STABILISATION OF SOIL WITH MARBLE DUST AND RICE HUSK IN HIGHWAY SUBGRADE

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Abstract - In today climatic changes, lack of stable ground for development of infrastructures is very common. In fact of this, construction of buildings on unsuitable ground is unavoidable and making a suitable ground before constructions is real difficult issue for Geotechnical Engineers. To overcome the difficulties experienced with problematic soil in geotechnical applications on one side and safe disposal of solid wastes on the other side, an attempt is made in this investigation to explore the possibilities of utilizing wastes to improve the engineering behavior of problematic soil. In this, in this present investigation the type of waste namely marble dust and rice husk for stabilization is selected to study the effects of same on the properties of problematic soil.

Key Words: Marble dust, Rice husk, Alluvial soil, clayey soil

1. INTRODUCTION

Soil is a major component of the earth's surface which sustains life. It is made up by the disintegration of rocks due to various environmental processes like changing weather, volcanic action, erosion of rocks by water etc. Some of the various types of soil that are found in our country are alluvial soil, laterite soil, black cotton soil or expansive soil etc. The type and availability of these soils are based upon the climatic and geographical location of a particular area. Apart from helping the plants growth, soil also helps the humans to carry out all the basic activities on it like travelling, construction, agriculture etc. A developing country like India demands rapid growth in its infrastructure i.e. a proper network of roads and buildings for development. All the constructions related to civil engineering, like a simple house or a multi-storey building, a road or a highway, everything is built on the soil. It is very important to check all the engineering properties of the soil like the cohesion, capillarity, permeability etc before starting any constructional work on it because all the soils are not suitable for construction always.

Before starting the construction of any project, site selection is the foremost objective of engineering department. One of the main purposes of site selection or investigation is to determine stable and good quality soil where the construction is to be done. It also helps in collecting all the relevant information about soil and its properties. Afterwards, soil with the best quality is selected for construction so that it would result in better structure. Foundation is the main part of any construction and it largely depends upon the type of soil. Foundation soil is the one that carries all the loads of structure and good foundation gives more stability to the structure.

2. Materials

The following materials are used for the study:

I. Soil

II. Marble Dust

III. Rice Husk

I. Soil

The biologically active, porous medium that has developed in the uppermost layer of Earth's crust. Soil is one of the principal substrata of life on Earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of injurious wastes, and as a participant in the cycling of carbon and other elements through the global ecosystem. It has evolved through weathering processes driven by biological, climatic, geologic, and topographic influences. In this study the type of soils used as material i.e. alluvial soil and clayey soil.

Soil is classified into five major groups:

a. Alluvial Soil

Alluvial soils are founds mostly in the regions of Northern India as well as in Peninsular India. Some of the states where alluvial soil deposits are found are Punjab, Haryana, and Gujarat etc. These soils are highly fertile soil as they are formed by the silt deposition of the Indo-Gangetic-Brahmaputra rivers. These soils are loose and porous in nature as they are found near the river deposits which are continuously eroded due to flow of water.

b. Black Cotton Soil

Black cotton soil is found in the states of Gujarat, Karnataka and Maharashtra etc. They cover the portion of western India as well some parts of south India as well. The black cotton soil is not much suitable for construction as it has the property of swelling and shrinking with the change in the moisture content in it.

c. Laterite Soil

These types of soils are rich in iron and aluminium and are mostly found in the areas of Kerala, Tamil Nadu and Orissa. These are found in hot and tropical climatic conditions due to which these are very soft in nature and can be cut easily. These types of soil are rich in minerals like iron and aluminium. Due to the high iron content in them they are red in colour.

d. Desert Soil

Desert soil is found mainly in the desert areas of Rajasthan and Gujarat. These soils have low density and are very pervious in nature. These soils are also called as arid soils and occupy about 33% of the world's total land area.

e. Marine Soil

These types of soils are found in the coastal areas of Gujarat, Tamil Nadu, and Kerala etc. These soils have very low shear strength and are considered as highly compressible. These soils contain huge amount of organic matter in them, thus supporting the vast plant and animal life near the coastal area.

