III — 9 SOME RECENT RESEARCH ON STRESS DISTRIBUTION AND GEOMETRIC NON-LINEARITY OF REINFORCED EARTH BY THE APPLICATION OF FINITE ELEMENT TECHNIQUE

BY

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ABSTRACT

The first part (A) of the paper represents the result of the recent research on the stress distribution of reinforced earth by the finite element method under triaxial loading condition with variable types and forms of reinforcement and outlines the effect of radial stress , vertical stress , shear stress and circumferential stress. Stress ratio of reinforced samples have also been reported and discussed in this paper.

The second part (B) of the paper describes the geometric non-linearity of reinforced earth using finite element technique and summarizes the effect of stress-strain relation obtained from the material non-linearity (M N L) and geometric non-linearity (G N L) under different confining pressure and loading condition.

INTRODUCTION

In the fourteen years since Vidal (1 , 2) , a French engineer , developed the first commercial use of reinforced earth a large number of reinforced earth structures have been investigated in France , the United States of America , Australia , the United Kingdom , Canada and Japan (3 - 7) . While the majority of this structures are earth retaining structures , to-date much attention has not been given on the effect of stress distribution and geometric non-linearity of reinforced earth by the application of finite element technique. The main purpose of this paper is to briefly describe the result of recent research on reinforced earth under triaxial loading condition with variable confining pressure , types and form of reinforcements and outlines their effects within the soil samples. The detail results obtained from this programme of investigation have been reported by author etal (8 - 10) .

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(A) - STRESS DISTRIBUTION

Idealization and Adoption of Finite Element Technique:-

Conventional engineering structures can be visualized as an assemblage of structural elements interconnected at a discrete number of nodal points. If the force displacement relationships for the individual elements are known , it is possible to derive the properties and study the behavior of the assembled structure by using well known techniques of structural analysis.

In an elastic continuum the true number of interconnection points are infinite and here lies the biggest difficulty of its numerical solution. The concept of finite element attempts to overcome this difficulty by assuming the real continuum to be divided into elements interconnected only at a finite number of nodal points at which some fictitious forces, representative of the distributed stresses actually acting on the element boundaries, were supposed to be introduced. If such an idealization is permissible the problem reduces to that of a conventional structural type , well amenable to numerical treatment . Using such elements , the structural idealization is obtained by merely dividing the original continuum into segments of appropriate sizes and shapes , all of the material properties of the original system being retained in the individual elements. Finite element analysis has already been used to analyse reinforced earth structures.

In this investigation triaxial tests have been used to investigate the behavior of reinforced earth , reinforced with different types of reinforcements . Recent results from a number of triaxial tests on reinforced cohesionless and cohesive soil samples with different reinforcing elements have been obtained from the experimental programme of the present investigation . To analytically determine the stress distribution within the reinforced soil specimen under triaxial loading condition , finite element method has been used.

The present problem has been solved utilising the procedure available for the problem of stress distribution in bodies of revolution of axi-symmetric solids under axi-symmetric loading. For the axi-symmetric elastic continuum the finite element model comprises of assemblage of triangular ring elements connected by nodal rings located at the corners of each element . During loading each element deforms in accordance with the constitutive relationship corresponding to its material properties.

Discussions of Stresses within the Sample :-

The stress components σ_z , σ_r , σ_θ , and τ_{rz} under different applied total vertical loadings and chamber pressures were evaluated through the finite element technique . To compare the natures of stress distribution in unreinforced and reinforced samples , stress ratios have been computed . Stress ratios have not been computed in cases where stress reversals have occured . Stress distribution within a reinforced sample - cohesionless and cohesive - is much different from that in an unreinforced sample.

In the case of the cohesive samples used in the numerical analysis increase in the vertical stress near the axis and reduction at the boundary are observed . The stress decreases systemically from the axis towards the boundary . All the other stress components are generally increased due to the presence of reinforcements and stress reversals at a few locations for some components are noted . The variation of these components across the section is not uniform . In the case of cohesionless samples vertical stress components show an erratic distribution . Both the increase and decrease due to the presence of reinforcements are more pronounced in the case of cohesionless samples than in the case of the cohesive samples . A large increase in the other stress components is observed in the reinforced cohesionless sample . As in the case of cohesive sample the variations are non-uniform . All the stress comonent are sensitive to the friction factor used in the numerical analysis both in the case of cohesive and cohesionless samples. It is , therefore , important that an appropriate friction factor for the given conditions is used in the evaluation of stress components within a reinforced earth soil mass .

CONCLUSIONS

Based on the results of this research , the following conclusions may be drawn :-

1. Stress distribution in a reinforced soil is much different to that in a corresponding unreinforced soil mass . Concentration , reductions and reversals in stress components occur due to the induction of reinforcements .

2. Stress distributions are sensitive to the mobilised friction and / or adhesion between the reinforcements and the soil .

