

BEHAVIOUR OF MODELLED ROCKFILL MATERIAL
UNDER HIGH CONFINING PRESSURES

BEHAVIOUR OF MODELLED ROCKFILL MATERIALS
UNDER HIGH CONFINING PRESSURES

KAUSHAL KUMAR GUPTA

THESIS SUBMITTED TO THE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

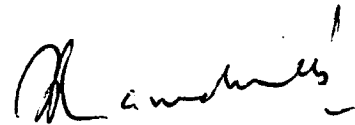
DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

MAY, 1980

CERTIFICATE

This is to certify that the thesis entitled, "BEHAVIOUR OF MODELLED ROCKFILL MATERIALS UNDER HIGH CONFINING PRESSURES" being submitted by Mr. Kaushal Kumar Gupta to the Indian Institute of Technology, Delhi for the award of the degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him. Mr. Kaushal Kumar Gupta has worked under my guidance for the submission of this thesis which to my knowledge has reached the requisite standard.

The thesis or any part thereof, has not been submitted to any other University or Institution for the award of any degree or diploma.



(PROFESSOR T. RAMAMURTHY)
Soil Mechanics and Foundation Engineering
Department of Civil Engineering
Indian Institute of Technology, Delhi
New Delhi-110016
INDIA

ACKNOWLEDGEMENTS

The author expresses his gratitude to Dr. T. Ramamurthy, Professor, Soil and Rock Mechanics, for his guidance and encouragement throughout the research programme. The author is also grateful to Dr. S.K. Gulhati, Professor and Head of Civil Engineering department for his encouragement.

Thanks are due to the staff of Soil Mechanics Laboratory and Workshop of Civil Engineering Department for their continuous help during the experimental work. Shri A.S. Bonga (late) deserves special mention for his help in fabricating the equipment.

The author is also thankful to Shri Dilbagh Lal for the preparation of figures and to Shri Jagdish Kumar for typing the thesis.

The author would also like to express his gratitude to his colleagues and friends particularly to Dr. Anil Kumar, Dr. A.K. Nagpal, Dr. C.G. Prabhakar Narayan, Dr. G.V. Rao, Dr. T.S. Rekhi, Dr. B.S. Satija and Dr. B. Shankariah for their co-operation and useful suggestions during this research programme.

ABSTRACT

Primarily three modelling techniques have been put forward to evaluate the design parameters for the analysis of problems related to large size particulate materials, like rockfills, which require formidable dimensions of test equipment to simulate the field conditions. To study the effectiveness of modelling, three uniform fractions ($d_{50} = 0.096, 1.0$ and 3.4 mm) each of mineral Calcite and Quartz were tested in isotropic consolidation and consolidated drained triaxial compression tests under confining pressures upto 127 kg/cm^2 using lubricated end platens. The ratio of average sizes of coarsest to the finest fraction was of the order of 35. Results of white Badarpur sand and Pyramid dam material have also been utilized in support of the techniques developed from this study for the prediction of the behaviour of large particle size material. Modelling of prototype material, using parallel gradation obtained by geometrically reducing the size of the material, appeared to be promising in evaluating the parameters. Straight line graphical representations on appropriate scales have been obtained to predict the behaviour of prototype material likely to be subjected to higher confining pressures by testing modelled material under lower confining pressures greater than 3 kg/cm^2 . It is possible to predict the coefficient of uniformity, specific surface area, increase in area under the grain size distribution curve of the large size particulate

material subjected to higher confining pressures. Methods have also been developed to predict the constant 'a' and 'b' of hyperbolic stress-strain relationship for large size particulate material subjected to higher confining pressure in order to built-up stress-strain curves. Volumetric strains due to isotropic consolidation and shear, angle of shearing resistance, angle of interparticle friction by separating the boundary energy component, coefficient of earth pressure at rest and ratio of principal strains ($\delta \epsilon_3 / \delta \epsilon_1$) could be evaluated for the prototype material from the study of modelled materials. For most of the graphical representations, the relative average diameter is plotted on semilog scale, therefore, it may be possible to predict the results conveniently for relative average diameter upto 100. The technique of predicting the behaviour of prototype material appeared to be valid for application to both uniform and well graded materials.

CONTENTS

	Page
Certificate	i
Acknowledgement	ii
Abstract	iii
Contents	v
List of tables and figures	viii
Notations	xx
CHAPTER I INTRODUCTION	1
CHAPTER II LITERATURE REVIEW	6
Compressibility	7
Stress-strain and strength characteristics	15
Axial strain at failure	15
Volume change characteristics	22
Mohr's rupture envelope and angle of shearing resistance	29
Constitutive relationships	38
Components of strength	45
Effect of shape and gradation	55
Degradation of material	60
Modelling technique	65
CHAPTER III PROGRAMME OF TESTS-EQUIPMENT AND TEST PROCEDURE	80
Programme of tests	80
Preparation of test material	80
Equipment	87

	<u>Page</u>
Triaxial Test Equipment	
Triaxial cell for 38 mm diameter specimen	87
Triaxial cell for 100 mm diameter specimen	89
Lateral pressure application system	89
Loading frame	93
Load measuring system	93
Volume change measuring system	95
Accessories	95
EXPERIMENTAL PROCEDURE	98
Triaxial test	98
Preparation of specimen	98
Isotropic consolidation test	103
Shearing of test specimen	104
Dismantling of specimen	105
Grain size distribution	108
Membrane penetration calibration test	108
CHAPTER IV RESULTS AND DISCUSSION	109
Degradation of Materials	109
Particle size distribution	109
Coefficient of uniformity	117
Coefficient of curvature	131
Specific surface area	137
Area under the grain size distribution curve	146
Stress-strain and strength behaviour	160
Compressibility characteristics	160
Axial strain at failure	177
Volumetric strains during shearing	185
Strength	206
Strain ratio	244
Coefficient of earth pressure at rest	248
Angle of interparticle friction	251

CHAPTER V	CONCLUSIONS	259
CHAPTER VI	FUTURE WORK AND LIMITATIONS	264
	REFERENCES	266
APPENDIX 1	Details of rubber membrane sandwiches and teflon sandwiches	273
APPENDIX 2	Details of rubber membrane	274
APPENDIX 3	Tabular representation of results	275
APPENDIX 4	Graphical representation of results	295
	BIO-DATA	329