II. Marble Dust

Marble Dust is a waste product of the marble stone. This dust is produced in the process of cutting of marble stone. Marble stone is a type of metamorphic rock that is produced as a result of transformation occurred in the lime stone. In India, marble processing industry generates around 7 million tons of wastes mainly in the form of powder during sawing and polishing processes. Out the total waste generated, the state of Rajasthan alone contributes around 6 million tons of marble dust annually i.e. about 95% of the total marble dust production. This poses a huge threat to the environment and the people because most of this marble dust is dumped into the open area which causes a major environmental concern. Although there are proper areas dedicated to the dumping of this waste, but marble dust being a very fine powder is capable of flowing away with the wind. Thus the marble dust spreads along the outer areas also and gradually settle on the plants and animals of the surrounding areas. The spreading of marble dust in the surrounding areas certainly creates necrotic ecological conditions for flora and fauna thereby changing the landscapes and habitats gradually. Thus it becomes very important to utilize this huge amount of waste in a proper manner. To combat the effect of this waste material to the surrounding area, it is used in various processes such as in the production of concrete as well as in the process of soil stabilization. Utilizing marble dust in the process of stabilizing the soil is increasing day by day due to the low cost of this material as well as for its ease of availability.

III. Rice Husk

Rice husk are the hard protective coverings of rice grains which are separated from the grains during milling process. Rice husk is an abundantly available waste material in all rice producing countries, and it contains about 30%–50% of organic carbon. In the course of a typical milling process, the husks are removed from the raw grain to reveal whole brown rice which upon further milling to remove the bran layer will yield white rice. Current rice production in the world is estimated to be 700 million tons. Rice husk constitutes about 20% of the weight of rice and its composition is as follows: cellulose (50%), lignin (25%–30%), silica (15%–20%), and moisture (10%–15%). Bulk density of rice husk is low and lies in the range 90–150 kg/m^3. Sources of rice husk ash will be in the rice growing regions of the world, as for example China, India, and the far-East countries. Rice husk is the product of incineration of rice husk. Most of the evaporable components of rice husk are slowly lost during burning and the primary residues are the silicates. The characteristics of the ash are dependent on, composition of the rice husk, burning temperature and burning time. Every 100 kg of husks burnt in a boiler for example will yield about 25 kg of rice husk. In certain areas, rice husk is used as a fuel for parboiling paddy in rice mills, whereas in some places it is field-burnt as a local fuel. However, the combustion of rice husk in such cases is far from complete and the partial burning also contributes to air pollution.

3. Soil Stabilization

Soil stabilization is a general term for any physical, chemical, biological, or combined method of changing a natural soil to meet an engineering purpose. Usually compaction is done to stabilize the soil. Apart from compaction, draining out of the excess water also helps in increasing the stability of the soil. Adding various materials in the soil also helps in stabilizing it. Lime and cement have been the main sources of soil stabilization since many years. But gradually, utilization of cement for stabilization is decreased because of its increasing cost and the pollution caused in the environment due to CO_2 emitted during its production. Utilization of lime is also not much suitable because lot of CO_2 is emitted during its production too. These facts necessitated the need for utilizing the waste products from various industries so that they can be used as an alternative to the conventional resources. Some of the waste products used for the stabilization of soil are fly ash, marble dust, foundry sand, rice husk ash etc. The fly ash generation in 2011 in India was about 112 million tons per year which increased to about 170 million tons in 2012 and about 225 million tons by 2017. While fly ash is a waste product generated from the coal based thermal power plants, marble dust and foundry sand are the waste products from the marble stone and the metal casting industries respectively. Various studies have proved that utilization of these waste materials as a soil stabilizing agent have not only improved the soil properties but also helped in reducing the cost of the project gradually. There are three main methods of stabilization i.e. mechanical stabilization, chemical stabilization and stabilization with the help of geo synthetics. These three methods are as followings:

I. Mechanical Stabilization

Mechanical solutions involve physically changing in the property of the soil somehow, in order to affect its gradation, solidity, and other characteristics. Dynamic compaction and vibro compaction are the two techniques used for mechanical stabilization. In vibro compaction the soil is compacted with the help of vibrations while dynamic compaction uses a heavy weight for the same. This is one of the oldest methods of stabilizing the soil.

