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Laboratory performance of unpaved roads reinforced with woven coir geotextiles

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ABSTRACT

The results of an experimental study conducted to investigate the beneficial use of woven coir geotextiles as reinforcing material in a two-layer pavement section, are presented. Monotonic and repeated loads were applied on reinforced and unreinforced laboratory pavement sections through a rigid circular plate. The effects of placement position and stiffness of geotextile on the performance of reinforced sections were investigated using two base course thicknesses and two types of woven coir geotextiles. The test results indicate that the inclusion of coir geotextiles enhanced the bearing capacity of thin sections. Placement of geotextile at the interface of the subgrade and base course increased the load carrying capacity significantly at large deformations. Considerable improvement in bearing capacity was observed when coir geotextile was placed within the base course at all levels of deformations. The plastic surface deformation under repeated loading was greatly reduced by the inclusion of coir geotextiles within the base course irrespective of base course thickness. The optimum placement position of coir geotextile was found to be within the base course at a depth of one-third of the plate diameter below the surface.

1. Introduction

Unpaved roads are usually used for low volume traffic and serve as access roads. Being basically an agricultural country low volume roads play a very important role in the rural economy and resource industries in India. When unpaved roads are built on soft foundation soils, large deformations can occur, which increase maintenance cost and lead to interruption of traffic service. The use of geosynthetic products as an inclusion in flexible pavements for reinforcement has been demonstrated to be a viable technology through studies conducted over the last three decades (Cancelli and Montanelli, 1999; Chan et al., 1989; Collin et al., 1996; Fannin and Sigurdsson, 1996; Gopal and Anil, 1994; Hufenus et al., 2006; Leng, 2000; Love et al., 1987; Miura et al., 1990; Moghaddas-Nejad and Small, 1996; Perkins, 1999; Som and Sahu, 1999) which results in increased service life of the pavement or reduced base thickness to carry the same number of load repetitions. Benefits of reducing base course thickness are realized if the cost of the geosynthetic is less than the cost of the reduced base course material. In developing countries like India cost and availability of geosynthetics are the major constraining factors for the construction of reinforced soil structures. High cost of geosynthetics and stringent environmental protection requirements make it important to explore alternative natural products to make the constructions cost efficient and eco-friendly (Sarsby, 2007; Rawal and Anandjiwala, 2007; Chauhan et al., 2008). But deterioration over time limits the use of natural geotextiles to temporary applications only. One of such applications can be in unpaved road over soft subgrade where the rate of plastic deformation (rut development) due to repeated traffic loads is faster during the initial stage and gets stabilized later (Fannin and Sigurdsson, 1996). In this case, it is expected that consolidation of the soft subgrade soil will make reinforcement unnecessary in the long-term. Natural fibre geotextiles can be a feasible solution in such applications where these products are meant to serve only during the initial stage and final strength is attained by soil consolidation due to passage of vehicles. These natural materials include coir, which is the husk of coconut, a common waste material where coconuts are grown and subsequently processed. Coir fibre is strong and degrades slowly compared to other natural fibres due to high lignin content (Rao and Balan, 2000). The degradation of coir depends on the medium of embedment and climatic conditions and is found to retain 80% of its tensile strength after 6 months of embedment in clay (Rao and Balan, 2000). Coir geotextiles are presently available with wide ranges of properties. Closely woven coir geotextiles possess high tensile strength and pullout resistance (Subaida et al., 2008) which can be economically utilized for temporary reinforcement purposes.

In unpaved roads, major functions of geotextile materials include filtration, separation, and reinforcement. Coir geotextiles

