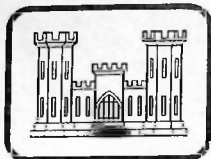


4/79



*Luikell*

TECHNICAL REPORT S-78-15

# GYRATORY SHEAR APPARATUS DESIGN, TESTING PROCEDURES, AND TEST RESULTS ON UNDRAINED SAND

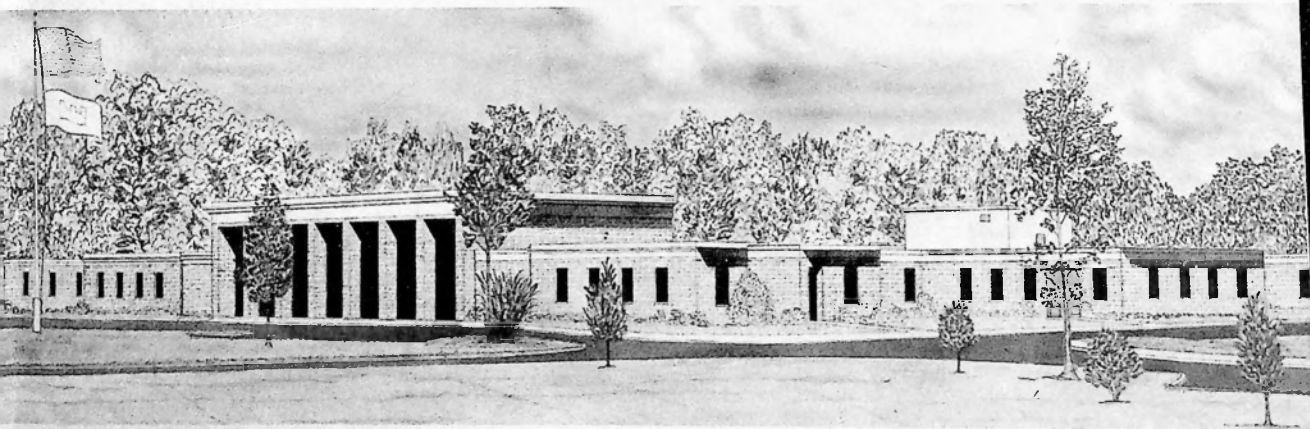
by

Arthur Casagrande and Franklin Rendon  
Pierce Hall  
Harvard University  
Cambridge, Massachusetts 02138  
Harvard Soil Mechanics Series No. 89

October 1978

Final Report

Approved For Public Release; Distribution Unlimited



Prepared for Office, Chief of Engineers, U. S. Army  
Washington, D. C. 20314

Under Contract No. DACW39-74-C-0026

Monitored by Geotechnical Laboratory  
U. S. Army Engineer Waterways Experiment Station  
P. O. Box 631, Vicksburg, Miss. 39180

## PREFACE

This investigation was conducted and this report was prepared by Professor Arthur Casagrande and Mr. Franklin Rendon under Contract No. DACW39-74-C-0026 as part of the ongoing work at the U. S. Army Engineer Waterways Experiment Station (WES) under CWIS Work Unit 31145, "Liquefaction of Dams and Foundations During Earthquakes."

The study was initiated at the request of Mr. Ralph W. Beene, who monitored the work for the Office, Chief of Engineers, U. S. Army. The WES Contracting Officer's Representative was Dr. W. F. Marcuson, III, Research Civil Engineer, Earthquake Engineering and Vibrations Division, Geotechnical Laboratory (GL). General guidance and direction were provided by Mr. S. J. Johnson, Special Assistant (now retired), GL, and Mr. J. P. Sale, Chief, GL.