II. Chemical Stabilization

Chemical solutions are the techniques that rely on adding an additional material to the soil that will physically interact with it and change its properties. Lime and cement are the most common materials that are being used for stabilizing the soil. But with the advent of new materials and excess of industrial waste available, lime and cement are now used less. Some of the industrial wastes that are used are fly ash, kiln dust, marble dust, foundry sand etc.

III. Geosynthetic Stabilization

Geo-grids are used in geo synthetic stabilization, to reinforce the soil. Geo-grid with reduced aggregate thickness option is designed for urban area and this provides a stable working platform corresponding to 97 percent of CBR. Soil modification and soil stabilization are the two processes to provide strength to the weak soil. Soil Modification changes the characteristics of soil by adding soil amendments to strengthen physical and chemical conditions to improve the bearing capacity of the soil. Soil Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to commercially available admixtures that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil. The main purpose of the soil stabilization process is to increase the bearing capacity of the soil, thus making it fit for construction. A lot of methods are employed for stabilizing the soil.

4. Highway Subgrade

In transport engineering, highways subgrade is the native material underneath a constructed road, pavement or railway track. It is also called formation level. The term can also refer to imported material that has been used to build an embankment. Subgrades are commonly compacted before the construction of a road, pavement or railway track, and are sometimes stabilized by the addition of asphalt, lime, portland cement or other modifiers. The subgrade is the foundation of the pavement structure, on which the subbase is laid down. The load-bearing strength of subgrade is measured by California Bearing Ratio test, falling weight deflecto meter back calculations and other methods. A subgrade's performance generally depends on two interrelated characteristics:

I. Load Bearing Capacity: The subgrade must be able to support loads transmitted from the pavement structure. This load bearing capacity is often affected by degree of compaction, moisture content, and soil type. A subgrade that can support a high amount of loading without excessive deformation is considered good.

II. Volume Changes: Most soils undergo some amount of volume change when exposed to excessive moisture or freezing conditions. Some clay soils shrink and swell depending upon their moisture content, while soils with excessive fines may be susceptible to frost heave in freezing areas. Ash, especially on the Big Island, can present volume change problems.

Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil Stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub-grade materials, varying from expansive clays to granular materials. This process is accomplished using a wide variety of additives, including rice husk, lime, fly-ash, and Portland cement, marble dust and foundry sand. Other material byproducts used in Stabilization include lime-kiln dust and cement-kiln dust.

There are advantages and disadvantages of many of these soil stabilizing agents:

I. Many of the "green" products have essentially the same formula as soap powders, merely lubricating and realigning the soil with no effective binding property. Many of the new approaches rely on large amounts of clay with its inherent binding properties. Bitumen, tar emulsions, asphalt, cement, lime can be used as a binding agents for producing a road base. When using such products issues such as safety, health and the environment must be considered.

II. The National Society of Professional Engineers (NSPE) has explored some of the newer types of soil stabilization technology, specifically looking for "effective and green" alternatives. One of the examples utilizes new soil stabilization technology, a process based on cross-linking styrene acrylic polymer. Another example uses long crystals to create a closed cell formation that is impermeable to water and is frost, acid, and salt resistant.

III. Utilizing new soil stabilization technology, a process of cross-linking within the polymeric formulation can replace traditional road/house construction methods in an environmentally friendly and effective way.

IV. There is another soil stabilization method called the Deep Mixing method that is non-destructive and effective at improving load bearing capacity of weak or loose soil strata. This method uses a small, penny-sized injection probe and minimizes debris. This method is ideal for re-compaction and consolidation of weak soil strata, increasing and improving load bearing capacity under structures and the remediation of shallow and deep sinkhole problems. This is particular efficient when there is a need to support deficient public and private infrastructure.