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were reported to possess good filtration and drainage properties (Ramanatha Ayyar et al., 2002; Lekha and Kavitha, 2006; Babu, 2007). The benefits of using reinforcements in flexible pavements depend largely on the quality and thickness of the granular base and location of the geosynthetics within the pavement structure (Chan et al., 1989) along with other factors such as mechanical properties of reinforcement material (Perkins, 1999), subgrade strength (Cancelli et al., 1997), nature of interaction between soil and geosynthetics (Ghosh and Madhav, 1994) and applied load magnitude. The reinforcement mechanisms in geosynthetic reinforced pavement include base course lateral restraint, increase in stiffness of the base course aggregate layer (Bender and Barenberg, 1978), reduction of shear stress in the subgrade soil (Love et al., 1987), improved vertical stress distribution on the subgrade (Milligan et al., 1989) and tensile membrane action (Giroud and Noiray, 1981). Significant rut depth and high stiffness of the geosynthetic must be provided to initiate the membrane effect and thus to enhance the bearing capacity of the subgrade (Som and Sahu, 1999; Gobel et al., 1994). The placement position of reinforcement is the main factor affecting the bearing capacity of reinforced granular soil and higher bearing capacity has been observed when the depth of placement of reinforcement is decreased (Akinmusuru and Akinbolade, 1981; Fragazy and Lawton, 1984; Sankariah and Narahari, 1988; Reymond, 1992). The optimal position was reported to lie at the base of the fill with a very soft subgrade and a fill thickness less than 0.4 m (Cancelli and Montanelli, 1999; Haas et al., 1988; Miura et al., 1990). Babu (2007) reported increased bearing capacity when woven and non-woven coir geotextiles were used at the interface of silty clay subgrade and granular base course of 150 mm thickness. It has been found that the membrane effect of reinforcement diminishes with an increase in the thickness of the road aggregate layer (Hufenus et al., 2006; Kinney et al., 1998). With higher fills, the depth effect of a wheel load is generally too small to mobilize a noticeable tensile force within the reinforcement when placed just above the subgrade. At small deformations an efficient mobilization of tensile strength of reinforcement is dependent on both interlock and stiffness (Fannin and Sigurdsson, 1996) in which case the effective location appears to depend on both the quality and thickness of the granular material in which the geotextile is installed and the magnitude of the applied loads. Also the role of geotextile/geogrid used as aggregate reinforcement is purely structural, and no separation benefit should be expected. In this case it is not placed directly at the interface, but rather at an optimum depth within the granular base (Ashmawy and Bourdeau, 1995). The interaction between soil and inclusion depends upon the limiting friction or adhesion at their interface (Ghosh and Madhav, 1994). Reinforcement placed high up in the granular layer hinders lateral movement of the aggregate due to frictional interaction and interlocking between the fill material and the reinforcement which raises the apparent load-spreading ability of the aggregate and reduces the necessary fill thickness (Chan et al., 1989; Gobel et al., 1994; Miura et al., 1990; Moghaddas-Nejad and Small, 1996; Perkins, 1999). Coir geotextile develops good interface friction with granular fill (Ajitha and Jayadeep, 1997; Subaida et al., 2008) which can induce tensile stress in the reinforcement when embedded within the fill material. Such minor changes in horizontal stress distribution can cause significant changes in system performance. Hence, when used as reinforcement in unpaved roads, laying of coir geotextile must be carried out so as to take full advantage of this biodegradable material during the early period of construction when much of the working of membrane action cannot be expected.

No significant study has been reported on the use of coir geotextiles as aggregate reinforcement in unpaved road sections. Hence a detailed experimental study has been planned to investigate the reinforcing benefits of woven coir geotextiles in a laboratory two-layer pavement section and the present paper describes the results so obtained. Two types of woven coir geotextiles and two base course thicknesses were adopted in the study. The effectiveness of such applications was investigated through a series of monotonic and repeated loading tests conducted under well-controlled testing conditions.

2. Materials used for the study

The subgrade of test sections consisted of clay having a liquid limit of 60% and plastic limit of 25%. The clay is classified as CH (as per Indian Standards) and had a specific gravity of 2.47. Optimum moisture content and maximum dry density were obtained as 25% and 15 kN/m^3 respectively in standard proctor test. To prepare the test sections clay was compacted to a dry density of 12 kN/m^3 at a water content of 46%, to simulate the natural condition of the clay deposit during the time of collection. The CBR value obtained at this water content and density was 1.2%.

The base course aggregate was a crushed stone with the particle size distribution shown in Fig. 1. The material is classified as GW as per Indian Standards and had a specific gravity of 2.67. Maximum dry density obtained was 20 kN/m^3 at a water content of 5.5%. The material was compacted to 90% of maximum dry density at a moisture content of 5% to make the base course in all tests. Direct shear tests performed at stress levels ranging from 100 to 300 kPa resulted in a friction angle of 48.3°.

Two types of woven coir geotextiles designated as MMA2 and MMA3 were used as reinforcements in the study. Woven coir geotextile is designated as mesh matting based on the type of warp yarn. Fig. 2 shows photographs of these two types of geotextiles. The properties of geotextiles used are presented in Table 1.

3. Test set-up

The experiments were conducted in a concrete tank of size 1.5 m length, 1 m width and 1 m depth. A reaction frame was fabricated using steel channels and plates to take up the loading and to hold the loading devices to be placed at the centre of the tank. Load was applied through a circular plate, 200 mm in diameter and 25 mm thick. The vertical load was applied on the footing through a steel shaft using a mechanical device based on the principle of screw motion that was measured using a proving ring of 50 kN capacity. Load was transferred to the plate through a steel ball kept in a groove which was made at the centre of the footing to ensure the applied load to be vertical. The settlement of the plate was

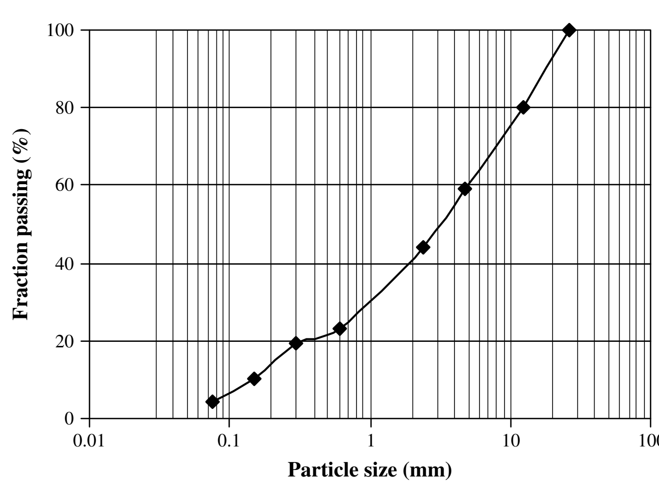

Fig. 1. Particle size distribution of base course material.