(B) - GEOMETRIC NON-LINEARITY

Adoption of Geometric Non-linearity :-

Since the triaxial specimens undergo large deformations inclusion of geometric non-linearity in the finite element analysis is necessary . Problems involving geometric non-linearity arise both from non-linear strain - displacement relations and from finite changes in geometry . In view of the severe constraints , only geometric non-linearity due to finite changes in geometry has been considered now . The iterative method has been used for this purpose . It consists of applying the incremental load and using the resulting displacements to revise the locations or co-ordinates of the nodal points at each cycle of iteration . The new geometry is used to re-compute the stiffness and stresses . Only three iterations could be employed under each loading increment . Typical stress-strain curves for a reinforced sample are given in Fig. 1.

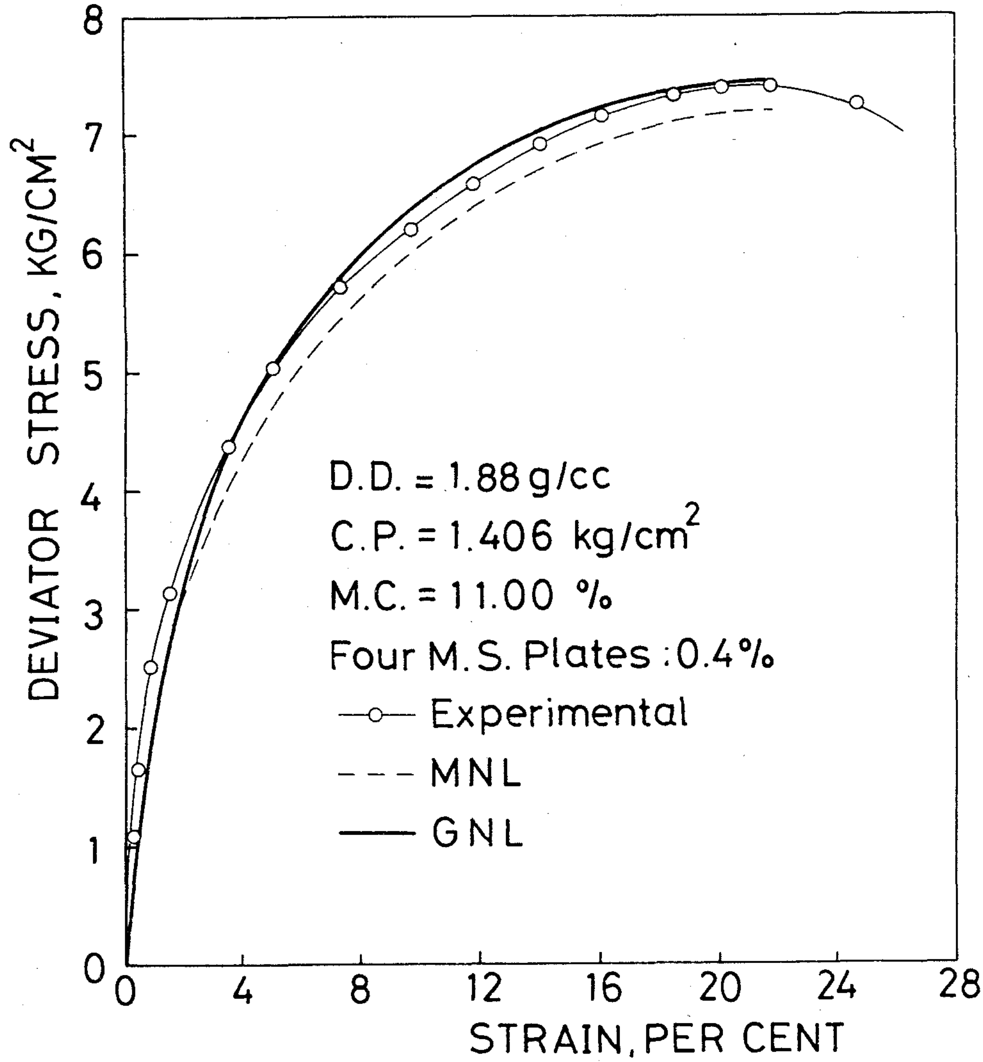

FIG. 1.-Typical Stress-Strain Curves of Reinforced Silty Clay Sample

SUMMARY AND CONCLUSIONS

The stress-strain relation of the reinforced triaxial samples theoretically obtained have been compared with the experimental results in this paper . The stress-strain relations obtained show that the material non-linearity (M N L) and the geometric non-linearity (G N L) are almost the same initially under small loading increments but the solution with the incorporation of geometric non-linearity is slightly better than the material non-linearity under higher loading increments . The nature of variation of the different stress components across the specimen remains essentially same while the magnitudes of the various stress components are different in the geometric non-linearity solution . The stress values are generally larger . The modelling used for the geometric non-linearity seems to be appropriate in view of the correlation between the experimental and analytical results .

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APPENDIX 11.-NOTATION

The following symbols are used in this paper:

σ_z = Vertical stress ;

σ_r = Radial stress ;

σ_θ = Circumferential stress ;

τ_{rz} = Shear stress in r-z plane ;

C.P. = Confining pressure ;

M.S. = Mild steel;

M.C. =Moisture content and

D.D. = Dry density .