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Flexible pavement design for rural roads by improving expansive soil

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Abstract— **The rural roads are the basic infrastructure required for the development of rural areas. Rural roads have been planned and constructed under various rural development programs of the Government of India. On the other hand many roads that are built in rural areas could not be sustained. Careful examination of these has revealed that most efforts have not been effective due to the fact that in those programmes, the roads were not understood to be engineering structures. Many of the technical aspects of road making were never given due importance in rural road; e.g., adequate compaction of subgrade, drainage, required cross drainage and host of others. Poor subgrade soil conditions can results in inadequate pavement support and reduce pavement life. Our projects aims are to designing an all-weather road for a chosen rural site which has weak soil strata. There are plenty of appropriate technologies for rural road construction and maintenance using locally available materials. We also aim at using all these to the optimum level.**

Key Words: Black cotton soil, Stabilization, Lime, Cement, CBR

I. INTRODUCTION

Providing good road network is very essential for the development of any country. In India, there are about more than six lakh villages located in different terrain conditions, e.g., plains,hilly and mountainous region, deserts, swamps, coastal region, backwater area, tribal pockets, etc…The climatic conditions also vary from place to place to a great extent. Social, economical and educational development of these villages greatly depends on accessibility. A large number of villages in rural India are still not connected with the all weather roads. The employment opportunities and necessities likes health, education cannot reach masses without a system of proper road communication system must be a priority.

The rural roads are the basic infrastructure required for the development of rural areas. Rural roads have been planned and constructed under various rural development programmes of the Government of India. Serious effects through these programmes also could not make all-weather connectivity to more than 50percent of six lakh villages. On the other hand, many roads that are built in rural areas could not be sustained. Careful examination of these has revealed tha most efforts have not been effective due to the fact that in those programmes, the roads were not understood to be engineering structures. Many of the technical aspects of roads were never given due importance in rural roads; e.g, adequate compaction of subgrade, drainage, required cross drainage and host of others. Our project aims at eliminating the inhibition of technical details and also in designing an all-weather road for chosen rural site which has weak soil strata. There are plenty of appropriate technologies for rural road construction and maintenance using locally available materials as well as local agricultural implements.We also aim at using all these to the optimum level.

2.ADVANTAGES OF LIME

- Lime can be used to treat soils in order to improve their workability and load-bearing capacity.
- It can substantially increase the stability, impermeability and load bearing capacity of the subgrade.
- The effect of lime will be reduction of the swelling potential of an expansive soil texture.
- It will reduce the maximum dry density, freeswell and swelling capacity under 50kpa pressure.
- Consolidation characteristics improve the compressive index, coefficient index,and strength characteristics.

3.OBJECTIVES

- The main objective of our project is to improve the characteristics of the problematic and expansive soil such as high compressible clay and effect of stabilization process.
- To stabilize the soil using lime
- To study the strength of stabilized and unstabilized soil.
- To compare the influence of cement and lime in stabilization.

4.LITERATURE REVIEW

Mohammad Jafari et al in (2012) were investigated on Effect of waste tire cord reinforcement on unconfined compressive strength of lime stabilized clayey soil under freeze–thaw condition. In their paper, stabilization and fiber reinforcement are simultaneously examined as a soil modification method. A series of unconfined compression tests was carried out to investigate the effects of tire cord waste products on mechanical characteristics of a lime stabilized and unstabilized clayey soil subjected to freezing and thawing cycles. Several specimens were prepared at three percentages of lime (i.e. 0%, 4%, and 8%) and four percentages of discrete short nylon fiber (i.e. 0%, 0.5%, 1%, and 1.5%) by weight of dry soil.

Ezekwesili Ene et al in (2009), were investigated on Some basic geotechnical properties of expansive soil modified using pyroclastic dust. they reports an investigation of the influence of pyroclastic rock dust on the geotechnical properties of expansive soil. The plasticity, linear shrinkage, compaction, California bearing ratio (CBR) and shear strength characteristics of the soil when mixed with varying proportions of pyroclastic rock dust were investigated. The results show significant reduction in plasticity and linear shrinkage of expansive soil with increasing amount of pyroclastic rock dust. The maximum dry density, optimum water content, shear strength and CBR all increased with increasing pyroclastic rock dust content.

