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Evaluation of lateritic soil stabilized with Arecanut coir for low volume pavements

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ABSTRACT

Soil stabilization is a common method used by engineers and designers to enhance the properties of soil with different stabilizers. From ancient times, usage of natural fiber in soil as reinforcement is an effective technology adopted. This paper presents the effect of including randomly spaced Arecanut coir to the soil mix. The engineering properties and bearing capacity of a soil get enhanced by stabilizing it with Arecanut coir and a binding material (cement). The information available on experiments and research on the behavior of soil cement mixtures were collected and a few studies conducted on fiber reinforcement were referred. The current study mainly focuses on the durability test and physical evaluation of soil cement mixtures reinforced with Arecanut coir. Coir content was varied from 0.2% to 1% with an increment of 0.2%. For further improvement, a uniform dosage of 3% cement was added to soil. Laboratory tests including the Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), durability and fatigue behavior, were conducted as per standards. The test results indicated that the improvement in characteristics of the soil cement coir mixtures were functions of coir dosage, soil type and curing days. Durability test satisfied at 1% Arecanut coir with 3% cement. The stress–strain values were determined and damage analysis was conducted for the higher dosage of Arecanut coir using KENPAVE software. From the results it is observed that, the Arecanut coir reinforced cement soil mix can be used for low volume roads (traffic ⩽1 million standard axles) and few design cases have been discussed.

Introduction

Subgrade is a structure formed by natural or borrowed soil, on which other granular layers of pavement such as sub-base, base and surface courses are laid. The quality and stability of subgrade is a major factor responsible for the adequate performance and service of any road during its life span. Lateritic soils have been found in the coastal region, along the Konkan belt of India. High rainfall, temperature and humidity with alternative wet and dry period, which are ideal conditions for laterization, makes nearly 40% of the soils in the area laterites. Its color ranges from red to yellowish red and depth from 30 to 150 cm. The laterites have been mostly originated from igneous rocks and are well drained residues with the presence of excessive Iron and Aluminum.

India is considered as the largest Arecanut producing country in the world. The total area under cultivation is 264,000 hectares and the annual production is 313,000 metric tonnes, with the states Karnataka and Kerala accounting for nearly 72% of total production. Among all the natural fiber-reinforcing materials, Arecanut fibre

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appears to be a promising material because it is inexpensive, abundantly available and the crop is very high potential perennial. The husk of the Arecanut is a hard fibrous portion covering the endosperm. It constitutes 30–45% of the total volume of the fruit. Areca husk fibers are predominantly composed of hemicelluloses.

The concept of soil reinforcement was first developed by Vidal (1996). It was established that the introduction of reinforcement elements in a soil mass increases the shear resistance of the soil matrix. Lekha and Sreedevi (2005) studied on coir fiber for stabilization of weak subgrade soils, which included treating the weak soil with coir fibre at different quantities and studying the changes in Optimum Moisture Content (OMC), Maximum Dry Density (MDD) and California Bearing Ratio (CBR) values. The OMC was found to be increased with the increase in the percentage of coir fibre content and correspondingly, MDD decreased. Tang et al. (2007) investigated the effects of discrete short polypropylene fiber (PP-fiber) on the strength and mechanical behavior of uncemented and cemented clayey soil. The test results indicated that the inclusion of fiber reinforcement within uncemented and cemented soil caused increase in the Unconfined Compressive Strength (UCS), shear strength and axial strain at failure, decrease in the stiffness and the loss of post-peak strength, and change in the behavior of cemented soils from brittle to more ductile.

