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SHEAR STRENGTH CHARACTERISTICS OF EARTH-ROCK MIXTURES. REPORT 1--ETC(U)
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SHEAR STRENGTH CHARACTERISTICS OF EARTH-ROCK MIXTURES

REPORT 1. SURVEY AND EVALUATION OF EXISTING LABORATORY APPARATUS FOR LARGE-SCALE TESTING OF COMPACTED ROCK AND EARTH-ROCK MIXTURES

ARMY ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

FEBRUARY 1970

MISCELLANEOUS PAPER S-70-7

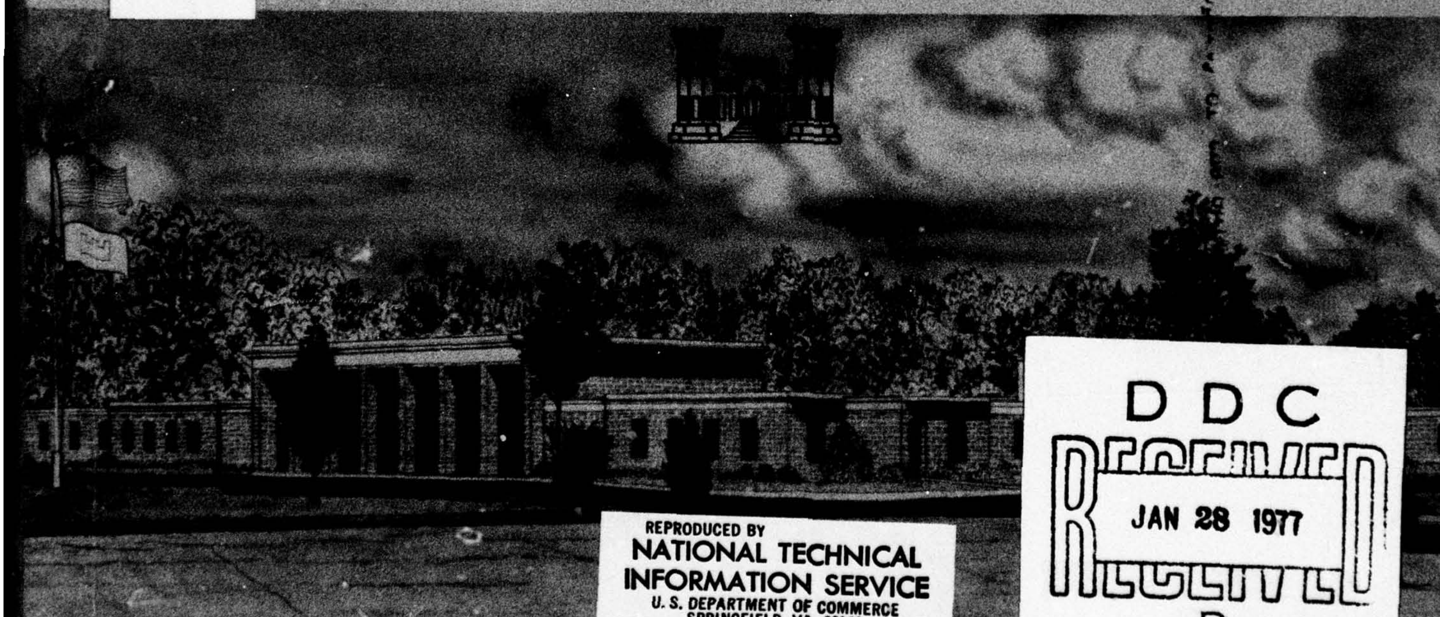
SHEAR STRENGTH CHARACTERISTICS OF EARTH-ROCK MIXTURES

Report I

SURVEY AND EVALUATION OF EXISTING LABORATORY APPARATUS FOR LARGE-SCALE TESTING OF COMPACTED ROCK AND EARTH-ROCK MIXTURES

by

A. H. Feese



February 1970

Sponsored by Office, Chief of Engineers, U. S. Army

Published by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

The restrictive statement on MP S-70-7 regarding transmittal of document outside the Department of Defense should be removed.

R. G. AHLVIN
Assistant Chief
Soils and Pavements Laboratory

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MISCELLANEOUS PAPER S-70-7

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

This report contains the results of a survey of existing apparatus capable of testing large-diameter specimens of compacted rock and earth-rock mixtures in laboratories not only of the Corps of Engineers (CE) but also of outside organizations. The study was performed under ES 543, "Shear Strength Characteristics of Earth-Rock Mixtures." The survey was specifically requested by the Office, Chief of Engineers, by letter dated 8 October 1969, subject: Laboratory Testing of Compacted Rock and Earth-Rock.

The survey was conducted by Mr. A. H. Feese of the Southwestern Division Laboratory under the general direction of Messrs. J. P. Sale, J. R. Compton, and B. N. MacIver, Soils Division, U. S. Army Engineer Waterways Experiment Station (WES).

Director of WES during the conduct of this work and preparation of this report was COL Levi A. Brown, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
tons (2000 lb)	907.185	kilograms
foot-pounds	0.138255	meter-kilograms

SHEAR STRENGTH CHARACTERISTICS OF EARTH-ROCK MIXTURES

Report 1

SURVEY AND EVALUATION OF EXISTING LABORATORY APPARATUS FOR LARGE-SCALE TESTING OF COMPACTED ROCK AND EARTH-ROCK MIXTURES

Introduction

1. In an ENGCW-ES letter dated 8 October 1969, the U. S. Army Engineer Waterways Experiment Station (WES) was requested by the Office, Chief of Engineers, to prepare a report evaluating the capabilities of laboratories within and outside the Corps for performance of research testing of large-diameter specimens of compacted rock and earth-rock mixtures. At the meeting of the Advisory Board on Soil Mechanics at Urbana, Illinois, on 7-8 August 1969, it was suggested that research on these materials might be performed more economically by contract to selected laboratories than by development of a suitable facility by the Corps.

2. This report was prepared by Mr. A. H. Feese, Southwestern Division, at the request of WES. Information compiled from the literature and through direct contacts with individuals and laboratories, both private and government, is summarized herein. The report comprises four main sections, devoted respectively to triaxial, plane strain, consolidation, and compaction test apparatus.

3. Consideration was given to broadening the scope of the report to include, for example, discussion of "model" specimen tests, in which particle sizes are reduced by some geometric scale ratio. A finding that such tests provide test data which are directly applicable to prototype materials would dispose of or at least decrease the need for very large scale testing. The studies that have been made or are now under way, however, relate largely to rockfill materials containing very small quantities of minus No. 200 fines, and research study results are applicable to clean rockfill and not to earth-rock mixtures. The factors involved in modeling are extremely complex in any case, and require study beyond that so far

given. Therefore, no effort is made in this report to examine this aspect in depth.

Triaxial Apparatus

4. A total number of 15 triaxial apparatus accepting specimens from 12 to 44 in. in diameter have been identified at various locations around the world (no consideration has been given to equipment within the Sino-Soviet bloc countries). Excluded from this total for obvious reasons are the many triaxial apparatus where the confining pressures are applied by an internal vacuum. Distinctive characteristics of individual apparatus are discussed in the following paragraphs.

California Department of Water Resources

5. A facility specifically designed for testing rockfill materials is owned by the State of California Department of Water Resources and operated by the University of California at its Richmond Field Station, about six miles from the main campus at Berkeley. Total cost of the facility is estimated at about $1 million. A concise description of the facility was presented by Mr. C. K. Chan, Director, at the Seventh International Conference on Soil Mechanics and Foundation Engineering; this presentation is contained in Appendix A.

6. The facility is housed in a masonry building approximately 100 by 80 ft in size, shown in fig. 1, designed specifically for this use. The building contains a materials reception and handling area, a test area for the large (36 in. diameter) triaxial and plane strain machines, an inclosed instrumentation and controls room, two offices sufficient for four or five men, and a laboratory for triaxial tests corollary to the large-sample tests. Details of the 12- and 36-in.-diam triaxial apparatus are given in table 1.

7. The large triaxial apparatus is shown in fig. 2. The chamber, shown being lowered into place in the photograph, weighs 15 tons; the assembled cell weighs about 30 tons. A total membrane thickness of

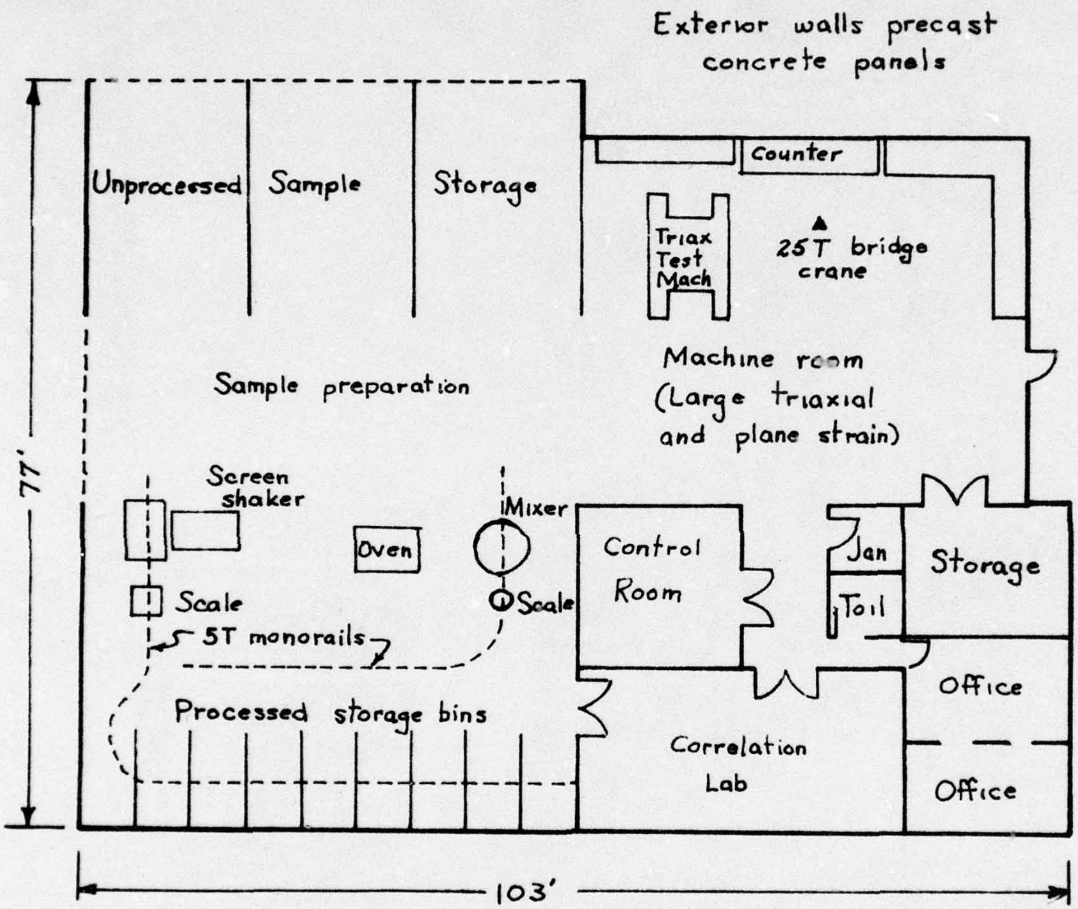

Fig. 1. Floor plan of the rockfill testing facility at the University of California

