STUDIES ON ENGINEERING
BEHAVIOUR AND USES OF GEOTEXTILES
WITH NATURAL FIBRES

By

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Dedicated to

My

Parents
CERTIFICATE

This is to certify that the thesis entitled "Studies on Engineering Behaviour and Uses of Geotextiles with Natural Fibres" submitted by Mr. Balan K. to Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is a record of the bonafide research work carried out by him. Mr. Balan K. has worked under my supervision for the submission of this thesis, which to my knowledge has reached the requisite standard.

This thesis, or any part thereof has not been submitted to any other University or Institution for the award of any degree or diploma.

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ABSTRACT

Geosynthetics are being widely used in civil engineering, to solve a variety of problems related to drainage, separation and reinforcement. Geotextiles with natural fibres such as jute, coir and sisal are emerging as an alternative to polymeric geotextiles for application in temporary or in non-critical structures, where a shorter life span may be adequate. Wide acceptance of geotextiles with natural fibres was hitherto hindered due to their biodegradability. As of now geotextiles with natural fibres are being used in erosion control applications. In the context of sustainable development, these environmental friendly materials can be used in developing countries, since they are abundantly available and are generally lower in cost compared to their synthetic counterpart. Research on these materials is required to understand their behaviour thoroughly in order that one may use them rationally and confidently.

In view of the inadequate information on the engineering characteristics, biodegradability and the behaviour in different applications, an exclusive laboratory test programme and a field trial were designed on the following natural materials from Indian sources,

i) coir fibre and coir yarns,
ii) woven coir and jute geotextiles,
iii) non-woven coir geotextiles with and without HDPE scrim, and
iv) coir mattings of two different aerial densities.
More specifically, the work included an evaluation of

a) the physical characteristics of these materials, and the biodegradability behaviour of coir/jute geotextiles in different soil environment,

b) the comparative performance of natural fibre strip drains of different types, and

c) the behaviour of coir geotextiles/fibres in reinforcement through laboratory study and that of erosion control through a field study.

The material characteristics studies of the natural geotextiles used, include the mass per unit area, thickness and compressibility, apparent opening size and the in-isolation tensile strength. It also includes the in-soil tensile strength determination of woven coir geotextile. The studies revealed that the mass per unit area of natural geotextiles are higher than that of synthetic. Based on the results obtained from thickness measurements, it is recommended that the thickness of natural geotextiles can be determined as the value corresponding to a normal pressure of 2 kPa after one minute of application of pressure. The compressibility of woven jute geotextile is slightly higher than the woven coir.

The tensile strength of woven geotextiles of coir and jute is generally not influenced by the width, length of sample and the deformation rate used. For both woven and non-woven geotextiles, the narrow strip tensile strength test value was found to be a little higher than that of wide width in both machine and cross-machine direction. Based on the results of the extension test results it is recommended that the tensile strength of natural geotextiles can be taken as that corresponding to wide width specimen (200mm wide x 100mm length) at a deformation rate of 10 mm/min
determined in a constant rate of extension machine. The strength of natural geotextiles decreases significantly and the failure strain increases considerably when soaked. In-soil tensile strength of coir geotextile was higher than in isolation and is influenced by the grain size of the soil.

Accelerated degradation studies on specimens of jute fabric/coir yarn were conducted in different environments by keeping them in a humidity cabinet maintained at a temperature of 30 ± 1°C and a relative humidity of 90 ± 1%. Soil burial at shallow depths were also conducted.

The studies revealed the fact that the degradation of coir/jute geotextile is very complex in nature. The main factors, that are found to influence the degradation behaviour are the density of fabric/yarn, the soil type, pH, organic content and moisture content of soil, the climatic conditions and the depth of embedment. The life of coir is found to be much longer than jute under the same environmental conditions. Both varieties degrade at a faster rate in sand with high organic content followed by clay with high organic content/burial, sand and finally saturated clay, where the degradation is the least. There is also an increase in moisture absorption capacity with degradation. From the overall behaviour of natural geotextiles in burial and considering the rate of degradation in sand and clay it can be presumed that natural geotextiles of jute and coir can have a life of more than one and two to three years respectively.

From the reinforcement aspects of the woven coir geotextile studied, it was found that the tensile and friction behaviour of woven coir geotextile are akin to that
of an extruded geogrid. The interface friction aspects from pull-out and modified
direct shear were influenced by the type of soil. Even at low range of sustained
loading the initial strain developed in coir geotextile was more than 10%. Triaxial
tests on cohesionless soil reinforced with randomly distributed coir fibre reveal that
inclusion of coir fibre increases the shear strength parameters and is significantly
influenced by the length of the fibre.

Four different varieties of **natural fibre strip drains** made of non-woven coir
geotextile as core and woven jute/HDPE as filter sleeve has been developed. Their
performance in consolidating soft soil was compared with two other varieties of
natural fibre drains made of woven jute as filter sleeve and coir rope/jute rope as
core. The physical and hydraulic characteristics of all the drains were tested in
isolation and in-soil and the results were compared with that specified for synthetic

The studies reveal that drain Type F (fabricated in line with Lee et al. 1989)
satisfies all the criteria for synthetic drains. Drain Type B, Type D, Type A and Type
C (the newly developed varieties) satisfy the specifications in general except the
compression rate and thickness under sustained loading. Drain Type E (developed by
Indian Jute Industries’ Research Association) matches all the criteria except the
discharge capacity. From the model tank studies it is concluded that the efficiency of
drain Type F and Type B was nearly similar in consolidating soft soils. The efficiency
of drain Type E was the least of all. The thickness of natural fibre drains was more
and consequently the weight per metre length is much higher than the usual synthetic
prefabricated drains.
The service life of the drains can be expected to a minimum of one year and in some cases it would be even upto three years. Based on the evaluation, in the order of decreasing performance, the drains could be ordered as follows; Type F and Type B are the best, Type C, Type A, Type D and finally Type E, which is not recommended for use.

A field trial on erosion control using coir mattings was conducted in a rubber plantation area on the foothills of Western Ghats at an elevation of 22.5 m above Mean Sea Level, in Malappuram District of Kerala state, India, having an average rainfall of 250 cm. An area of 583 sq.m. with a slope of 66(), abandoned for plantation due to severe erosion, was selected for the trial. The field trial clearly showed how the coir net led to proper growth in vegetation. The system with stood the severe monsoon of the season of more than 350 cm of rainfall. Eventhough both varieties of mattings are satisfactory it was observed that Type A matting with small aperture is found to be more effective.

On the whole the studies conducted had characterized the engineering behaviour of geotextiles with natural fibres and their degradation behaviour. The studies also brought forth their use in erosion control and ground improvement through strip drains and reinforcement.
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