

# **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.



2 May 2002

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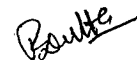
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(Rakesh Kumar Dutta)

## 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  $\phi'$  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  $\phi'$  and beyond this critical confining pressure the value of  $\phi'$  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.

# CONTENTS

	<b>Page No.</b>
<b>CERTIFICATE</b>	(i)
<b>ACKNOWLEDGEMENT</b>	(ii)
<b>ABSTRACT</b>	(iii)
<b>CONTENTS</b>	(ix)
<b>LIST OF TABLES</b>	(xvi)
<b>LIST OF FIGURES</b>	(xx)
<b>NOTATIONS</b>	(xxxii)
<b>CHAPTER 1 INTRODUCTION</b>	
1.0 GENERAL	1
1.1 SCOPE OF WORK	1
1.2 OBJECTIVES OF THE STUDY	3
1.3 CHAPTER OUTLINE	4
<b>CHAPTER 2 LITERATURE REVIEW</b>	
2.0 GENERAL	7
2.1 STRENGTH CHARACTERISTICS OF REINFORCED SOIL	7
2.1.1 Experimental Studies on Sand with Randomly Distributed Fibres	9
2.1.2 Studies with Natural Fibres	16
2.2 CHIPS OF SCRAP RUBBER TYRES	16
2.2.1 Typical Application	18
2.2.2 Field Studies	19
2.2.2.1 Limitation	23
2.2.3 Laboratory Studies	23
2.2.3.1 Compressibility of tyre chips	23

2.2.3.2 Shear strength of tyre chips	24
2.3 STUDIES ON TYRE CHIPS-SOIL MIXTURES	24
2.3.1 Shear Strength of Tyre Chip-Soil Mixtures	24
2.4 STUDIES ON USED PLASTIC	26
2.5 BEARING CAPACITY OF FOOTINGS ON SAND OVER CLAY	29
2.6 STUDIES ON UNPAVED ROAD MODELS	32
2.6.1 Behaviour of Unpaved Roads	32
2.6.2 Mechanism	34
2.6.3 Behaviour Under Static Loading	34
2.6.4 Analytical Models	41
2.6.5 Behaviour Under Repeated Loading	45
2.7 STUDIES ON COIR GEOTEXTILES	48
2.7.1 Studies on Characterization of Tensile Strength and Durability	52
2.7.2 Coir Geotextiles in Ground Improvement	60
2.8 SUMMARY AND CONCLUSIONS	61
<b>CHAPTER 3 EXPERIMENTAL WORK</b>	
3.0 GENERAL	63
3.1 MATERIALS	63
3.1.1 Sand	63
3.1.2 Kaolinite	63
3.1.3 Inclusions	63
3.1.3.1 Tyre chips	66
3.1.3.2 Plastic strips	66
3.1.3.3 Tensile strength	66

3.1.4 Reinforcements	71
3.1.4.1 Woven coir geotextiles	71
3.1.4.1.1 <i>Material composition</i>	71
3.1.4.1.2 <i>Physical properties</i>	71
3.1.4.2 Non-woven coir geotextiles	71
3.1.4.2.1 <i>Material composition</i>	78
3.1.4.2.2 <i>Physical properties</i>	78
3.1.5 Strength Testing	78
3.2 TRIAXIAL TESTS	81
3.2.1 Apparatus	81
3.2.2 Experimental Procedure	81
3.2.3 Parameters Varied in Triaxial Testing	81
3.2.3.1 Tyre chips	81
3.2.3.2 LDPE strips	82
3.2.3.3 Used packaging strips	82
3.3 OTHER TESTS ON TYRE CHIP SAND ADMIXTURES	84
3.3.1 Compressibility Test	84
3.3.2 Repetitive Load Test	84
3.4 MODEL TESTS	84
3.4.1 Experimental Set up	84
3.4.1.1 Model tank	84
3.4.1.2 Preparation of model	87
3.4.1.3 Assembly	87
3.4.1.4 Test procedure	87
3.5 CONCLUDING REMARKS	90