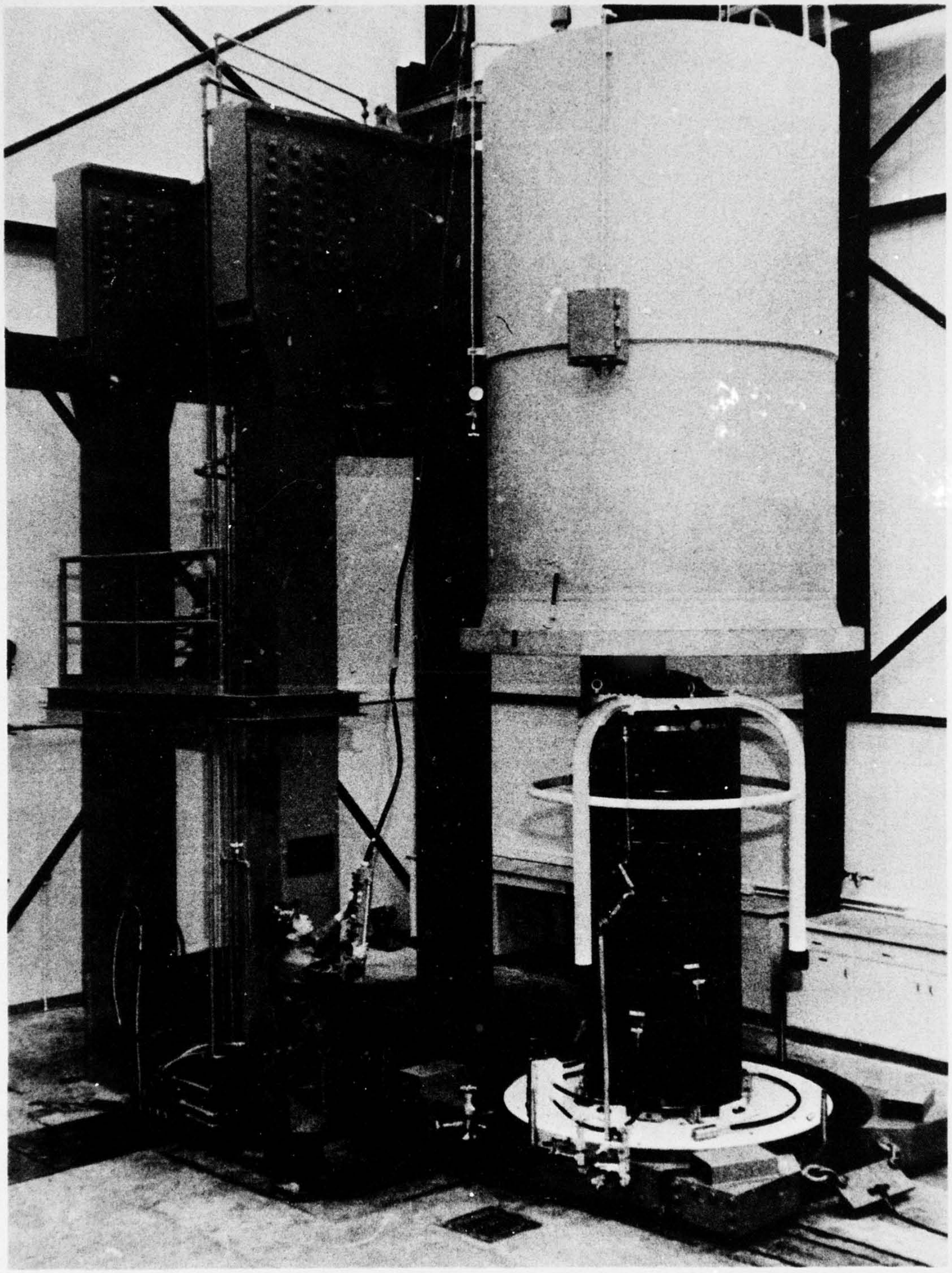

Fig. 2. Assembling the triaxial apparatus for 36-in.-diam specimens at the University of California

Table 1

Summary of Characteristics of Triaxial Apparatus at University of California, Richmond Field Station

		California Department of Water Resources	University of California - Richmond Field Station
Specimen:	Diameter, inches	36	12
	Height, inches	90	30
	Max. particle used, inches	6	2
Chamber:	Permissible confining pressure, lb/sq.in.	750	1,000
	Diameter, inches	80	18
	Special Features	-	Bayonet locks to base.
Piston:	Diameter, inches	18	12
	Special Features	-	-
Axial Load:	Capacity, lb.	4,000,000	600,000
	Method of Application	Hydraulic piston	Hydraulic piston from below.
	Method of Measuring	Load cell	Load cell
Axial Strain:	Rate, inches/minute	0.1	Variable; closed-loop hydraulic controls.
	Method of Measuring	Potentiometer	Potentiometer
Radial Strain		Girth gages at five elevations.	No provisions.
Volumetric Strain		Pore and chamber water movements.	Pore water movement.
Pore Pressure		Transducers, top and bottom, located outside chamber.	Transducers outside chamber.
Back Pressure, lb/sq. in.		300	300
Data Recording		Tape punched at manual signal; 18 channels.	Manual or with control system for large triaxial.
Specimen Preparation		Vibrating disk; 10 layers	Vibrating disk; 8 - 10 layers.
Manpower Requirements		Two men.	One man.
Additional Remarks		Stress-control testing system not satisfactory. Pressure chamber weight 15 tons. Total chamber weight 30 tons.	Closed-loop electrohydraulic system for any desired axial load application. Weight about 1,000 pounds.
		Membrane consists of sheets of 1/8" neoprene inclosed between 1/16" and 1/8" cylindrical membranes; total thickness 1-1/16 inch.	Membrane consists of layered neoprene, as large triaxial; total thickness 5/16 inch.

1-1/16 in. is used. A 1/16-in. membrane is placed in the specimen former during compaction, then 1/8-in. sheets of neoprene are hung about the specimen to a thickness of 7/8 in. A 1/8-in. sealing membrane is then applied.

8. The 12-in. apparatus has a maximum chamber pressure of 1000 psi. A 600,000-lb hydraulic cylinder is mounted in a well below floor level, with the end of the ram modified to provide the pedestal for the specimen. Reaction is provided by the chamber, at the upper end of which is a load cell. The chamber is secured to the base by bayonet locks. Axial strains are measured electrically. Recordings of digital voltmeter readings are usually accomplished manually, but the control and recorders for the 36-in. triaxial machine can also be used. It is noted that a closed-loop electro-hydraulic system can be used to program any desired load application.

South Pacific Division Laboratory

9. The South Pacific Division (SPD) apparatus,[1*] shown in fig. 3, takes a 12-in.-diam specimen with a 27-in. height. Details are given in table 2. Maximum chamber pressure is 500 lb per sq in. The chamber, weighing about 1000 lb, is lifted by a crane to a universal testing machine for axial stressing; both 200,000- and 300,000-lb capacity machines are available. Back pressures to 150 lb per sq in. may be applied. Pore pressures are measured at the ends of the specimen by transducers, or a null system can be utilized for measurement of pore pressures at the lower end. Transducers "built" into the specimen at various elevations are rendered less useful than desired by their low capacities. Basic design was accomplished in 1962, but refinements have been made periodically.

Geo-Testing, Inc.

10. Geo-Testing, Inc., San Rafael, California, has a triaxial chamber for 12-in.-diam specimens essentially identical to the SPD chamber. Mr. E. B. Hall, who designed the SPD chamber, is president of Geo-Testing, Inc.

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* Raised numerals refer to Literature Cited at end of report.

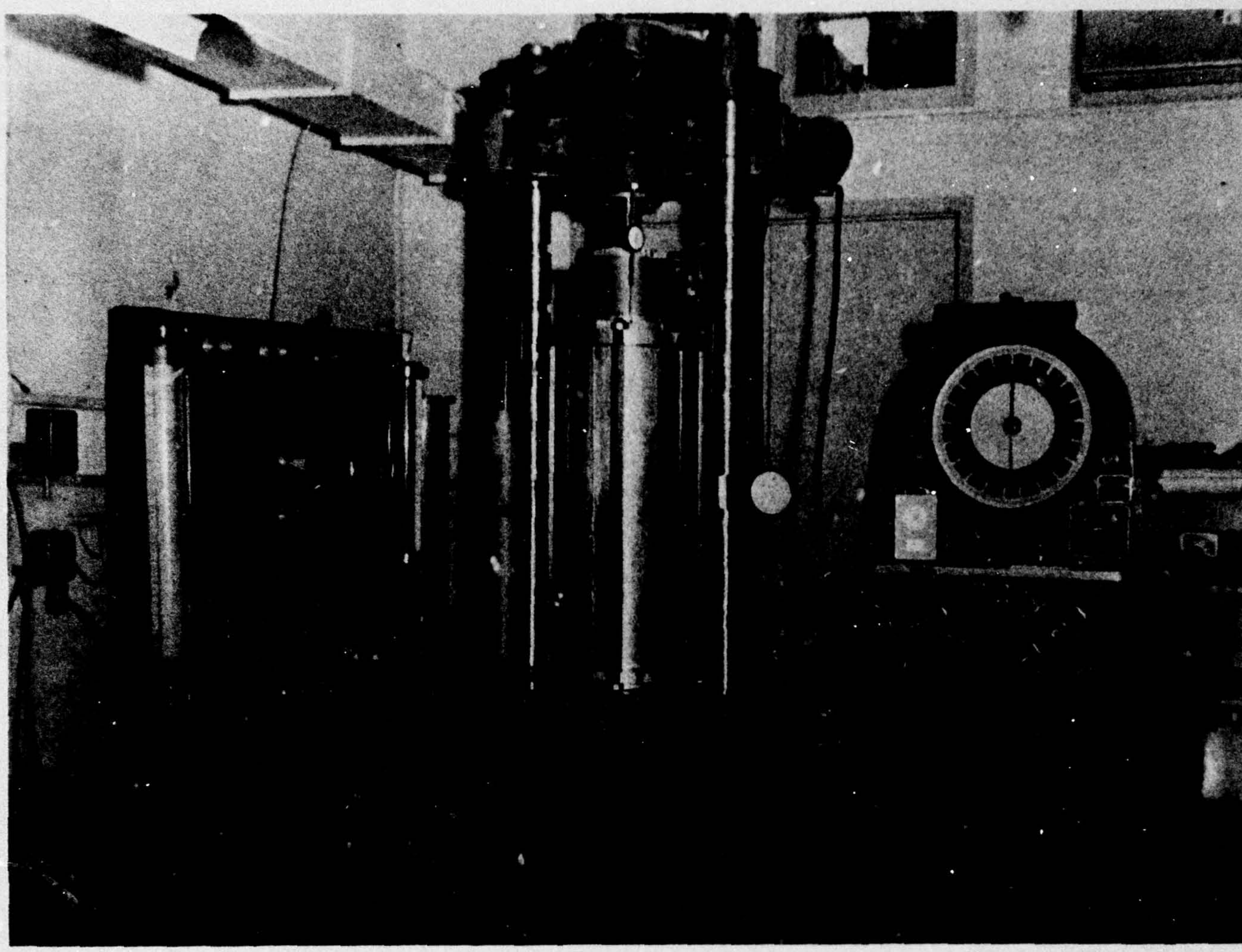

Fig. 3. Triaxial apparatus for 12-in.-diam specimens at the South Pacific Division Laboratory