Kumar and Singh (2008) tried different combinations of polypropylene fiber and fly ash on soil. It was observed that the addition of fiber to soil satisfy all the geotechnical properties to meet the requirements of sub base layer. Bijayananda et al. (2011) conducted a series of laboratory soaked and unsoaked CBR tests on randomly oriented fiber reinforced and unreinforced specimens of clayey soil, compacted at OMC and MDD. Coir fiber has been used as a reinforcing material to investigate its beneficial use in rural road subgrade soil. From CBR test results, the engineering performance of coir fiber inclusion was examined. The results indicated that the inclusion of coir fiber enhanced the CBR strength of the soil specimens significantly. Clayey soils mixed with fibers showed remarkable increase in the CBR strength in comparison with the same soils without fiber inclusions. That is, randomly oriented discrete fiber reinforcements in clayey subgrade offered higher resistance to penetration than unreinforced one, under similar loading conditions. Shankar et al. (2012) studied on lithomargic clay stabilized with different percentages of sand and coir and improvement in almost all properties was observed. The CBR both in soaked and unsoaked condition, increased as the percentage of sand increased from 0 to 40 and coir from 0 to 0.5. When the sand content increased from 0 to 40%, the UCS values of blended soil for both light and modified compaction densities increased up to a certain limit, whereas, the increase of coir content from 0 to 0.5% resulted in a continuous increase in UCS. Even though Arecanut coir is a biodegradable material, according to Ramaswamy and Aziz (1989) its strength and condition beyond a period of one year after placement should not be of any concern as by that time the coir would have already played a very important role in providing a self-sustaining subgrade for most types of soils. The loss of strength of the coir with time can be well compensated by the gain in strength of the subgrade within the same time frame.

Kar and Pradhan (2012) studied on soil stabilized with fly ash and fiber reinforced fly ash for low volume roads. Soaked CBR values for reinforced fly ash soil showed good improvement. A study by Sarbaz et al. (2014) on soil specimens reinforced with palm fibers and bitumen coated fibers showed that palm fibers significantly increases the CBR strength of the sand specimens. Amadi (2014) conducted a series of durability tests on black cotton soil with cement kiln dust and quarry fines, and the results observed for higher dosage of these stabilizers satisfied the durability criteria. Maheshwari et al. (2012) conducted a series of laboratory tests on unreinforced and fiber reinforced black cotton soil with different amount of fibers and there was a significant increase in CBR value with the inclusion of fibers. As per Indian Road Congress (IRC) standard IRC 37-2001, the flexible pavement sections resting on fiber reinforced soil for traffic volumes of 1–150 msa were designed and modeled using finite element software Plaxis 2D. Considerable reduction in deformation was obtained on the top of subgrade due to reinforcing of subgrade soil using fibers. Lekha et al. (2013) studied on laterite soil using Zycosoil chemical, and analysis conducted in KENPAVE software showed that Water Bound Macadam (WBM) can be replaced with treated soil for low volume roads.

Many researchers have tried to investigate the field performance of soils stabilized with randomly added fibers (Grogan et al., 1994, Newman et al., 2008, Hufenusa et al., 2006 Santoni et al., 2001, Zhang et al., 2003). Santoni and Webster (2001) reported fiber stabilization as an effective method for military airfield and road applications based on the field test conducted on sandy soil stabilized with fibers. For mixing fibers with the sand uniformly, a self-propelled rotary mixer was used. The sand fiber layer was turned over with the front end loader and four passes were provided with the mixer to obtain a proper sand-fiber mix throughout the layer. Tingle et al. (2002) also followed this methodology for mixing fibers and sand in the field, and performed full-scale field tests.

No study has been reported on the usage of Arecanut coir fibre for stabilization of soil. Since Arecanut crops are available abundantly in Dakshina Kannada District of Karnataka, a laboratory study has been carried out to study the properties of lateritic soil with this fibre and cement. The main objective of this study was to determine the contribution of Arecanut coir to the shear strength of lateritic soil. A series of tests were carried out to investigate the effect of coir content on the behavior of soil.

Materials and methods

Lateritic soil

Lateritic soil was procured from NITK Surathkal campus, Dakshina Kannada District, India. The geotechnical properties like specific gravity, soil classification, consistency limits, compaction characteristics, UCS and CBR values were conducted as per the relevant Indian standard procedures. The test results are tabulated in Table 1. From the grain size distribution curve in Fig. 1, it can be depicted