## CHAPTER 4 BEHAVIOUR OF SAND-TYRE CHIP ADMIXTURES

4.0 GENERAL	91
4.1 COMPRESSIBILITY OF SAND-TYRE CHIP MIXTURES	91
4.2 REPETITIVE LOAD TESTS ON SAND-TYRE CHIP MIXTURES	95
4.3 TRIAXIAL BEHAVIOUR OF SAND	98
4.3.1 Sand	98
4.3.1.1 Stress-strain relationships	98
4.3.1.2 Volume change behaviour	101
4.4 BEHAVIOUR OF SAND-TYRE CHIP MIXTURES	101
4.4.1 Stress-Strain-Relationships	101
4.4.1.1 Comparison	101
4.4.2 Volume Change Behaviour	111
4.4.3 Strength Ratio	111
4.4.3.1 Comparison	121
4.4.4 Strength Characteristics	121
4.4.4.1 Comparison	124
4.4.4.2 Comparison with sand-gravel mixtures	124
4.4.5 Constitutive Relationships	125
4.4.5.1 Hyperbolic stress-strain relationship	125
4.4.5.2 Initial tangent modulus	136
4.4.5.3 Secant modulus	136
4.5 CONCLUSIONS	145
4.5.1 Compressibility	145
4.5.2 Shear Strength	146

## **CHAPTER 5 BEHAVIOUR OF SAND-PLASTIC STRIP ADMIXTURES**

5.0 GENERAL	147
5.1 TRIAXIAL TEST RESULTS	147
5.1.1 Stress-Strain-Relationships	147
5.1.2 Volume Change Behaviour	156
5.1.3 Strength Ratio	165
5.1.3.1 Influence of aspect ratio	168
5.1.4 Strength Characteristics	169
5.1.5 Constitutive Relationships	174
5.1.5.1 Hyperbolic stress-strain relationship	174
5.1.5.2 Initial tangent modulus	189
5.2 APPLICATION TO FOOTINGS	195
5.2.1 Ultimate Bearing Capacity	195
5.2.2 Bearing Capacity Ratio	199
5.2.2.1 Comparison	199
5.3 ESTIMATION OF SETTLEMENTS	202
5.3.1 Elastic Settlement	207
5.3.2 Consolidation Settlement	208
5.4 CONCLUSIONS	214

## **CHAPTER 6 MODEL TESTING WITH COIR GEOTEXTILES**

6.0 GENERAL	215
6.1 TENSILE STRENGTH	215
6.1.1 General	215
6.1.1.1 Wide Width Tensile Strength of Woven Coir Geotextiles	226

6.1.1.2 Wide width tensile strength of non-woven coir geotextiles	232
6.1.2 Conclusions	235
6.2 MODEL TESTING	235
6.2.1 Monotonic Load Tests	235
6.2.1.1 Models reinforced with woven coir geotextiles	235
6.2.1.1.1 <i>Effect of aperture size and tensile strength</i>	237
6.2.1.2 Models reinforced with non-woven coir geotextiles	237
6.2.1.3 Comparison of behaviour woven and non-woven coir reinforced models	242
6.2.1.4 Comparison with geosynthetic reinforced model	248
6.2.2 Analytical Models	252
6.2.3 Repetitive Load Tests	257
6.2.3.1 Permanent deformation	257
6.2.3.1.1 <i>Comparison</i>	259
6.2.3.2 Apparent resilient modulus	259
6.3 CONCLUSIONS	262
<b>CHAPTER 7 SUMMARY AND CONCLUSIONS</b>	
7.0 INTRODUCTION	265
7.1 STUDIES ON TYRE CHIP ADMIXTURES	265
7.1.1 Compressibility Behaviour	265
7.1.2 Shear Strength Behaviour	266
7.2 STUDIES ON SAND-PLASTIC STRIP ADMIXTURES	267
7.2.2 Triaxial Behaviour	267

7.2.3 Use in Foundation	268
7.3 STUDIES ON COIR GEOTEXTILES	269
7.3.1 Tensile Strength Characterisation	269
7.3.2 Two Layer Model Pavement Studies	270
7.4 CONCLUDING REMARKS	272
7.5 FUTURE SCOPE OF WORK	272
REFERENCES	274
APPENDIX A	283
APPENDIX B	298
APPENDIX C	312
BIODATA	322