Table 2

Summary of Characteristics of Triaxial Apparatus at South Pacific Division and South Atlantic Division

		South Pacific Division	South Atlantic Division
Specimen:	Diameter, inches	12	15
	Height, inches	27	32½
	Max. particle used, inches	2½ and 3	2 and 3
Chamber:	Permissible confining pressure, lb/sq.in.	500	400
	Diameter, inches	-	21
	Special Features	-	-
Piston:	Diameter	4	5
	Special Features	Chevron packing with O-rings.	Ball bushings with Quad-rings.
Axial Load:	Capacity, lb.	200,000	2[illegible]0,000
	Method of Application	Universal machine.	Self-contained hydraulic piston.
	Method of Measuring	Pressure gauge.	Pressure gauge.
Axial Strain:	Rate, inches/minute	Variable; minimum about 0.001.	Variable; minimum about 0.001.
	Method of Measuring	Dial gauge.	Dial gauge.
Radial Strain		No provision.	No provision.
Volumetric Strain		Pore and chamber water movements.	Pore and chamber water movements.
Pore Pressure		Transducers, top and bottom; null system bottom only.	Null system with mercury column.
Back Pressure, lb/sq.in.		150	Can approach 400 at very low confining pressures.
Data Recording		Manual	Manual
Specimen Preparation		Vibrating table (4 layers) or dynamic compaction.	Vibrating table or dynamic compaction
Manpower Requirements		Two or three men.	Two men.
Additional Remarks		Two rubber membranes with polyethlene strips between. Weight 1,200 pounds.	Two rubber membranes with Tygon strips between. Weight 2,400 pounds.

North Pacific Division Laboratory

11. The North Pacific Division Laboratory has a device patterned after an early version of the SPD chamber,[2] capable of chamber pressures to only 100 lb per sq in. The device has been used infrequently, and is without many of the refinements built into the present SPD device.

South Atlantic Division Laboratory

12. The South Atlantic Division apparatus, designed and built by Soiltest, Inc., accepts a 15-in.-diam by 32-1/2-in.-high specimen. Figure 4 shows a cross section through the device, and details are given in table 2. With exception of the self-contained hydraulic ram, the apparatus is of generally unimaginative design, approximating a blown-up version of the traditional smaller chamber. Magnitude of axial stress is computed from supply pressure gage readings, and the rate of stress application is regulated manually through the hydraulic system controls. Pore pressure is measured by means of a device patterned after the Geonor device. Weight of the filled chamber is about 2400 lb. The combination of maximum allowable chamber pressure and deviator stress limits measurable strengths to $\phi = 35$ deg at $c = 0$. The cost of the apparatus as now quoted by Soiltest, Inc., is about $14,000 without pore pressure measuring devices.

Swiss Federal
Institute of Technology

13. For the design of Goeschenenalp Dam in Switzerland, the Laboratory for Hydraulic Research and Soil Mechanics of the Swiss Federal Institute of Technology in Zuerich built a triaxial apparatus to accept specimens 20 in. in diameter by 36 in. in height.[3] Details are given in table 3. The maximum chamber pressure is stated to be 70 psi, though the only test results reported were obtained by using an internal vacuum to provide the confining pressure. A relatively small-diameter piston enters the head of the chamber from above, with a hydraulic jack and hand pump supplying the necessary force. Deviator stress is measured by three hydraulic load cells below the specimen. During the reported vacuum triaxial tests, volume changes were measured by the weight of water entering or leaving the chamber.

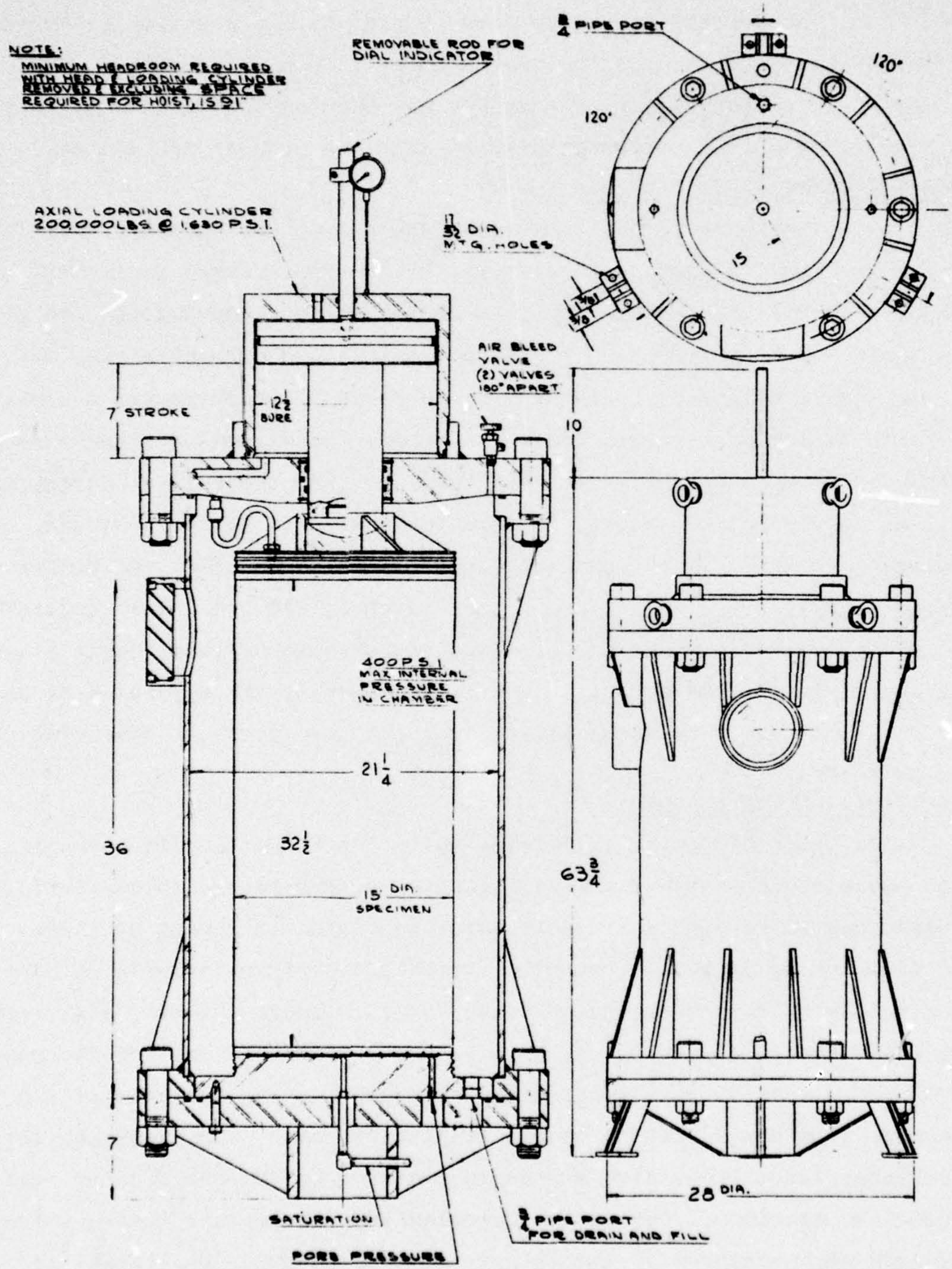

Fig. 4. Triaxial apparatus for 12-in.-diam specimens manufactured by Soiltest, Inc., for the South Atlantic Division Laboratory

Table 3

Summary of Characteristics of Triaxial Apparatus at Swiss Federal Institute of Technology and Snowy Mountain Authority

		Swiss Federal Institute of Technology Switzerland	Snowy Mountain Authority Australia
Specimen:	Diameter, inches	19-7/8	22-1/2
	Height, inches	35-7/16	45
	Maximum particle used, inches	4	4-1/2
Chamber:	Permissible confining pressure, lb/sq.in.	71	200
	Diameter, inches	-	-
	Special Features	-	-
Piston:	Diameter, inches	-	-
	Special Features	-	Rotating piston bushing
Axial Load:	Capacity, lb.	-	-
	Method of Application	Hydraulic jack with hand pump.	-
	Method of Measuring	Three hydraulic load gauges below specimen.	-
Axial Strain:	Rate, inches/minute	-	-
	Method of Measuring	Dial gauge.	-
Radial Strain		No provisions.	-
Volumetric Strain		Chamber water movement.	Unidentified provisions.
Pore Pressure		No provisions.	Unidentified provisions.
Back Pressure, lb/sq.in.		No provisions.	-
Data Recording		Manual	-
Specimen Preparation		-	-
Manpower Requirements		-	Three Men.
Additional Remarks		In single published reference, confining pressure applied by internal vacuum only.	Membranes are rubber, protected by a liner of polyethlene sheeting and hairfelt.

Snowy Mountain Hydro-
electric Authority, Australia

14. An apparatus accepting specimens 22-1/2 in. in diameter and 45 in. in height is in use by the Snowy Mountain Hydroelectric Authority in Australia.[6] The few details available are given in table 3. The maximum chamber pressure which can be applied is 200 lb per sq in., and a rotating piston bushing is utilized for decreasing piston friction. There are provisions for measuring volumetric strain and pore pressure. An interesting procedural detail is the use of hairfelt and polyethlene strips to protect the rubber membrane from puncture.

Water and Power
Authority, West Pakistan

15. Three triaxial apparatus accepting specimens 24 in. in diameter by 60 in. in height are owned by the Water and Power Authority of West Pakistan. Details are given in table 4. Designed for use in the design of Tarbella Dam, the apparatus were built by Clockhouse Engineering and Instrument Company of England for Tippetts, Abbett, McCarthy, and Stratton (TAMS), with Drs. Roscoe and Rowe as consultants. Details of the chamber are shown in fig. 5 (3 sheets). The specimen is seated atop a self-contained hydraulic ram; axial stress is measured through a load cell located above the specimen. The machines and specimens are beautifully instrumented, and the overall design is perhaps the most sophisticated now in existence. The cost is estimated by TAMS at about $300,000 for the three units together with all accessory equipment, but manufacturers in the United States would undoubtedly increase this sum appreciably, possibly by a factor of two.

