CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Summary

Nowadays, the available land with good bearing capacity is not sufficient enough to meet the increasing population demand. This leads to the option of construction activities on weak soil characterised by poor bearing capacity and high settlement. In such situations insitu stabilization of soil is inevitable. Among the different soil stabilization techniques, soil reinforcement is fast replacing all other stabilization techniques. In countries where the availability and cost of petroleum-based geosynthetic reinforcing materials are major constraining factors, reinforced soil systems using natural materials have tremendous application possibilities. Coir geotextiles have been found to be a suitable choice for erosion control applications. With the inherent properties of woven coir geotextile and also hand knotted netting, particularly strength, their potential for application as reinforcement in loose/weak soil deposits calls for detailed examination. With this objective, the reinforcing effect aspects of both woven coir geotextile and hand knotted coir netting have been brought forth in the present study.

A series of small scale laboratory tests were carried out to evaluate the effect of coir reinforcement on pressure-settlement response of model footing on a loose sand. One type of woven coir geotextile (designated as H2M6) and two varieties of hand knotted coir nettings (designated as NA1 and NA2) were used for this purpose. The study primarily aimed at determining the effect of single and multi-layered woven coir geotextile and hand knotted coir netting layer(s) of different configurations on the strength improvement of such footings and also to obtain an insight into the reinforcing
mechanism. Effect of parameters such as depth of reinforcement placement, length of reinforcement and multi-layer was analysed. From the results, it has been concluded that, behaviour in the whole makes this material suitable for reinforcing loose sandy soil deposits for temporary engineering applications. From the present results, in conjunction with the earlier research on the reinforcement aspect of coir geotextiles, it can be concluded that the above mentioned types of coir geotextiles and hand knotted coir nettings can be used successfully to reinforce loose soils.

A few studies have been reported in the past to examine the potential of coir as a randomly reinforcing material. An attempt has been also made in the present study to examine whether soft clay soils can be effectively stabilized/strengthened through installation of sand-coir fibre composite columnar reinforcement in plate load tests on soft clay beds. Influence of area as well as configuration of columns on the pressure versus settlement behaviour of soft clay is identified and isolated. The study indicates that, strength improvement sufficient enough to eliminate the need for a deep foundation is achievable through the use of the proposed technique.

Coir being biodegradable material and loses its tensile strength over a period of time. However, this material is eventually converted into organic matter which in turn aggregates the soil particles and tries to retain its improved properties for a certain period. In many situations, the construction carried out gets stabilized by this period. No significant study has been reported in the literature on the degradation behaviour of coir geotextile and hand knotted coir nettings. As part of the present research work, durability of coir geotextile and hand knotted coir netting were examined by testing the samples after subjecting them to continuous wetting as well as alternate wetting and drying cycles. Both reduction in tensile strength and loss of weight of coir samples
were investigated. The subsequent section presents the salient conclusions arrived at from the reported research work.

7.2 Conclusions

Based on the results of the research work and subsequent analysis, the following specific conclusions are drawn:

(1) Woven coir geotextile and hand knotted coir netting are appropriate products for stabilization of loose sand. The short-term bearing capacity of woven coir geotextile/hand knotted reinforced sand bed is significant even at small values of normalized settlement and the geotextile/ netting can be expected to be at least equally effective as many of the synthetic materials used previously.

(2) About three-fold increase in strength obtained even with a single layer of woven coir geotextile and more than two-fold increase in strength obtained with hand knotted coir netting suggest that bearing capacity sufficient enough to eliminate the need of a deep foundation is achievable by the proposed technique. Of the two varieties of hand knotted coir netting used, the type NA2 with 20-22 knots per running metre is found to be a better choice of reinforcement.

(3) Optimum depth of placement below the base of footing, of a single layer of woven coir geotextile reinforcement lies in the range 0.33B-0.5B and for the hand knotted coir nettings range lies in the range of 0.25B-0.4B.

(4) Optimum value of geotextile length is about two times the width of the footing for woven coir geotextile while in the case of hand knotted coir netting, the same is about three. The degree of improvement obtained
with length ratio of 1.2 is also significant. These findings are different from those reported in the literature and confirm that no single reinforcing mechanism can fully explain the behaviour of all reinforced soil systems.

(5) Multi-layer coir geotextile reinforced soil system is most effective when the subsoil upto a depth of 0.4B-0.8B is reinforced with three to four layers of geotextile. As far as hand knotted coir netting is concerned, optimum beneficial effect is obtained by reinforcing the zone of soil up to a depth of about 0.4B-0.6B beneath the footing with three layers of netting.

