

CONSTITUTIVE MODELLING OF REINFORCED SOIL

by

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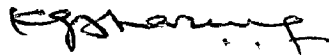
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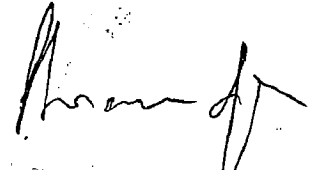
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CERTIFICATE

This is to certify that the thesis entitled "CONSTITUTIVE MODELLING OF REINFORCED SOIL" being submitted by Mr. KRISHNA MURARI SONI to the Indian Institute of Technology, Delhi, India, for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard, fulfilling the requirements for DOCTOR OF PHILOSOPHY degree. The research report and the results presented in this thesis have not been submitted, in part or full, to any other University or Institute, for the award of any degree or diploma.



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ABSTRACT

A number of geotechnical engineering structures are constructed on the deposits having poor soil conditions. Various techniques to improve such soils include compaction, preloading and stabilization. A fast emerging technique to improve poor soil conditions is to use reinforcement in the soil. This technique is now being used all over the world in various applications in structures such as embankments, foundations, retaining walls and pavements. A detailed investigation of the behaviour of the reinforced soils has therefore become imperative. Very limited studies have been made on the effect of various factors on the behaviour of reinforced soil and on the constitutive modelling of the reinforced soil behaviour.

In the present study, a comprehensive testing programme has been devised to study the stress-strain-volume change behaviour of reinforced soils. The behaviour has been investigated on three aspects, the effect of the type of reinforcement, the effect of the spacing of the reinforcement and the effect of the stress paths. Ennore sand has been used in the experimental investigation. Needle punched non-woven and woven geotextiles made of polypropylene have been used as the reinforcement. Drained triaxial tests have been conducted using strain controlled, stress controlled and GDS computer

controlled triaxial test equipments on cylindrical samples of approximately 38 mm in diameter and 76 mm in height. Four series of tests have been conducted following six stress paths, three on compression side and three on extension side. Hydrostatic compression path tests have been conducted to understand the bulk behaviour. The non-woven geotextiles have been placed at the centre in one series and at one third each height of the sample in the disc form in other series. The woven geotextile discs have been placed at one third each of the height of the sample. Tests on unreinforced soils have also been conducted to compare the behaviour with reinforced soils. Stress-strain-volume change behaviour of the unreinforced and reinforced soils has been studied considering the effect of type and spacing of the reinforcement, and the effect of the stress paths. Simplified methods have been proposed to predict the strength of unreinforced and reinforced soils for various stress path and the coefficient of interface friction for reinforced soils. Prediction charts have also been presented to predict the strength of reinforced soil and to determine the coefficient of interface friction from triaxial tests.

Hierarchical model developed by Desai and his co-workers is capable to include various complexities such as non-associativeness, stress path dependency and anisotropy. The model is based on the principle of mechanics and has the

provision to include further polynomials required to include additional response. This model is used to characterise the behaviour of unreinforced and reinforced soils in the present study. Theory of elasto-viscoplasticity has been used to obtain the solutions. Two computer programs have been developed to determine the material constants of the soil and the interface. Reinforced soil has been modelled as a single homogeneous material and also considering separate properties of the soil, the reinforcement and the interface. Predictions have been made for the tests used to determine the material constants and also those not used. Predictions have also been made from the second method considering separate properties of various components of the reinforced soil. Another computer program using finite element formulation has been used for the purpose in which soil and interface have been modelled using hierarchical model and the reinforcement using von-Mises criterion. The solutions for nodal displacements have been obtained by forward difference scheme introducing a tolerance for convergence.

From the investigation, it has been found that

- i) reinforced soils exhibit higher failure strains and volume contraction than unreinforced soils for all the stress paths. Failure strains and the strength increase with increase in number of layers. Failure strains, volume change, initial tangent modulus and the percentage

increase in strength over unreinforced soil are stress path dependent.

- ii) reinforced soils with non-woven geotextiles exhibit higher failure strains, strength and coefficient of interface friction than woven geotextile in reinforced soil. Non-woven geotextile reinforced soils show lower values of initial tangent modulus than those of woven geotextiles for all stress paths.
- iii) predictions of stress-strain-volume change response of unreinforced and reinforced soils using hierarchical model are, in general, satisfactory.
- iv) the strength of the reinforced soils can be predicted from number of layers, their spacings, coefficient of interface friction and angle of internal friction of unreinforced soil in a triaxial test. Predictions of the strength and coefficient of interface friction are good compared to the experimental results.

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