S. Koliaset al in (2005), were discussed on Stabilization of clayey soils with high calcium fly ash and cement.in their research the effectiveness of using high calcium fly ash and cement in stabilizing fine-grained clayey soils (CL,CH) was investigated in the laboratory. Strength tests in uniaxial compression, in indirect (splitting) tension and flexure were carried out on samples to which various percentages of fly ash and cement had been added. Modulus of elasticity was determined at 90 days with different types of load application and 90-day soaked CBR values are also reported.

5.Nature and Behavior of Expansive Soils

Expansive soils undergo high volumetric changes with moisture fluctuations. This behavior is attributed to the presence of clay minerals with expanding lattice structure. Among them, montmorillonite is the most common of all the clay minerals in expansive clay soils. The mineral is made up of sheet like units. Montmorillonite minerals exhibit high shrinkage and swelling characteristics.

Kaolinite is another most common mineral whose structure is made up of gibbsite sheets joined to silica sheets through the unbalanced oxygen to separate the layers, and as a result Kaolinite is relatively stable and eater is unable to penetrate between the layers. So Kaolinite shows little swell on wetting. China clay is almost pure Kaolinite.

Illite is another mineral whose structure is similar to that of montmorillonite except that there is substantial replacement of silicones by aluminium in the tetrahedral layers and potassium ions are between the layers serving to balance the charge resulting from the replacement and to tie the sheet units together. The cation bond of Illite is weaker than the hydrogen bond of Kaolinite, but is stronger than the water bond of montmorillonite.

6.Soil Stabilization

Soil stabilization is the process of improving the engineering properties of the expansive soil and thus making it more stable. It is required when the soil available for construction is not suitable for intended purpose. However, the term stabilization is generally are restricted to the process which alter the soil materials itself for improvement of its properties. A cementing material or a chemical is added to a natural soil for the purpose of stabilization. Soil stabilization is used to reduce the permeability and compressibility of soil mass in earth structures and to increase its strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highway and air fields. Soil stabilization is used to make an area trafficable within a short period of time for military and other emergency purposes. Sometimes, soil stabilization is used for city and sub-urban street to make them more noise absorbing.

7.Cement

Cement is an adhesive materials used to stabilize the problematic soil. The ordinary Portland cement is now available in three grades, namely 33, 43, 53 grades; the numbers is indicating the compressive strength of cement – sand mortar cubes in N/mm^2 at 28 days.

The soil stabilized with cement is known as soil cement. The cementing action is believed to be the results of chemical reaction of cement with the silicious soil during hydration. The binding action of individual particles through cement may be possible only in coarse – grained soils. In fine grained, cohesive soils, only some of the particles can be expected to have cement bonds, and the rest will be bonded through natural cohesion. Almost every inorganic soil capable of pulverization can be successfully stabilized with cement requirement will increase with the increase in the specific area of soil.

8.Black Cotton Soil

Soil used in this study is a blackish gray clayey silt of intermediate plasticity. This soil is normally defined as black cotton (BC) soil in India. The soil is collected from shallow depth from Sathy rural road of Tamil nadu state India. The various properties of the soil are listed.

9.Advantages of Soil Stabilization

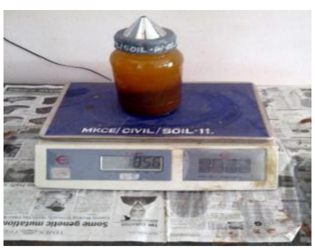
Stabilizing soil with binders is now an extremely cost effective method of converting poor quality soil into strong impermeable medium. This enable production of pavements, embankments, reinforced earth structures, railways, bulk fill applications, housing and industrial units in areas where they were not previously economically viable. Many years' experience has proved the effectiveness of this method. This combined with rising cost of conventional civil engineering, has transformed soil stabilization into the most cost effective method of preparing sites for all construction projects.