Comision Federal de
Electricidad, Mexico

16. A very large apparatus constructed for the Comision Federal de Electricidad in Mexico was used in the investigation of materials for El Infiernillo Dam. A cross-section is shown in fig. 6, and details are given in table 4. The triaxial chamber is spherical, about 14-1/2 ft in diameter by 98 in. in height. The specimen is constructed inside the

Table 4

Summary of Characteristics of Triaxial Apparatus at Water and Power Authority and Comision Federal de Electricidad

		Water and Power Authority West Pakistan*	Comision Federal de Electricidad Mexico
Specimen:	Diameter, inches	24	44.5
	Height, inches	60	98.5
	Maximum particle used, inches	-	7
Chamber:	Permissible confining pressure, lb/sq.in.	500	350
	Diameter, inches	42	Spherical, 14 ft. diameter.
	Special Features	Measured with transducers and gauges.	-
Piston:	Diameter, inches	24	-
	Special Features	-	-
Axial Load:	Capacity, lb.	1,100,000	3,000,000
	Method of Application	Hydraulic ram from below.	Nine hydraulic cylinders between loading ring and base plate.
	Method of Measuring	Load cell.	Amsler pendulum dynamometer.
Axial Strain:	Rate, inches/minute	0.01 - 0.1	-
	Method of Measuring	Linear potentiometers (2).	Electrical entensometers.
Radial Strain		Transducers actuated by helical springs.	Electrical extensometers.
Volumetric Strain		Pore and chamber water movements.	Pore water movement.
Pore Pressure		Piezometer tips at quarter points; transducers and pressure gauges.	No provisions.
Back Pressure, lb/sq.in.		100	-
Data Recording		Direct-reading gauges and three 6-channel recorders.	-
Specimen Preparation		Two-piece vibrohammer, two layers.	Disk vibrator, 10-inch lifts.
Manpower Requirements		-	-
Additional Remarks		-	Empty weight 20 tons. Membrane consists of two rubber sleeves (6 mm and 3 mm thickness) with two inches of sand between; corrugated cardboard adjacent to specimen.

* Three identical units

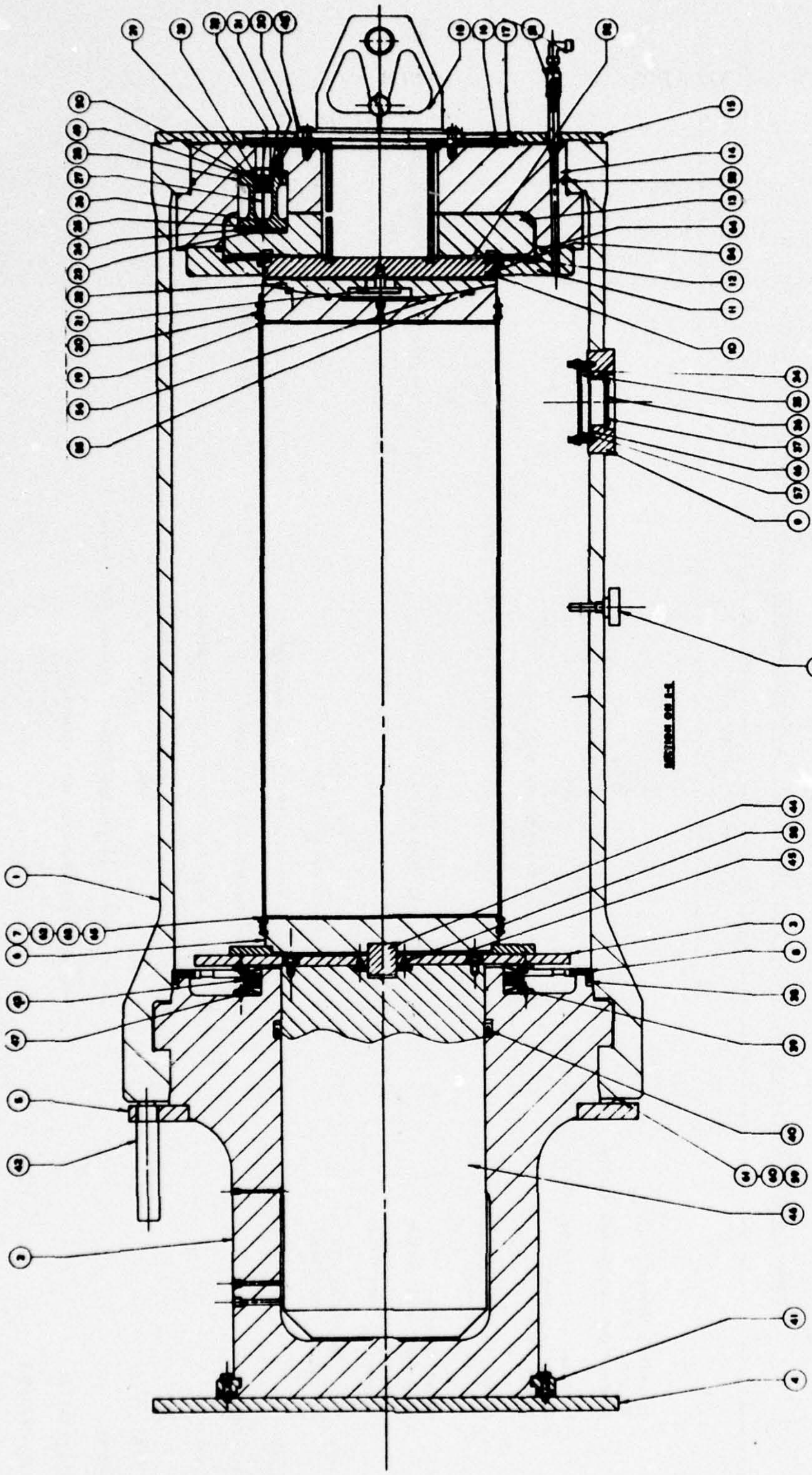

Fig. 5. Triaxial apparatus for 24-in.-diam specimens manufactured by Clockhouse for the Water and Power Authority of West Pakistan

Fig. 5
Sheet 1 of 3

Legend

TRIAXIAL APPARATUS FOR 24-INCH DIAMETER SPECIMENS

CLOCKHOUSE ENGINEERING LTD

Cell Assembly Parts List

No.	Description	Quantity
1	Bell	1
2	Cell base	1
3	Ram top plate	1
4	Sole plate	1
5	Bell turntable	1
6	Bottom platen	1
7	False platen (bottom)	1
8	Seal retaining ring	1
9	Porthole	5
10	Anti-side load body	1
11	Load cell bottom retaining plate	1
12	Bottom anti-side load diaphragm	1
13	Load cell body (bottom)	1
14	Load cell body (top)	1
15	Bell top plate	1
16	Top anti-side load diaphragm	1
17	Cover plate	1
18	Bell lifting beam	1
19	False platen (top)	1
20	Top platen	1
21	Spherical seating retaining screw	1
22	Top platen spherical seating	1
23	Pad	3
24	Anti-extrusion disc	3
25	Collet cap	3
26	Collet	3
27	Transducer rod	3
28	Elastic member load cell	1
29	Transducer housing	3
30	Anti-extrusion tube	3
31	Disc spring	3
32	Circlip	3
33	Transducer	3
34	Bezel	5
35	Porthole glass	5
36	Porthole Perspex	5
37	Bezel	5
38	Seal	1
39	Clamp	36
40	Seal	1

Fig. 5
Sheet 2 of 3

No.	Description	Quantity
41	Clamping ring for cell	1
42	Bell lifting cylinder	3
43	Bellows	1
44	Spigot	1
45	Platen plate	1
46	Ram	1
47	Clamp ring	2
48	Anti-extrusion tube	3
49	Anti-extrusion disc	3
50	Pad	3
51	Cock, 1/2 in.	4
52	Anti-friction disc	1
53	Bell top seal	1
54	Anti-side load body seal	1
55	Spherical seating seal	1
56	Spherical seating seal	1
57	Porthole clamping washer	5
58	Spigot seal (o-ring)	1
59	Spindle	6
60	Roller	6
61	Bearing	6
62	Pore water disc	24
63	Pore water disc	24
64	Bottom retaining plate seal	1
65	Pore water disc	24
66	Porthole sealing washer	5
67	Temperature gauge	1

Fig. 5
Sheet 3 of 3

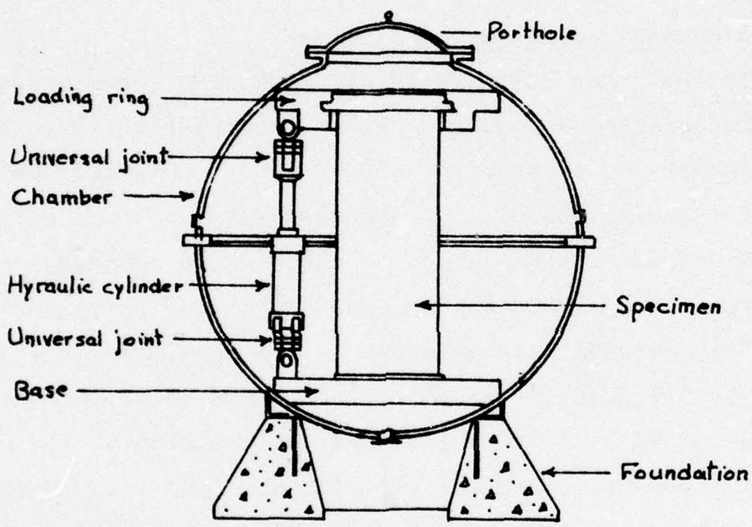

Fig. 6. Triaxial apparatus for 44-in.-diam specimens at the Comision Federal de Electricidad of Mexico

chamber, with egress for materials and technicians by a porthole in the top. Maximum permissible chamber pressure is about 350 lb per sq in. Axial loading up to 1500 tons is accomplished through nine hydraulic cylinders joining a loading ring (at the top of the specimen) to the base plate. The cylinders operate in groups of three, with each group subject to individual control. Axial and circumferential strains are measured electrically. There are no provisions for pore pressure measurement. Membranes are of unique 4-layer construction: soft corrugated cardboard adjacent to the specimen to protect the inner membrane, then two rubber membranes, respectively 3 and 6 mm thick, separated by 2 in. of hand-tamped sand.

Technischen Hochschule, Karlsruhe, Germany

17. In 1957, the Institut fuer Bodenmechanik und Grundbau of the Karlsruhe Technischen Hochschule put into operation a triaxial apparatus for specimens 39 in. in diameter and 79 in. in height.[4] Details are given in table 5. Fabrication of the apparatus was by Johann Keller of Renchen, Germany. A schematic diagram of the chamber and pressure controls is shown in fig. 7. Maximum chamber pressure is 140 psi, and there is no provision for applying back pressure to the specimen. Deviator stress is applied by a hydraulic ram built into the head of the chamber; this stress is measured by a hydraulic load cell mounted at the bottom of the ram where it comes into contact with the specimen cap. Pore pressures are measured by several Maihak piezometers placed at different elevations along the axis of the specimen.

Elektro-Watt, AG, Switzerland

18. To provide data for the design and construction of Mattmark Dam in Switzerland, the firm of Elektro-Watt, AG, of Zuerich designed an apparatus to accept specimens 24 in. in diameter by 48 in. in height.[5] Details are given in table 5. This apparatus, which was fabricated by Jenny-Pressen, AG, of Frauenfeld, Switzerland, is essentially an updated version of the Karlsruhe apparatus, as can be seen in fig. 8. However, the chamber pressure is limited to 70 psi.