Directors of the WES during this investigation were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

## CONTENTS

	<u>Page</u>
PREFACE . . . . .	ii
LIST OF FIGURES . . . . .	v
NOTATION . . . . .	vii
DEFINITIONS . . . . .	xi
CHAPTER 1 INTRODUCTION . . . . .	1
1.1 Purpose and Scope . . . . .	1
1.2 History of Gyrotory Apparatus and of Investi- gations Performed . . . . .	1
1.3 Acknowledgments . . . . .	2
CHAPTER 2 MECHANICS AND PRINCIPAL FEATURES OF GYROTORY APPARATUS FOR PERFORMING CYCLIC RECIPROCATING (X) TESTS AND GYROTORY (Y) TESTS . . . . .	4
CHAPTER 3 ASSEMBLY OF APPARATUS, TEST PROCEDURES, AND USE OF APPURTENANT EQUIPMENT . . . . .	8
3.1 Apparatus Support Assembly and Gyrotory Arm Assembly . . . . .	8
3.2 Membrane and Slinky (Flat Coil Spring) . . . . .	8
3.3 Preparation of Test Specimen and Assembly of Confining Elements . . . . .	8
3.4 Assembly of Apparatus . . . . .	10
3.5 Saturation of Specimen . . . . .	11
3.6 Consolidation of Specimen Under Desired Effective Stress . . . . .	12
3.7 Application of Back Pressure . . . . .	12
3.8 Application of Shear Force in X and Y Tests . . . . .	13
3.9 Recording Pore Pressures and Deflections . . . . .	14
3.10 Slippage in Transmission . . . . .	14
3.11 Freezing of Test Specimen . . . . .	15
3.12 Disassembly of Equipment, Removal and Cutting of Frozen Specimen, and Determination of Distribution of Water Content . . . . .	16
CHAPTER 4 GENERAL INFORMATION ON TESTS PERFORMED AND TYPICAL TEST RESULTS . . . . .	19
4.1 Description of Sand Used in Tests . . . . .	19
4.2 Definitions of W, X, and Y Tests, and Number of Tests Performed . . . . .	19
4.3 Distribution of Relative Density in W Tests . . . . .	20
4.4 Statistical Parameters for Analyzing Redistribution of Relative Density in X and Y Tests . . . . .	21
4.5 Review of Three Typical Reciprocating (X) Tests . . . . .	22
4.6 Review of Three Typical Gyrotory (Y) Tests . . . . .	27

	<u>Page</u>
CHAPTER 5 THE MECHANICS OF PORE PRESSURE RESPONSE AND OF CYCLIC DISPLACEMENTS IN X AND Y TESTS . . . . .	30
5.1 General Comments on Liquefaction . . . . .	30
5.2 Analysis of Typical Cycles Without and With Liquefaction/Dilation Response in Reciprocating (X) Tests . . . . .	33
5.3 Analysis of Typical Cycles Without and With Liquefaction/Dilation Response in Gyratory (Y) Tests . . . . .	39
5.4 Comparison of Response of Saturated Sand in X and Y Tests . . . . .	42
CHAPTER 6 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS . . . . .	44
6.1 Development, Capabilities, and Limitations of the Gyratory Shear Apparatus . . . . .	44
6.2 Recommendation to Investigate Redistribution in Cyclic Triaxial Tests . . . . .	44
6.3 Discussion of Test Results . . . . .	45
REFERENCES . . . . .	50
APPENDIX A DETAILED DESCRIPTION OF GYRATORY APPARATUS AND SHOP DRAWINGS . . . . .	83
A.1 Lateral Confinement of Specimen by Slinky (Flat Coil Spring) and Rubber Membrane . . . . .	83
A.2 Slinky Guide Columns . . . . .	84
A.3 Base, Cap, and Valves . . . . .	84
A.4 Application of Vertical Load . . . . .	85
A.5 Equipment for Saturation and Application of Back Pressure . . . . .	86
A.6 Application of Horizontal Force . . . . .	86
A.7 Gyratory Sliding Plate and Gyratory Test Starting Plate . . . . .	87
A.8 Reciprocating Sliding Plate . . . . .	88
A.9 Measurement of Horizontal Displacements . . . . .	88
A.10 Measurement of Vertical Displacements . . . . .	90
A.11 Pore Pressure Measurements . . . . .	90
A.12 Auxiliary Devices for Placement and Compaction of Specimens . . . . .	91