pressure is zero. The test can be conducted only on saturated cohesive soils, which can stand unsupported without confining pressure.

Procedure

- The initial length, diameter and weight of the specimen shall be measured and the specimen placed on the bottom plate of the loading device. The upper plate shall be adjusted to make contact with the specimen.
- The deformation dial gauge shall be adjusted to zero.
- Force shall be applied so as to produce axial strain at a rate of 1/2 to 2 percent per minute.
- Force (Proving Ring) and deformation readings shall be recorded at suitable intervals;
- The frequency of the readings shall be more at the initial stages; the frequency may 0.0be reduced at higher percentage of strain. Up to 6 percent strain, the readings may be taken at every 30 s ; after 6 percent, the frequency may be halved and beyond 12 percent, it may be decreased further.
- The failure pattern shall be sketched carefully and shown on the data sheet or on the sheet presenting the stress-strain plot.
- The angle between the failure surface and the horizontal may be measured, if possible, and reported.

References

IS 2720 (Part 10) — 1973: Indian Standard Methods of Test For Soils: Part 10 Determination of Unconfined Compressive Strength.

5. California bearing ratio test

The CBR test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The harder the surface, the higher the CBR value. Typically, a value of 2% equates to clay, while some sands may have a CBR value of 10%. High quality sub-base will have a value of between 80-100% (maximum).

The CBR test is carried out on soils with a maximum particle size of 20mm. (Note: For material greater than 20mm please see Plate Bearing Tests). The technique involves driving a small cylindrical plunger (approx 50mm) into the ground at a uniform rate, using a four wheel drive vehicle as the reaction load to provide the force.

Tests are normally carried out at surface level or at depths of between 500-1000mm in 20-30m intervals along the proposed construction centreline. A minimum of three tests are usually carried out at each site.

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IS: 2720 (Part 16)-1979 Indian Standard Methods of test for soils: Part 16 Laboratory determination of CBR.

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