1. Reduce the need for existing borrows pit materials and prospecting of new borrows pit sources, thereby protecting the environment for future generations.
2. Reduce the need for land fill site for dumping of poor materials as well as construction waste.
3. Allow faster construction.
4. Save time.
5. Environmental friendly.
6. Save global warming.
7. Improves the engineering properties of soil.
8. Sustainable increase in resilient modulus values.
9. Sustainable improvement in shear strength.
10. Continued strength gain with time, even after periods of environmental or load damage.

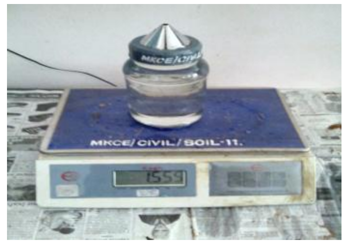
METHOD OF TESTING

a. Specific gravity test

Specific gravity is defined as the ratio of the unit weight of the soil to unit weight of water. Specific gravity is needed for various calculation purposes in soil mechanics. The specific gravity of the soil particles lies within the range of 2.65 to 2.85. Soils containing organic matter and porous particles may have specific gravity value below 2.0. Soils having heavy substance may have values above 3.0.



The specific gravity test is done using pycnometer. In this method the empty weight if the pycnometer is taken and its weight is given as W1. Then dry soil is half filled in pycnometer and it's weighed as W2. Then its lid is closed. From the small hole from the top of the lid, water is filled. Then it is weighed and reading is noted as W3. After this water is fully filled in pycnometer up to the top end of the lid and its weighed as W4. From the mathematical calculation specific gravity is calculated.



b.Wet sieve analysis

The wet sieve analysis is carried out according to the recommendations of IS: 2720(Part IV)-1985. Most sieve analysis is carried out dry. But there are some applications which can only be carried out by wet sieving. This is the case when the sample which has to be analyzed is e.g., a suspension which must not be dried; or when the sample is a very fine powder which tend to agglomerate (mostly <45 μm) in a dry sieving process. This tendency would lead to a clogging of the sieve meshes and this would make a future sieving process impossible. A wet sieving process is setup like a dry process: The sieve stack is clamped onto the sieve shaker and the sample is placed on the top sieve. Above the top sieve a water spray nozzle is placed which supports the sieving process additionally to the sieving motion. The rinsing is carried out until the liquid which is discharged through the receiver is clear. Sample residues on the sieves have to be dried and weighed. When it comes to wet sieving it is very important not to change to sample in its volume (not swelling, dissolving or reaction with the liquid).The portion of the soil passing 4.75mm IS sieve is oven raid at 105° to 110° C. The oven raid material shall then be riffled so that a fraction of convenient mass is obtained. This shall be about 200 g if a substantial proportion of the material only, just passes the 4.75mm IS sieve or less if the largest size is smaller. The fraction shall be weighed to 1% of its total mass and the mass recorded. The riffled and weighed fraction shall be spread out in the large tray or bucket and covered with water.

c.Liquid limit

The liquid t which a soil changes from plastic nal liquid limit test of Atterberg's of clay in a round bottomed p iameter and a groove was cut thr spatula, and the bowl was then str palm of one hand. 'A flow curve' mi logarithmic graph representing water content on the arithmetical scale and number of drops on the logarithmic scale. The flow curve is a straight line drawn as nearly as possible through the four or more plotted points. The moisture content corresponding to 25 drops as read from the curve shall be rounded off to the nearest whole number and reported as the liquid limit of the soil.

d.Plastic limit

The plastic limit is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. If the soil is plastic, this thread will retain its sl ry narrow diameter. The sample can then b he test is repeated. As the moisture content ation, the thread will begin to break apart at