Table 5

<u>Summary of Characteristics of Triaxial Apparatus at Technische Hochschule, Karlsruhe, and Elektro-Watt, AG, Zuerich</u>

		Technische Hochschule, Karlsruhe Germany	Elektro-Watt, AG, Zuerich Switzerland
Specimen:	Diameter, inches	39.4	24.2
	Height, inches	78.8	47.2
	Maximum particle used, inches	8	3
Chamber:	Permissible confining pressure, lb/sq in.	142	71
	Diameter, inches	63	40
	Special Features	Mortise and tenon connections to base.	-
Piston:	Diameter, inches	-	-
	Special Features	-	-
Axial Load:	Capacity, lb	550,000	225,000
	Method of Application	Hydraulic ram in chamber head.	Hydraulic ram in chamber head.
	Method of Measuring	Hydraulic load cell mounted between ram and specimen cap.	Electronic load cell mounted between ram and specimen cap.
Axial Strain:	Rate, inches/minute	Controlled-stress testing only.	Controlled-stress testing only.
	Method of Measuring	Graduated scale viewed through porthole.	Graduated tape connected to top of ram.
Radial Strain		Graduated girth gages viewed through portholes.	No provisions.
Volumetric Strain		Pore and chamber water movements.	Pore and chamber water movements.
Pore Pressure		Several Maihak piezometers embedded in specimen.	Several Maihak piezometers embedded in specimen.
Back Pressure, lb/sq in.		Not reported.	Not reported.
Data Recording		Manual.	Manual.
Specimen Preparation		Variable, depending on materials.	Vibrated in 2- to 4-in. layers.
Manpower Requirements		Three men.	-
Additional Remarks		Membrane consists of 4-mm filled rubber base layer plus as many 1-mm neoprene layers as required.	Membrane consists of onw 2-mm and one 3-mm rubber layers.

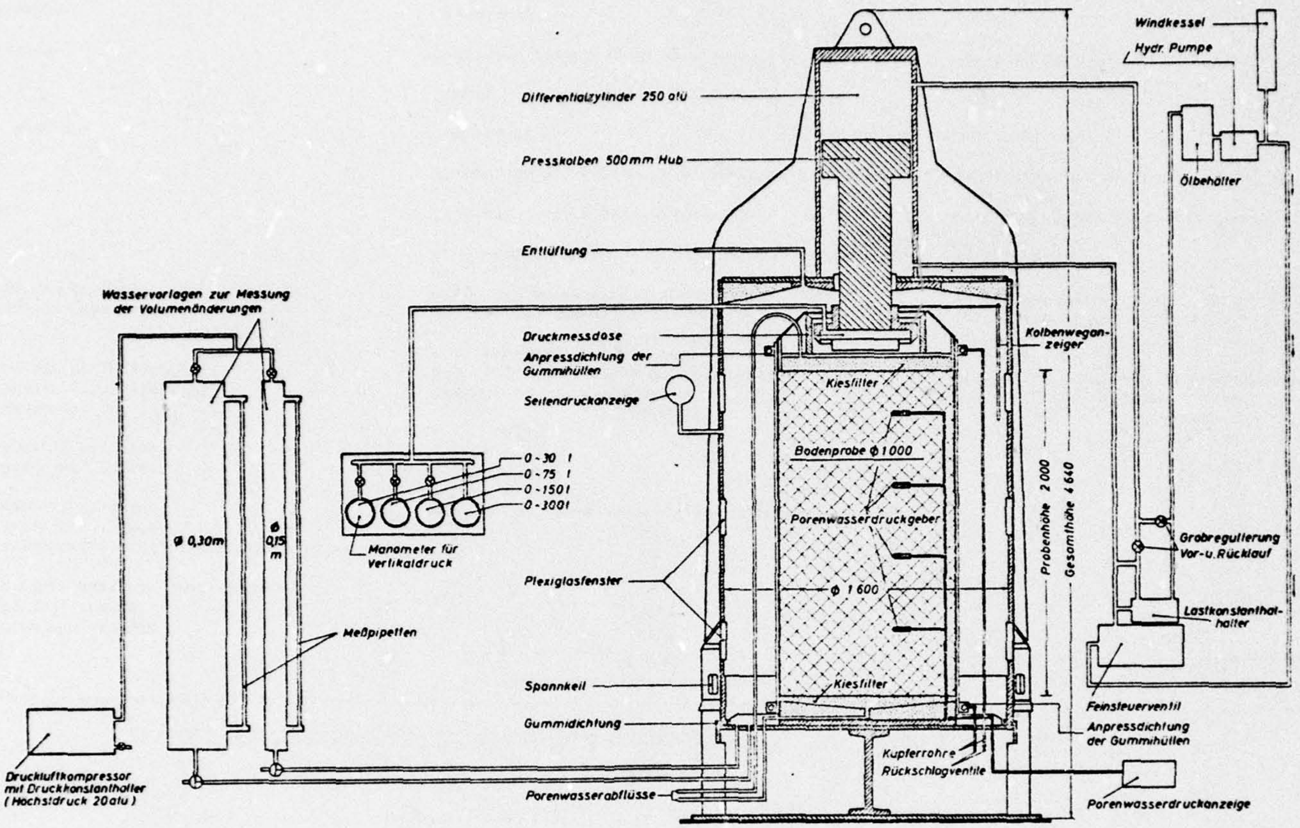

Fig. 7. Triaxial apparatus for 39-in.-diam specimens at the Technischen Hochschule, Karlsruhe, Germany

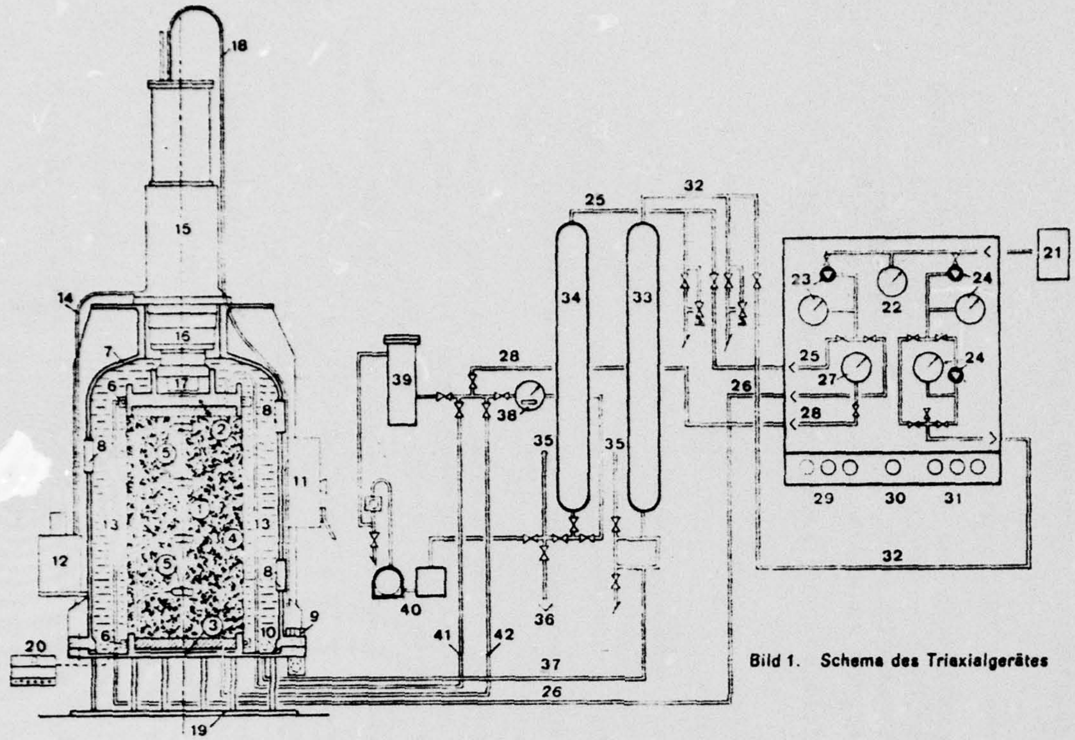

Bild 1. Schema des Triaxialgerätes

1 Bodenprobe
2 Obere Druckplatte mit eingebauter Filterplatte
3 Untere Druckplatte mit eingebauter Filterplatte
4 Gummimantel
5 Maihak-Porenwasserdruckgeber
6 Dichtungsschlauch mit Schutzring
7 Druckglocke
8 Schaugläser
9 Befestigungsschrauben
10 Dichtungsring
11 Steuertableau der Oeldruckpresse
12 Oelreservoir mit Pumpe
13 Glockenwasser
14 Oelleitung zur Presse
15 Oelpresse
16 Presskolben mit 400 mm totalem Vorschub (Δh)
17 Druckdose «System Huggenberger» für Messung der Vertikallast P
18 Kolbenweganzeigevorrichtung für Messung von Δh
19 Grundplatte
20 Maihak-Ablesegerät
21 Kompressor und Windkessel
22 Windkesseldruckmanometer
23 Einstufiges Druckreduzierventil mit Manometer für Dichtungsschläuche und Sättigung
24 Zweistufiges Druckreduzierventil mit Manometer für Druckglocke
25 Druckluftleitung zur Vorlage II
26 Druckluftleitung zu den Dichtungsschläuchen
27 Vakuum-Manometer
28 Leitung für Vakuumanzeige
29 Bedienungsknöpfe der Vakuumpumpe
30 Kontrollicht des Kompressors
31 Bedienungsknöpfe der Oelpresse
32 Druckluftleitung zur Vorlage I
33 Wasservorlage I für Druckglocke: Messung der Volumenänderung ΔV
34 Wasservorlage II für Pumpe: Messung der Sättigungswassermenge und des Konsolidationsausflusses sowie des Ausflusses beim drainierten Druckversuch
35 Wasserzufuhr
36 Kühlwasser für Presse
37 Wasserleitung zur Druckglocke
38 Wasser-Volumenzähler
39 Wasserabscheider
40 Vakuumpumpe
41 Leitung zur oberen Druckplatte
42 Leitung zur unteren Druckplatte

Fig. 8. Triaxial apparatus for 24-in.-diam specimens owned by Elektro-Watt, AG, Switzerland

Imperial College, England

19. A triaxial apparatus for specimens 12 in. in diameter has been developed at Imperial College, London. However, no details have yet been obtained on this device.

Discussion

20. Optimum requirements for research work in the triaxial testing of earth-rock mixtures are listed below:

- a. Specimen diameters to at least 24 in., and including 12-, 6-, and 2.8-in. specimens; specimen heights 2.5 times the diameters.
- b. Confining pressures to 750 lb per sq in.
- c. Axial loading capabilities for 45 deg friction angle. Loads should be measured by load cells located within the test chamber. The cell should permit measuring eccentricity of loading of the largest specimens.
- d. Piston stroke sufficient for axial strain of at least 30 percent.
- e. Provisions for measuring radial and volumetric strains in the larger specimens.
- f. Provisions for pore pressure measurement by pressure transducers. Measurements should be made at both top and bottom of a specimen, and, desirably, at intermediate elevations.
- g. Provisions for back pressure application to at least 150 lb per sq in.
- h. Automatic recording of all test data, with as many as possible of the data also given by direct-reading dials and gauges for checking during a test.

21. All the listed apparatus located in the United States are or can be made available for Corps use. It is understood that the Corps of Engineers has corresponded with English and Mexican authorities in regard to availability of the apparatus located in those countries. Comparison of the features of existing devices with the optimum requirements listed above, however, shows that few of the apparatus can meet many of the criteria listed above, lacking the special characteristics desirable in research instruments. The only facility in the United States providing the features needed is that operated by the University of California.

22. Preliminary informal discussions have disclosed that the University of California Rockfill Testing Facility is presently available for use by the Corps of Engineers. Arrangements for triaxial testing can be made by direct contact with Dr. H. B. Seed, Chairman of the Civil Engineering Department, University of California, Berkeley. The university will operate the facility until June 1971, when its contract with the Department of Water Resources expires. Disposition of the facility after that date is uncertain. There is a strong possibility that it could be made available to the Corps, under either Corps or University operation. Dr. Seed has expressed a preference that staffing be accomplished by the Corps rather than by the University, should the Corps arrange for the use or acquisition of the facility.