(6) The influence of number of reinforcement layers and vertical spacing between layers are to be considered together in any analysis of similar problems.

(7) Rate of improvement in strength with increasing values of normalised settlement is significant only for multi-layer coir geotextile and hand knotted coir netting reinforced soil system.

(8) Equations for obtaining a qualitative estimate of the strength improvement of footings resting on woven coir geotextile and hand knotted coir netting reinforced sand for different reinforcement configurations are presented.

For the H2M6 woven coir geotextile,

Strength Improvement Ratio = 0.85 N^{0.470} (z/B)^{-0.203} (p/B)^{-0.159} (L/B)^{0.315} (s/B)^{-0.271}

For the NA1 hand knotted coir netting,

Strength Improvement Ratio = 1.10 N^{0.735} (z/B)^{-0.063} (p/B)^{-0.137} (L/B)^{0.176} (s/B)^{-0.125}

For the NA2 type netting.
Strength improvement ratio = 1.48 N^0.463 (z/B)^0.060 (p/B)^{-0.142} (L/B)^{0.109} (s/B)^{0.181}

(9) Pressure versus settlement behaviour of soft clay bed reinforced with sand-coir fibre columns is appreciably better than that of untreated clay bed. The results are quite encouraging in that a strength improvement ratio of 1.5 to 2.0 would, in many situations, be sufficient enough to eliminate the need of a deep foundation.

(10) Provision of columnar reinforcement outside the loaded area results in soil improvement to some extent; however, it may not turn out to be cost-effective, in comparison with the provision of the same within the loaded area.

(11) For a chosen value of relative column area, provision of four identical sand-coir fiber columns just inside the corner locations of the proposed loaded area appears to be an optimum choice of column configuration for soil improvement.

(12) Strength improvement ratio shows a decrease at higher settlements/pressures.

(13) It is possible to develop a framework for prediction of the degree of soil improvement in terms of the relative column area, and normalized column depth.

From the tests with single central column,

Strength improvement ratio = 0.953 + 0.122 (z/B) + 2.835 (RCA)

From the tests with four corner columns,

Strength improvement ratio = 1.036 + 0.653 (z/B) + 2.808 (RCA)
(14) The tensile strength of both coir geotextiles and coir nettings significantly decreases with increase in number of cycles of alternate wetting and drying.

(15) The tensile strength of hand knotted coir nettings significantly decreases with increase of time, when kept permanently under water.

(16) Of all the coir products studied, woven coir geotextile (H2M6) exhibited only a marginal reduction in tensile strength even after 548 days (1½ years) of continuous submergence.

(17) Alternate wetting and drying results in loss of weight of the geotextile and nettings at a fast rate whereas the woven coir geotextile (H2M6) shows only a marginal reduction in weight with passage of time, when permanently kept under water.

(18) None of the coir products are durable under alternate wetting and drying condition while the woven coir geotextile (H2M6) can be used in situations where they are exist permanent likely under water.

7.3 Limitations of the present study

Only Laboratory model plate load tests were performed to investigate (i) the effect of woven coir geotextiles and hand knotted nettings on the pressure versus settlement behaviour of loose sand bed, (ii) the degree of improvement obtained using sand-coir fiber composite in the form of columnar reinforcement on soft clay bed. All the results presented have scale effects and hence can be considered to be only qualitative in nature. Large scale field tests are needed to quantify the strength improvement ratio for a given set of values of variables considered in the present study.
Hand knotted coir nettings in the present form, can be used for short term applications only, and at the same time, woven coir geotextile is seen to be effective for long-term applications when the same is likely to be permanently under water. The question on whether the reinforcement is needed for short-term or long-term applications is also relevant since one form of geotextile and netting will not be the optimal solution for all situations. Further, with advancement in durability enhancement studies on coir, woven coir geotextiles and hand knotted coir geotextiles are expected to be preferred choice of ground improvement for long term applications also.

7.4 Scope for future work

Large-scale fields tests are needed to quantify the bearing capacity ratio for a given set of values of variables considered in the present study. Enhancement in the durability of coir geotextiles would extend the applicability of the proposed method for long term needs. More performance related tests are required to be developed for the biodegradability aspect of coir geotextiles by applying different coatings to increase life of coir geotextiles.