5. LITERATURE REVIEW

Regarding the work under process the various researchers done for the stabilization of soil which are as under:

Arman, et al., (1972) studied the feasibility of improving the characteristics of organic soil by adding lime in Louisiana. Over 1100 samples of both inorganic and organic soil were evaluated. It was conducted that by adding lime the strength as well as plasticity of soil was considerably improved.

Malhotra, and John., (1986) had added brick aggregates to fly ash –lime stabilized expansive soil. They concluded that after a curing period of 28 days the stabilized soil achieved the strength and durability to be used as base course in pavement with cost less than conventional base course materials.

Bhasin, et al., (1988) made a laboratory study on the stabilization of black cotton soil as a pavement material using RHA, along with other industrial wastes like fly ash, bagasse ash, lime sludge, black sulphite liquor independently with and without lime. The RHA causes greater improvement than that caused by other wastes due to presence of higher percentage of reactive silica in it. In combination with lime, RHA improved the properties of black cotton soil significantly.

Katti, and Sankar., (1989) had studied the CBR strength characteristic of expansive soil by stabilizing it with lime and brick aggregates. There was significant increase in CBR value in brick-lime stabilization compared to lime stabilization.

Anand, et al., (2000) investigated the use of random and discrete oriented polypropylene fiber reinforcement on expansive soil. The results showed that fibers with different percentages improved the UCS of the soil and reduces both volumetric shrinkage strain and swell pressure of the expansive soil.

Pandian, et al. (2001) had added fly ash (class- F) up to 100% to black cotton soil at an increment of 10% and found that California bearing ratio (CBR) values of black cotton soil increased up to 20% addition of fly ash beyond it, CBR decreased. It again increased and attained an optimum value when the percentage of fly ash was 70%.

J. Prabakar, et al., (2002) used sisal fiber for soil stabilization. Siser fiber with different percentage (0.25%, 0.50%, 0.75% and 1.00%) and have different lengths (10mm, 15mm, 20mm and 25mm) are used. They found reduction in dry density with the increases in sisal fiber content as well as they found that shear stress increases nominally with the increases in fiber length up to 20mm and beyond 20mm shear stress is found to present a decrease in tend. Also shear stress increases with the increase in percentage of sisal fiber up to 0.75%.

Parsons, et al., (2004) based on this investigation uses of cement kiln dust in soil stabilization. Durability test were followed by strength test and atterberg limits. Relative values of soil stiffness were also tracked over a 28 days curing period. The test results show a significant improvement in performance with addition of cement kiln dust.

Amu, et al., (2005) had used (Class- F) fly ash and cement for stabilization of expansive soil. It was found that stabilizing effect of 9% cement and 3% fly ash was better than the stabilizing effect 12% cement.

Havanagi, et al., (2006) used mixed Copper slag (a waste generated during the manufacture of copper) with fly ash and expansive soils in different proportions and their suitability in embankment, sub base and base were investigated. The selected mixes were also stabilized at 3%, 6% and 9% of cement to make it suitable for base course.

Degirmenci, et al., (2007) had investigated the effect of phosphogypsum on liquid limit, plastic limit, IP, OMC, MDD and UCS of expansive soil. By stabilization with phosphogypsum, the IP reduced, MDD increased, OMC decreased, and UCS increased.

Hemlatha, et al., (2008) reviewed the effectiveness of various construction and demolition wastes for the sustainable development goal, studied and presented the various categories of such wastes and reported the use of fines from these wastes to be very effective, specially its significance in improving the CBR of the subgrade soil.

Osinubi, et al. (2009) had studied the effects of bagasse ash on compaction and strength characteristics of lime stabilized black cotton soil. At 8 % lime and 4% bagasse ash combination the highest CBR value was obtained.