Plane Strain

23. Only two large plane strain apparatus are known to be in existence. One is owned by the California Department of Water Resources and the other is owned by the Comision Federal de Electricidad in Mexico. As used herein, the term "plane strain" refers to a testing condition where deformation is not permitted in the direction of one principal stress while measurement of the other two principal stresses is possible.

California Department of Water Resources

24. A large plane strain apparatus is included in the rockfill testing facility at Richmond, California, as described in Appendix A. However, the apparatus has not yet been made operational. The specimen is to be 24 in. wide, 60 in. high, and 54 in. long. The large triaxial chamber will be used as the pressure cell, and the 4,000,000-lb testing machine used for application of major principal stress. The specimen is inclosed in a rubber membrane, with confining pressures ranging up to 700 lb per sq in. Pore pressures are to be measured through six 6-in.-diam porous stones in both the cap and the base. The end plates are fabricated concrete-filled

metal "boxes" joined by four long metal rods instrumented for determining intermediate principal stress values. The end plates and rods are designed for a net longitudinal pressure of 600 lb per sq in. and 0.35 percent strain; methods for decreasing friction on the end plates are being investigated at this time. Since the Rockfill Testing Facility is now being operated on a minimum budget, work is expected to progress rather slowly.

Comision Federal de Electricidad, Mexico

25. The large plane strain apparatus located in Mexico City does not use a pressure chamber filled with fluid or a membrane around the specimen. Rather, a specimen 27.5 in. wide, 71 in. high, and 29.5 in. long is inclosed on all sides by rigid metal surfaces,[7] as shown in fig. 9. All six surfaces acting on the specimen are covered with three layers of 4-in.-sq polyethylene sheets coated with grease to minimize friction. The two opposite walls applying the minor principal stress are each forced against the specimen by six 50-ton hydraulic jacks; these walls are free to move outward and to tilt, but are prevented from downward movement. The major principal stress is applied by a 600-ton hydraulic cylinder mounted at the top of the specimen. This vertical stress is measured both by the pressure in the hydraulic cylinder and by four hydraulic load cells placed below the specimen. Pressure capacity of the apparatus is equivalent to a chamber pressure of 310 psi. Axial strains up to 15 percent are possible. The apparatus is suitable only for testing dry specimens of granular material.

Discussion

26. No comparison between the units is possible at this time. However, the apparatus at Mexico City would not be suitable for testing earth-rock mixtures requiring back-pressure saturation and pore pressure measurements.

Consolidation

27. Large-scale consolidation tests have been conducted in the United States by the U. S. Bureau of Reclamation (USBR) in Denver, Colorado, and

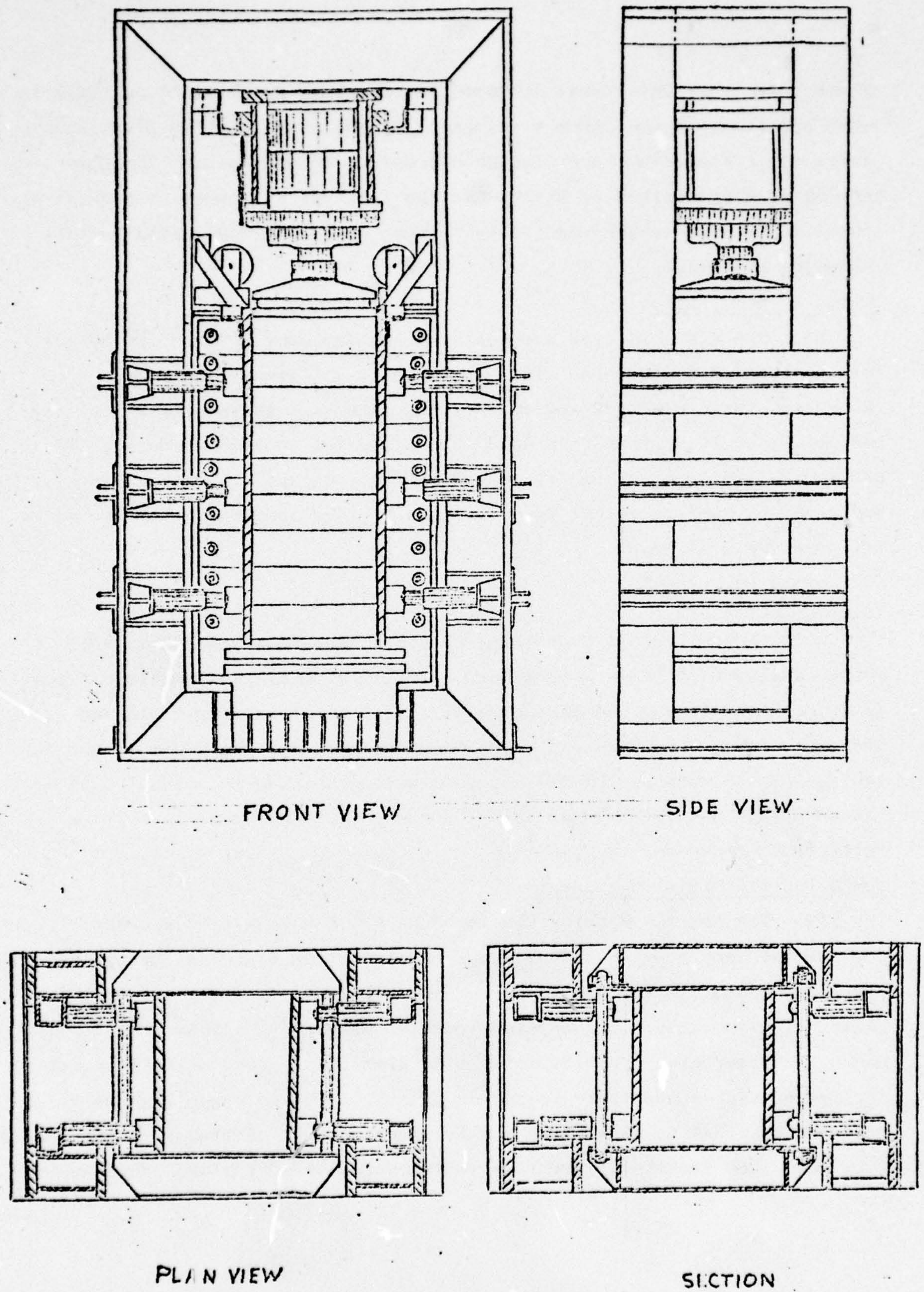

Fig. 9. Plane strain apparatus at the Comision Federal de Electricidad

by the California Department of Water Resources in Sacramento, California. A new apparatus is now under development by the South Pacific Division Laboratory. Apparatus have also been constructed and used by the Comision Federal de Electricidad of Mexico and the Istituto Sperimentale Modelli e Strutture (ISMES) in Bergamo, Italy. These devices are described in the following paragraphs.

Bureau of Reclamation

28. The USBR has used a mold 19 in. in diameter by 9 in. in height for particle sizes to 3 in. The apparatus is the fixed-ring type. Load is applied through a jack and compression springs. In investigation for one dam, 9 or 10 springs were used with a 100-ton jack to produce a 200 lb per sq in. (14 tons per sq ft) consolidation pressure. The apparatus is described by USBR personnel as very crude, but of some value in estimation of potential settlement.

California Department of Water Resources

29. The California Department of Water Resources uses 27-in.-diam molds ranging to 5 ft in height for materials with maximum particle sizes to 6 in. Load is applied through a specially built loading frame and hydraulic ram. The frame and molds were designed for pressures to 600 lb per sq in. (43 tons per sq ft). Consolidation testing is conducted at the laboratory in Sacramento, and is not performed at the Rockfill Resting Facility in Richmond.

South Pacific Division Laboratory

30. The apparatus being developed by SPD consists of a hydraulic compression machine with the necessary controls and capacity for applying loads from about 15 to 1000 lb per sq in. (1 to 70 tons per sq ft) to a 12-in.-diam specimen. The applied load is measured by a load cell located under the fixed-ring consolidometer; the pressures recorded are thus total applied pressures and there is no measure of effective consolidation stress. A projected floating ring, with the load cell placed similarly, will improve this situation somewhat. Problems so far encountered include excessive

elongation of testing machine columns under load, and difficulty in applying and controlling low pressures. At present, 10-in.-high specimens are being tested. The wall thickness of the consolidometer is 1 in.

Comision Federal de
Electricidad, Mexico

31. One consolidometer was designed for use with the large triaxial machine.[8] The test is of the floating-ring type, for a specimen 45 in. in diameter by 26 in. in height. Pressures to 100 tons per sq ft may be applied. The wall thickness of the ring is 1 in. Another apparatus makes use of a 19-1/2-in.-diam by 20-1/2-in.-high steel cylinder loaded by means of a 100-ton hydraulic jack. Vertical deformation is measured with three dial gages, and horizontal pressures are determined from responses of electrical strain gages mounted about the cylinder surface.

Instituto Sperimentale
Modelli e Strutture, Italy

32. The ISMES apparatus includes consolidation chambers of two sizes: (a) approximately 19-1/2 in. in diameter by 39-1/2 in. in height and (b) 51 in. in diameter by 78-1/2 in. in height.[9] Published data indicate that tests have been conducted with pressures in excess of 60 tons per sq ft, using hydraulic testing machines for stress application. The large height with respect to diameter was considered necessary to reduce the rigidity disturbances induced by the end plates, but at the cost of greatly increased side friction effects. To overcome both difficulties, chambers were designed which consisted of alternating rings of steel and of a highly deformable material, such as rubber or cork, glued together. A by-product of testing was the ability to measure the relationship between vertical and horizontal pressures.

Waterways Experiment Station

33. The Soil Dynamics Branch of the Soils Division of WES has constructed a chamber for one-dimensional compression of specimens 48 in. in diameter which might be adaptable for consolidation testing. To minimize wall friction, the chamber wall is comprised of steel rings 1 in. wide and 1 in. high, alternating with neoprene rings 1 in. wide and

0.2 in. high; the neoprene rings have beads on each face which engage grooves in the steel rings. Any number of rings can be used to accept specimens less than 12 in. in height to over 100 in. in height. The concrete structure housing the chamber can provide a reaction of 750,000 lb, giving a maximum stress of 300 psi on the specimen. A solid ring 24 in. in height is also available. Were the apparatus to be used for consolidation testing, an alternative method of loading would probably have to be developed instead of the dynamic loader being planned.

Compaction

34. Five Corps of Engineers' installations have apparatus for performing compaction tests on large-diameter specimens:

a. Albuquerque District, Cochiti Dam, New Mexico.

b. Baltimore District, Baltimore, Maryland.

c. South Atlantic Division Laboratory, Marietta, Georgia.

d. South Pacific Division Laboratory, Sausalito, California.

e. Waterways Experiment Station, Vicksburg, Mississippi.

Other organizations known to have large compaction apparatus are the Bureau of Reclamation, Denver, Colorado, and the California Department of Water Resources, Sacramento, California.

