ALTERNATE LOW COST MATERIALS IN GROUND IMPROVEMENT

by

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DEDICATED

TO

MY PARENTS

CERTIFICATE

This is to certify that the thesis entitled **ALTERNATE LOW COST MATERIALS IN GROUND IMPROVEMENT** submitted by **Mr. Rakesh Kumar Dutta** to Indian Institute of Technology, Delhi, for the award of the degree of the Doctor of philosophy is a record of the bonafied research work carried out by him. **Mr. Rakesh kumar Dutta** 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 university or institution for the award of any degree or diploma.

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2 May 2002

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(Rakesh Kumar Dutta)

ABSTRACT

The application potential of scrap tyres, used LDPE bags, used packaging strips and natural fibre products for possible ground improvement and other geotechnical applications is examined in this thesis through a comprehensive laboratory study.

The research programme included

(a) a study of the triaxial and compressibility behaviour of sand with randomly distributed scrap tyre chips,

(b) a study of the triaxial behaviour of sand with randomly distributed LDPE and used packaging strips,

(c) analysis of the experimental data to assess the improvement in the bearing capacity and settlement aspects of footings resting on reinforced sand bed over clay, and

(d) characterisation of tensile strength of non-woven and woven coir geotextiles, and

(e) a study of the behaviour of two layered model pavement systems with and without coir geotextile inclusion under monotonic and cyclic loading conditions.

Chapter 1 of the thesis, gives introduction to the present work along with a brief description of reinforced soil technique and its advantages. In Chapter 2, the available relevant literature has been reviewed. The test equipment used is described along with the detailed experimental procedures and test programme in Chapter 3.

The behaviour of sand-tyre chip admixtures is presented in Chapter 4. The behaviour of sand-plastic strip admixtures is presented in Chapter 5. Studies with coir geotextiles are included in Chapter 6. An overall summary of the work carried out and the salient conclusions drawn are highlighted in Chapter 7.

Compressibility of the sand-tyre chip (of three different sizes, manually obtained) admixtures were examined under two conditions, viz K_0– condition with chip contents upto 100 % and vertical stresses upto a maximum value of 1290 kPa and triaxial

condition with chip contents upto 20 % and confining pressure upto 276 kPa. The tests in the rigid mould (K_0 condition) indicated that pure tyre chips are highly compressible beyond a vertical stress of 200 kPa. The compressibility increases generally with chip content, particularly beyond 20 %. Also the compressibility of admixtures with a chip content of 20 % (by weight) or 26.22 % (by volume) is around 1 %. Beyond this percentage it is likely that chips will begin to have direct contact, exhibiting higher compressibility, the maximum being with 100 % chip content.

The triaxial compression tests indicated that the initial tangent modulus and secant modulus increase linearly with confining pressure. The modulus decreases with increase in chip content, the decrease being marginal at low confining pressure and significant at the highest confining pressure.

It is thus evident that for geotechnical applications tyre chip content in admixture should not normally exceed about 20 % and that the compressive load to be applied should not be more than say about 150 kPa. Beyond these levels large deformations may occur, which may not be permissible. Keeping these in view the triaxial testing was carried out with chip contents upto 20 % only.

From the drained triaxial compression testing on sand-chip admixtures presented in Chapter 4 it was generally concluded that the general stress-strain-volume change behaviour of tyre chip-sand mixtures is akin to that of sand. There is some improvement in the strength ratio on addition of inclusions. Tyre chip Type III (with an aspect ratio of 2) shows the best improvement at the least confining pressure and chip content of 20 %. In general, the strength improvement is the least at the highest confining pressure tested. There is an increase of about 2^0 in the value of ϕ' and is nearly the same for all types of chips. The value of cohesion intercept increases significantly and with a maximum value of 18 kPa for sand with 20 % Type III chips. The results obtained compare well with those on sand-gravel mixtures reported by Holtz and Gibbs (1956). It was also found that hyperbolic stress-strain relationships are valid for the admixtures studied. The predictions improve when the value of failure strain (actual or assumed on experience) is introduced into the relationship.

Two types of waste plastic viz used LDPE bags (Type IV) and used packaging strips (Type V) of different strength and thickness were utilized for the study. They were cut into different sizes. For both the types an aspect ratio of 1 and 2 were used. Based on the drained triaxial compression test results, upto a confining pressure of 276 kPa presented in Chapter 5, the following specific conclusions were drawn.