6. Index Properties Test

The various index properties test like specific gravity test, liquid limit test, plastic limit test, free swell index test and standard proctor compaction test conducted with various proportions i.e. 0.00%, 05.00%, 10.00%, 15.00%, and 20.00%

of marble dust and same proportions done with rice husk. The observations are shown below:

6.1. Specific Gravity

I. Specific gravity of alluvial soil is 2.66

II. Specific gravity of clayey soil is 2.78

6.2. Liquid Limit

Liquid limit is shown on next page with the help of graphical representation:

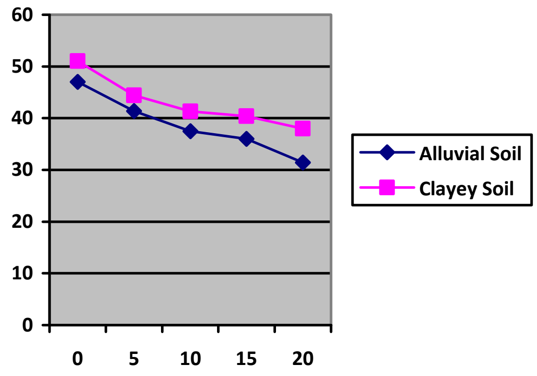

Fig. 1 Liquid limit values with various %ages of marble dust and rice husk in alluvial and clayey soil

6.3. Plastic Limit

Table 4.2 Plastic limit values with various %ages of marble dust and rice husk in alluvial and clayey soil

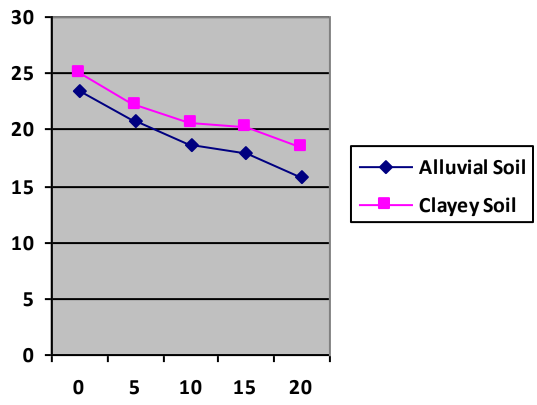

Fig. 2 Plastic limit values with various %ages of marble dust and rice husk in alluvial and clayey soi

6.4. Free Swell Index

Free swell index is an indicative swelling nature of expansive clay.

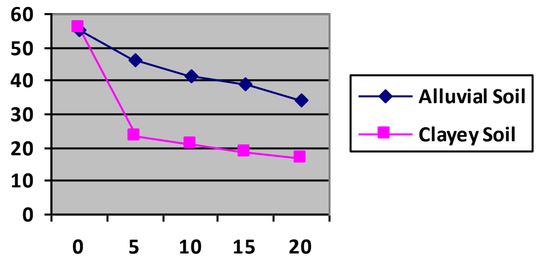

Fig. 3 Free swell index values with %ages of marble dust and rice husk in alluvial and clayey soil

6.5. Standard Proctor Compaction Test

The results obtained for soil with 0.00%, 05.00%, 10.00%, 15.00%, and 20.00% of marble dust and rice husk along with clayey and alluvial soil are shown below:

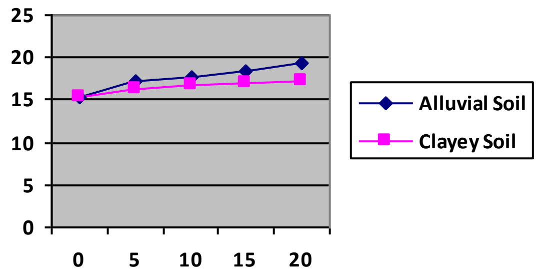

Fig. 4 Maximum dry density values with various %ages of marble dust and rice husk in alluvial and clayey soil

7. Engineering Property Test

Engineering property test i.e. California Bearing Ratio test have conducted with various proportions i.e. 0.00%, 05.00%, 10.00%, 15.00%, and 20.00% of marble dust and rice husk along with clayey and alluvial soil, the results are as under:

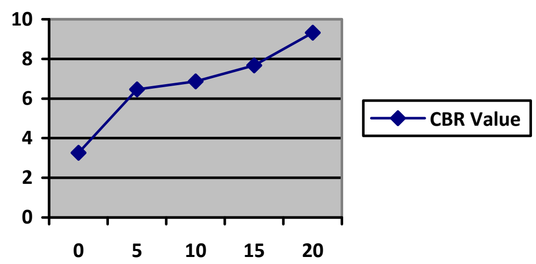

Fig. 5 CBR values with various %ages of marble dust and rice husk in alluvial soil with unsoaked sample

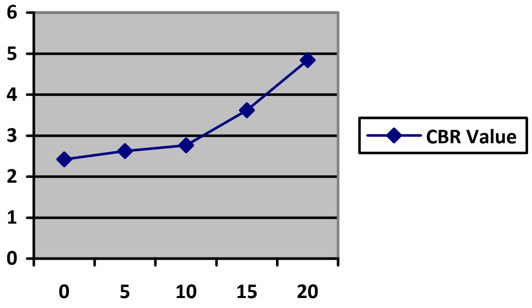

Fig. 6 CBR values with various %ages of marble dust and rice husk in alluvial soil with soaked sample

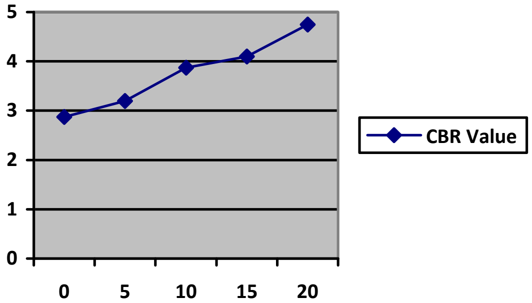

Fig. 7 CBR values with various %ages of marble dust and rice husk in clayey soil with unsoaked sample

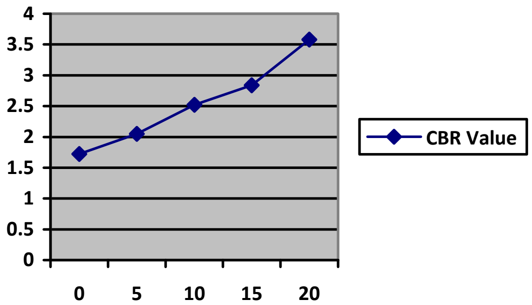

Fig. 8 CBR values with various %ages of marble dust and rice husk in clayey soil with soaked sample

Unsoaked CBR value of alluvial soils increases from 3.27 to 9.32 whereas soaked CBR value also increases from 2.42 to 4.84 in the case of clayey soil it is also increases from a value from 2.87 to 4.75 for unsoaked sample and for soaked sample value increases from 1.72 to 3.58 with the same proportion of marble dust and rice husk respectively.

8. Conclusions

The effect of addition of marble dust and rice husk in alluvial soils and clayey soil on the index properties, compaction characteristics and CBR values is concluded as under:

- The unsoaked CBR value of the soil **increases** from 3.27 to 9.32 whereas soaked CBR value from 2.42 to 4.84 only in the case of addition of marble dust and rice husk to alluvial soils.
- The plasticity index of the alluvial soils **decreases** steeply from 23.5% to 15.68% with the **increase** in %age of marble dust and rice husk and in case of clayey soils the plasticity index also **decreases** with the **increase** in %age of marble dust and rice husk i.e. reduced from 26.00% to 19.50%.
- Free Swell index also **decreases** in both soils with **increase** in %age of marble dust and rice husk i.e. from 55.00% to 33.93% and from 56.00% to 16.83%.
- The **maximum** and **minimum** dry density of alluvial soils is 19.25kN/m3 and 15.39kN/m3 respectively and for clayey soils it is 17.32kN/m3 and 15.39kN/m3 respectively. Maximum result obtained with **maximum** proportion and **minimum** result obtained without stabilization.
- As such alluvial soils are better performing type of soils than clayey soils for using these additives for soil stabilization.
- Marble dust and rice husk uses solve to certain extend the waste disposal problem also.

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