35. Characteristics of specific devices are given in table 6 and discussed in the following paragraphs. Compaction molds are most commonly 12 in. in diameter by in. in height. Specimens are usually compacted in 4-in. layers, using material passing the 3-in. screen. Height of hammer fall ranges from 12 to 24 in. The weight of the rammer and the number of blows per layer vary widely, from the CE standard hammer weighing 5.5 lb to the USBR hammer weighing 185.7 lb, with the blows correspondingly decreasing from 230 to 25 for 12-in. specimens. Impact pressure, i.e., energy per blow per unit area of rammer face, varies from 0.9 to nearly 7 ft-lb per sq in. Distinctive features of individual apparatus and procedures are described in the following paragraphs.

Table 6

Summary of Characteristics of Compaction Apparatus

Source	Spec. Diam., Inch	Spec. Ht., Inch	Spec. Volume Cu. ft.	Hammer Diam., Inch	Hammer Wt., Lb	Drop Ht., Inch	Impact Press/Blow, Ft-lb/sq.in.	No. of Layers	Layer Thickness Inch	No. of Blows per Layer	Compactive Effort, Ft-lb/cu ft	Maximum Particle, Inch	Compactor Description
Albuquerque	12	12	0.785	2	5.5	12	1.75	3	4	585	12,400	3	Mechanical; self-compen-
				4	11.5	24	1.83	3	4	140	12,400	3	sating for drop height;
				6	24.7	24	1.74	3	4	65	12,400	3	29 blows per minute. Mold
				9	55.6	24	1.75	3	4	29	12,400	3	rotated manually; blows can
	18	18	2.65	4	11.5	24	1.83	(3)	6	475	12,400	-	be applied in center area.
				6	24.7	24	1.74	(3)	6	220	12,400	-	
				9	55.6	24	1.75	(3)	6	98	12,400	-	
Baltimore	12	12	0.785	4	23.8	18	2.84	3	4	90	12,500	3	Manual; two-man operation.
				6	23.8	18	1.26	3	4	90	12,500	3	
South Atlantic	12	12	0.785	4	11.5	24	1.83	3	4	140	12,300	2 or 3	Manual; one-man operation(?)
					23.0	12	1.83	3	4	140	12,300	2 or 3	
South Pacific	12	8	0.5	8	30.0	18	0.90	2	4	72	12,400	2½ or 3	Manual; two-man operation.
Waterways Exp Sta	12	-	-	2	5.5	12	1.75	-	4.5	230	12,400	3	Manual; one-man operation.
Bureau of Reclamation	19.5	9	1.5	9.5	185.7	18	3.93	3	3	25	13,600	3	Mechanical; mold rotated manually.
Dept Water Resources, California	12	10	0.66	6	127.5	18	6.77	3	3.5	23	20,000	3	Hydraulically-operated mechanical.

Albuquerque District

36. This apparatus has been obtained very recently, and has not been put into use. The apparatus was manufactured by Howard and Company, 294 Lawrence Avenue, South San Francisco, California, to the specification reproduced in Appendix B. No drawings were furnished prospective bidders. The design and operation of the apparatus closely follow those of the standard Howard compactor. Molds of 6-, 12-, and 18-in. diameters can be used. Interchangeable hammers weighing 5.5 lb (2-in. diameter), 11.5 lb (4-in. diameter), 24.7 lb (6-in. diameter), and 55.6 lb (9-in. diameter) were furnished. Lifting of the hammer and adjustment of drop are accomplished mechanically, with drop height variable from about 4 or 5 in. to 24 in. The compactor delivers 29 blows per minute. The mold bases are mounted on friction plates to permit manual revolution during compaction, and provisions are also made for back-and-forth movement to permit center blows when required. The Albuquerque District has some reservations on these features because of the weight of the larger specimens.

Baltimore District

37. The Baltimore District apparatus was designed by District personnel in 1967, and modified slightly in 1969. The mold is 12 in. in diameter and 12 in. in height. The hammer is the sliding-weight type, weighing 23.8 lb. Interchangeable feet of 4- and 6-in. diameter are used. The weight is lifted manually, with two men being required. The hammer is patterned after the Marshall hammer used in compacting asphaltic concrete specimens, i.e., with a spring in the head. The 1969 modifications were largely the result of technicians' recommendations; the drop height was decreased from 24 to 18 in., and hammer weight and number of blows per layer were increased, respectively, from 20 to 23.8 lb and from 82 to 90 blows.

South Atlantic Division Laboratory

38. The South Atlantic Division apparatus was designed by Division personnel. A 12-in.-diam by 12-in.-high mold is used. In sizing the apparatus, the Division held the foot diameter-mold diameter ratio and the intensity of the contact foot pressure at about the same levels as in

the CE standard tests. Hammers were fabricated weighing 11.5 and 23 lb, for which drop heights were 24 and 12 in., respectively. These weights and heights were considered the maximums for efficient 1-man operation, and required that 140 blows per layer be applied to obtain standard compactive effort. The mold and hammer are identical to those described in the CE standards, but on the larger scale.

South Pacific Division Laboratory

39. The South Pacific Division apparatus makes use of a Soiltest mold with a 12-in. diameter and an 8-in. height. The hammer, weighing 30 lb, is the sliding-weight type; it is manually raised 18 in. and dropped to an 8-in.-diam plate. The specimen is compacted in two 4-in. lifts, with 72 blows applied to each.

Waterways Experiment Station

40. The WES has used a mold, 12.25 in. in diameter by 7 in. in height, with the standard 2-in.-diam, 5.5-lb hammer and 230 blows per 4-1/2-in. layer.

Bureau of Reclamation

41. The USBR uses a 19.25-in.-diam mold having a 9-in. height.[10] The mechanical compactor is about 12 ft in height. The hammer weighs 185.7 lb and has a diameter of 9.5 in. Lifting is accomplished through a mechanically actuated double-armed cam. The mold is mounted on a turntable which is rotated during compaction. Twenty-five blows per layer are applied to achieve standard compactive effort. The test was developed around a mold already on hand for permeability testing, and in establishing other procedural constants, the Bureau selected a value of 18-in. drop height and held the number of blows to 25, necessitating the use of the very heavy hammer.

California Department of Water Resources

42. The apparatus used by the Department of Water Resources in Sacramento consists of a hydraulically-operated mechanical compactor and a 12-in.-diam by 10.4-in.-high mold.[11,12] The hammer weighs 128 lb and

drops through a distance of 18 in. Twenty-three blows per layer are applied. In developing the apparatus and procedure, the moisture-density relationship of a soil passing the No. 4 sieve was established using a standard 4-in. mold, then with hammer diameter held at one-half the mold diameter and the number of flows held near 25, efforts were made to achieve an essentially identical moisture-density plot with the same material by using various hammer and mold combinations. It is noted that their standard compactive effort is 20,000 ft-lb per cu ft, or about 1.6 times the CE standard effort. The Department of Water Resources also has a compactor and 19.5-in. mold adapted from the USBR design described in the preceding paragraph.

Discussion

43. A search of the literature and direct contacts with other testing organizations revealed very little interest or information. Most of the work involving large particle sizes has been done in connection with rockfill materials containing little or no material finer than the No. 200 screen. In these instances, density data derived from test embankments are more informative than laboratory tests, and specimens for other tests, as triaxial and permeability, are most readily constructed by vibratory compaction methods. Devices for vibratory compaction are located in most of the CE laboratories and are standard equipment items in numerous others, with one very large (21 cu ft) mold with vibrating table located at the North Pacific Division Laboratory, Troutdale, Oregon. A similar device has been used by the South Atlantic Division.

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APPENDIX A

UNIVERSITY OF CALIFORNIA - ROCKFILL TESTING FACILITY

by Clarence K. Chan, Associate Research Engineer
Institute of Transportation and Traffic Engineering
University of California, Berkeley

Paper for presentation at the Speciality Session on Mechanical Properties of Rockfill and Gravel Materials, VII International Conference on Soil Mechanics and Foundation Engineering. August 1969, Mexico City.

The Rockfill Testing Facility of the University of California, which was completed early in 1968, currently provides equipment for testing triaxial specimens up to 91.5 cm diameter and plane strain specimens up to 61 cm in width. This paper will briefly describe the equipment used for conducting tests on large samples under traixial compression and plane strain conditions and for conducting correlation tests on small diameter specimens.

Large Triaxial Sample

The most impressive features of the facility are the 53 kg per sq. cm traixial chamber and the companion 1800 metric ton load frame. A line drawing of the chamber is shown on Figure 1. The sample is 91.5 cm in diameter and 229 cm high. The internal diameter of the chamber is 203 cm, and it has a wall thickness of 4.5 cm. The 46 cm diameter chrome plated steel piston has a stroke of 71 cm, permitting a total sample strain of 30 percent. A load cell is mounted at the end of the piston so that the friction from the bronze-lined guide and chevron packing do not affect the recorded axial load. The triaxial cell is fastened together at the base with 64 - 5.1 cm bolts. Retractable wheels allow the assembled cell to be pulled by cables into the load frame. Figure 2 shows the chamber being lowered over the base with the assembled sample on the base. In the background is the four posted load frame with the hydraulic piston in the upper head. The chamber is filled with water and the confining and back pressures are applied by regulated air over water in the calibrated volume tanks.

Instrumentation is provided for measuring:

a. Axial Load - The load cell mounted inside the chamber at the end of the piston is strain-gaged with full bridges to provide the total load and with half bridges to provide quadrant loads for eccentricity evaluation.

b. Axial Deformation - A ten turn potentiometer with a cable is used to measure the average deformation of the sample, and a backup is provided by the piston movement gage.

c. Volume Change - The volume change of the sample is monitored by observing movements of both the pore water and chamber water by means of separate calibrated cylinders utilizing air-water interfaces. Strain gage differential pressure transducers are used to translate the heights of water in the cylinders into electrical signals.

d. Radial Deformation - Circumferential gages at 5 elevations around the sample consist of fixed length bands attached to a cable on a drum which turn a potentiometer to indicate changes in length. The first bands used around the sample were essentially teflon tubing which slid within sections of teflon tubing on the rubber membrane. The volume changes indicated by these circumferential gages and the measurements of axial deformation indicated too little compression during consolidation, and too much compression during shear when compared to the measured pore water changes. This led to the hypothesis that the sliding friction was higher than the retracting spring tension which then cause slack in the gages during consolidation, i.e. the change in reading was too low, and that this slack during the initial part of shear makes it appear that the diameter is not increasing with axial deformation. It was necessary to place the bands on rollers to minimize the friction of the gage on the membrane before the volume changes calculated by dimensional measurements coincided with those made on the pore and chamber water.

e. Pressures - The chamber pressure and the pore pressure at the cap and at the base of the sample are monitored by pressure transducers in the lines immediately outside of the chamber.

Instrument data (18 channels) is recorded on a multipoint recorder and a digital data acquisition system with punched paper tape output. The data is then handled on a computer for reduction and analysis.

An important development at the facility was the membrane system employed for tests at high confining pressures on specimens with large particle sizes. The criterion chosen for the maximum particle size was one-sixth of the sample diameter. The membrane system selected after some preliminary testing consists of several layers of rubber to provide the necessary strength to bridge the large voids, covered by a thin outer membrane to provide a seal. The thickness of rubber employed on sixteen tests on 91.5 cm diameter samples of three different rockfill materials varied from 0.8 to 2.7 cm for confining pressures ranging from 2 to 46 km per sq. cm. The maximum corrections, calculated on the assumption that the membrane is an elastic shell which deforms as a right circular cylinder, were 2 percent of the deviator stress, and one percent of the confining pressure. The net effect on the computed angle of friction is less than 0.3°.