1. The strength ratio of the admixtures increases with the increase in strip content, but the influence decreases significantly with the confining pressures. The aspect ratio plays a predominant role in strength improvement.
2. Sand-plastic strip mixtures exhibit a bilinear behaviour. The behaviour upto around a confining pressure of 69 kPa, is an increase in the value of ϕ' and beyond this critical confining pressure the value of ϕ' is nearly equal to that of sand. The value of cohesion intercept increases with the increase in strip content and aspect ratio.
3. The initial tangent modulus generally increases linearly with increase in confining pressures as well as with the increase in inclusion content for Type IV A and Type IV B inclusion.

The results of the analytical work carried out on sand-plastic strip mixtures for their use in bearing capacity improvement of sand layer overlying soft clay were presented in Chapter 5, from which the following specific conclusions were drawn. It was found that the bearing capacity ratio (BCR) increases with an increase in H/B (where H= thickness of sand, below the foundation and B = width of the footing) upto a value of around 2.0, beyond which, the increase is insignificant. As expected, the value of BCR increases with an increase in inclusion percentage and length of strips. The presence of inclusions however do not influence the settlement.

The wide strip tensile strength testing of four non-woven and four woven coir geotextiles has been carried out to characterize these materials and presented in Chapter 6. The following conclusions were drawn.

1. All woven coir geotextiles used in the present investigation have more tensile strength in the machine direction than in the cross-machine direction. Their tensile strength is influenced by number of yarns and their runnage which, in a way is reflected by the mass per unit area.
2. All non-woven coir geotextiles used in the present investigation have more tensile strength and tensile elongation in machine direction than in the cross-machine direction. The behaviour of the non-woven coir geotextiles is influenced by the presence of the type of stitching, yarn used, coir-jute netting and the coir web weight. As such, the behaviour is more complicated than that of the woven coir geotextiles. Nevertheless, it was possible to relate the behaviour corresponding to each of these parameters. The maximum strength is observed for the non-woven product Type H where the web is supported by coir netting and stitched with jute yarn. This is followed by product Type G wherein there is jute netting along with stitching by jute yarn. The two remaining Types E and F do not have any netting and having both been stitched by PP thread, the contribution of the coir web becomes more evident in as so far the strength of the lightest product Type E is the least observed.
3. The variance in tensile strength and tensile elongation of non-woven coir geotextiles is more in comparison to woven coir geotextiles.

From the unpaved model testing it was seen that:

1. The bearing capacity of the reinforced models increase significantly due to the placement of the coir geotextiles at the interface of base course and subgrade. The effect of the reinforcement is prominent at higher deformations levels. The inclusion of coir geotextiles is also found to change the failure pattern from punching shear failure (unreinforced models) to general shear type failure.
2. The performance of a particular type of geotextile depends upon its physical and mechanical properties. In the case of woven geotextiles, the bearing capacity ratio decreases. With the increase in tensile strength of woven coir geotextiles, the bearing capacity ratio improves with an increase in tensile strength or decrease in aperture size. Non-woven geotextiles perform better than woven geotextiles probably due to better surface friction offered.
3. Cumulative permanent deformation of the models varies nonlinearly with number of load repetitions, increasing with an increase in the magnitude of repeated load.
4. The permanent vertical deformations of the reinforced models reduce substantially (upto 76 %) upto 1000 number of cycles, with both non-woven and woven geotextiles.
5. At a particular deformation level reinforced models can sustain higher number of load repetitions than the unreinforced models.

On the whole, the thesis has attempted to provide an insight into the various aspects of the engineering behaviour of sand with tyre chips, plastic strips and coir geotextiles through laboratory study and brought out their potential and application in a typical field situation as mentioned below.

1. Inclusion of tyre chips in sand improves the strength behaviour marginally and can be used advantageously as a fill material in construction of highway embankments

to save valuable coarse aggregate / sand.

2. Inclusion of plastic strips in sand improves the strength behaviour and consequently bearing capacity. This will not only save the scarce granular material but will also improve the ground and more so the disposal of used plastic will be in an environmental friendly manner.
3. There are many varieties of coir products available. The improved behaviour of coir geotextile reinforced model pavements can be of great advantage in constructing the rural roads.

The thesis ends with suggestions for further work.

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