The plastic limit is defined as the where the thread breaks apart at a diameter inch). A soil is considered non plastic if a rolled out down to 3mm at any moisture. The soil sample shall be mixed thoroughly with distilled water in an evaporating dish or on the flat glass plate till the soil mass becomes plastic enough to be easily molded with fingers. In this case of clayey soils the plastic soil mass shall be left to stand for a sufficient time (24 hours) to ensure uniform distribution of moisture throughout the soil. A ball shall be formed with about 8 g of this plastic soil mass and rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes/min counting a stroke as one complete motion of the hand satisfactory end point, provided the soil has been rolled into a thread of 3mm diameter immediately before. At no time shall an attempt be made to produce failure at exactly 3mm diameter by allowing the thread to reach 3mm, than reducing the rate of rolling or pressure or both, and continuing the rolling without further deformation until the thread falls apart. The pieces of crumbled soil thread shall be collected in an air tight container and the moisture content determined as described in IS: 2720 (part II) – 1973.The moisture content determined is the plastic limit of the soil. The plastic limit shall be determined for at least three portion of the soil passing 425 micron IS sieve. The average of the results calculated to the nearest whole number shall be reported as the plastic limit of the soil.

e.Standard Proctor Compaction Test

The standard proctor compaction test (SPCT) is carried according to the recommendations of IS: 2720 (part VII)-1980. It is a laboratory test used to determine the optimum water for a given compaction energy, for a given soil.

The proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

A 5-kg sample of air dried soil passing the 19mm IS test sieve shall be taken. The sample shall mixed thoroughly with a suitable amount of water depending on the soil type. The mould with base plate attached, shall be weighed to the nearest 1 g (M_1). The mould shall be passed on a solid base, such as a concrete floor or plinth and the moist soil shall be compacted into the mould, with the extension attached, in three layers of approximately equal mass, each layer being given 25 blows from the 2.6-kg rammer dropped from a height of 310mm above the soil. The blows shall be distributed uniformly over the surface of each layer.

California Bearing Ratio Test

The California bearing ratio (CBR) test is conducted according to the recommendations of IS: 2720 (part XVI)-1987. The ratio expressed in percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm is used. Where the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used. The test is performed by measuring the pressure is then divided by the pressure required to an equal penetration on a standard crushed rock material. CBR is used to find out indirectly the bearing capacity of the subgrade soil for the design of flexible pavement.

The dry density for a remoulding shall be either the field density or the value of the maximum dry density estimated by the compaction tests 1 see IS: 2720 (part 7) 1985, and IS: 2720 (part 8) – 1983, or any other density at which the bearing ratio is desired. The water content used for compaction should be the optimum water content obtained from the standard proctor test either light compaction or heavy compaction depending on the application. The material used in the remoulded specimen shall pass a 19 mm IS sieve. Allowance for larger material shall be made by replacing it by an equal amount of material which passes a19 mm. IS sieve but is retained on 4.75 mm IS sieve.

11.TESTING OF SOIL

a. Sieve analysis:

S.N0	DESCRIPTION	RESULT
1	Co efficient of curvature(cc)	1.227
2	Co efficient of uniformity(cu)	11.72
3	Fine grained soil	organic clay

b. Specific gravity by pycnometer:

S.N0	DESCRIPTION	RESULT
1	Specific gravity	2.28
2	Limit limit	30%
3	Plastic limit	17.55%

4	Plasticity index	12.45%

c. California bearing ratio

Method of treatment	3%	5%
Non treated soil	2%	2%
Treated with lime	65%	69%
Treated with cement	35.9%	48%

12.CONCLUSION

From the above discussions, the following conclusions can be drawn

- Lime can be used to improve CBR for the sub-grades by about 10 times. Simple tractor mounted agriculture equipment can be employed for construction and economy in construction when aggregates are to be brought from far off distance as well as due to reduced thickness of sub base / base course.
- Cement increases CBR of soil sub-grade by more than 100%. Impedes widespread occurrence of dust from loose fine material in the surface of the soil roadways and reduces cost of construction by 15 – 20%. The roads constructed using Cement minimize the material loss of gravel from erosion or abrasion by the traffic on the soil roadways preserving original transverse section and slopes and impedes widespread occurrence of dust from loose fine material in the surface of the soil roadways.
- The noteworthy feature of soil-Cement stabilization that it requires very little amount of aggregate, performs with increased life and reduce maintenance cost provide a good base for the field Engineers to experiment the construction of unsealed roads in rural areas and also in localities where aggregate are not available in normal leads.
- The fly ash strengthens soil sub-grade and further it prevents migration of fines of a sub-grade by as a filtration materials.

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