Figure 3 shows the large diameter triaxial test specimen being prepared in 10 layers within the three piece steel mold. The mixing equipment for each layer is essentially a drum rotated on a horizontal axis. The drum is charged with the desired quantity of the various sizes of material from the bins while suspended from a hoist balance. Physical movement of the drum is facilitated by a hoist mounted on a monorail. The drum is equipped with a full open trap door which is activated through a tripping mechanism when contact is made on the previously compacted layer. Each layer is compacted by use of a disk with a rotating unbalanced weight vibrator. A bridge crane in the testing bay is used to move the completed sample on to the triaxial cell base. Other support equipment includes the usual vibrating screens to separate the rockfill material before and after testing, vacuum pumps, and deaired water supply equipment for the pore water.

Large Plane Strain

The plane strain equipment is just completed and is shown in Figure 4. The test specimen will be 61 cm wide, 137 cm long, and 153 cm high. The sample will be restrained in the longitutional or intermediate principal stress direction by two end plates held together by four tie rods. The entire assembly of cap, base, end plates and tie rods will be placed inside the 203 cm internal diameter triaxial pressure chamber for testing.

Correlation Testing Equipment

Other equipment within the facility allows testing of 7.1 cm, 15.2 cm, and 30.5 cm diameter specimens. Minor variations in cell configuration and measurement methods have been used, but common throughout are: maximum chamber pressure of 70 kg per sq. cm, total available stroke for 35 percent axial strain and a sample height/diameter ratio of two and one-half. The main additional feature for this equipment is the closed-loop electrohydraulic system which can be used to program any desired axial load application. This equipment enables cyclic load tests to be performed as well as normal strength tests.

Conclusion

The Rockfill Testing Facility has been in operation for a year and a half. Three rockfill materials have been successfully tested with the large diameter triaxial test equipment together with correlation tests on smaller diameter specimens. The membrane system using layers of rubber has been used for pressures up to 46 kg per sq. cm without a single puncture. A circumferential gage has been refined and checked to provide consistent data. The large plane strain equipment is ready for testing rockfill material and a test program will be initiated in the coming months.

Acknowledgment

The Rockfill Testing Facility and operational budget were provided by the State of California Department of Water Resources.

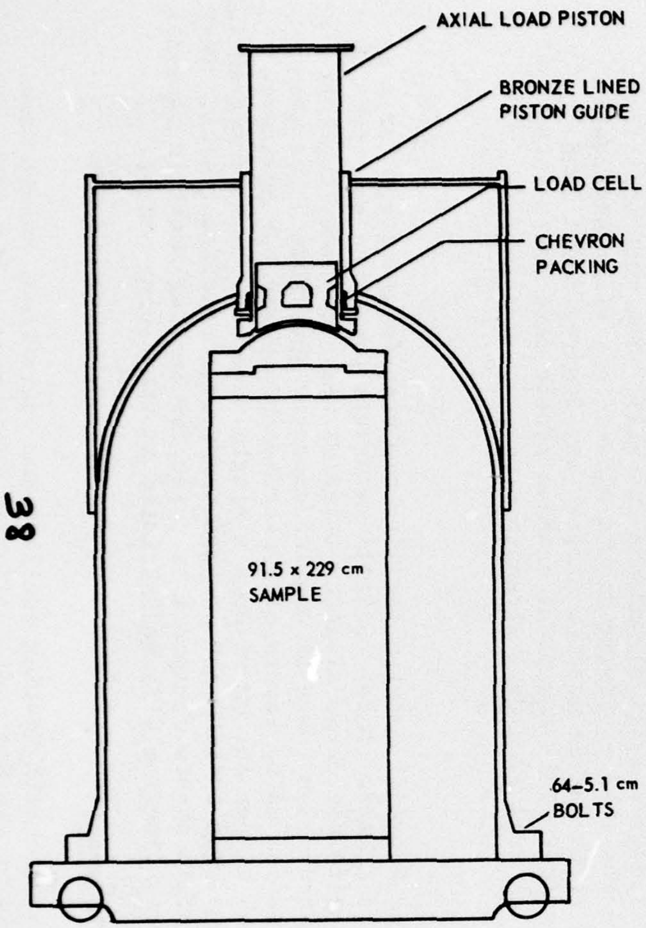

FIG. 1 LARGE TRIAXIAL CHAMBER

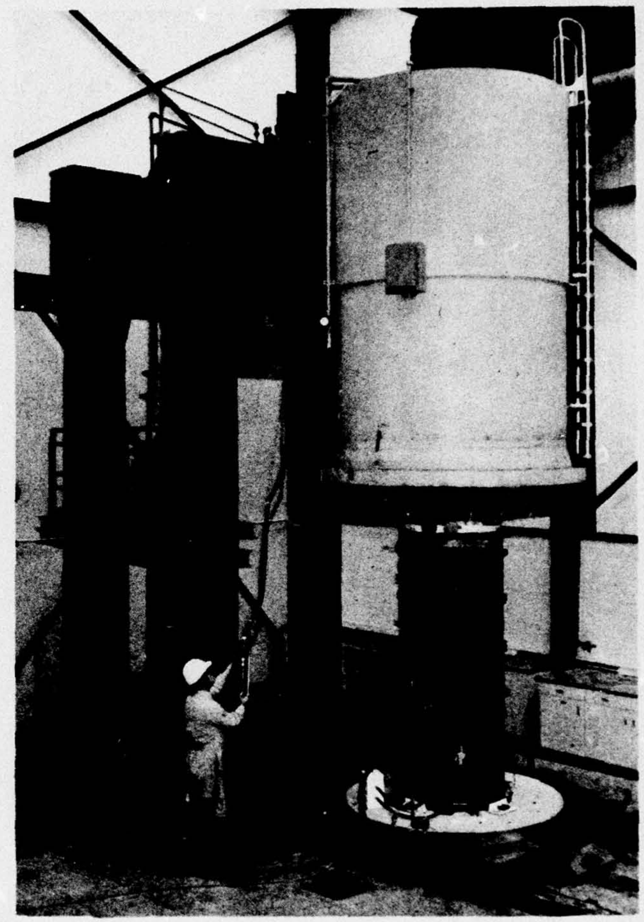

FIG. 2 LOAD FRAME AND TRIAXIAL CELL

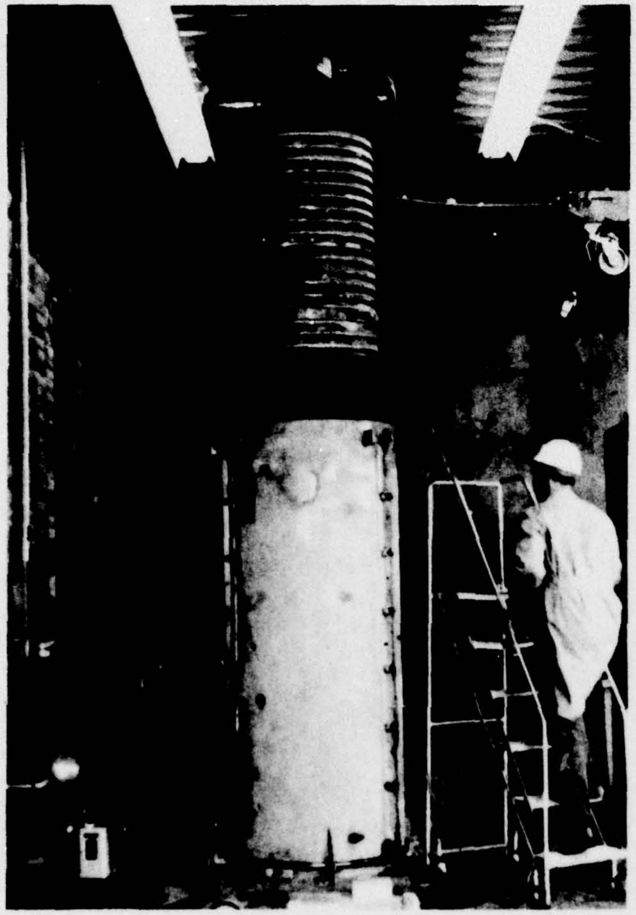

FIG. 3 SPECIMEN PREPARATION

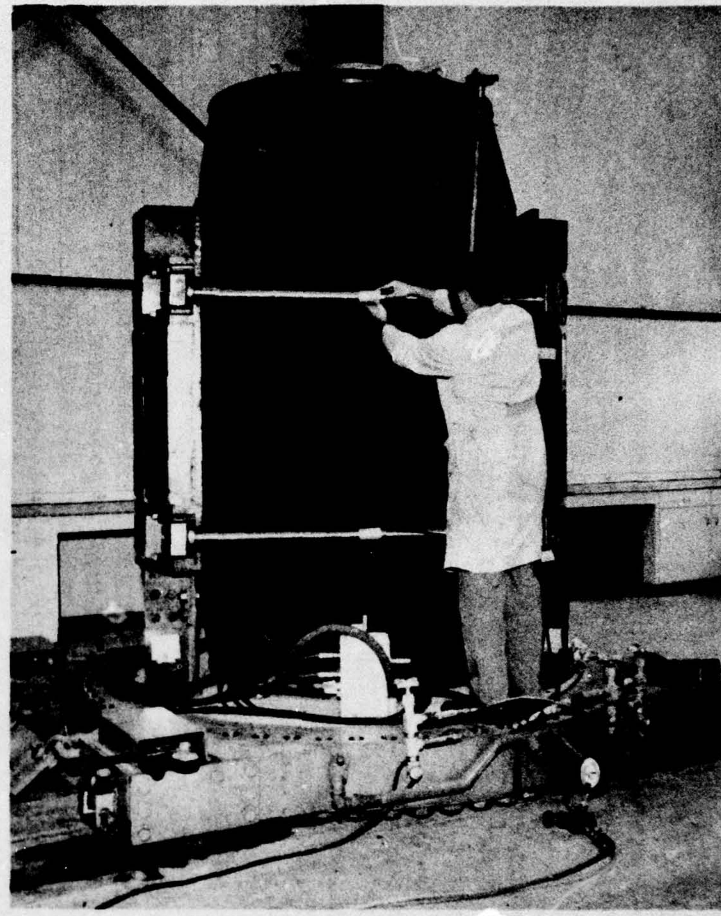

FIG. 4 PLANE STRAIN EQUIPMENT

APPENDIX B

SPECIFICATIONS FOR MECHANICAL SOIL COMPACTOR

Prepared by U. S. Army Engineer District, Albuquerque

Mechanical Soil Compactor complete with 5.5-pound, 11.5-pound, 24.7-pound and 55.6-pound hammers with foot diameters 2-inch, 4-inch, 6-inch, and 9-inch respectively. The machine shall be designed to provide drop heights of 24 inches for the 11.5-pound to 55.6-pound hammers, and 12 inches for the 5.5-pound hammer. The machine shall be self compensating for the required drop of the hammer regardless of the height of the material in the mold. The machine shall be so designed that each drop of the hammer will fall on a different area of the surface of the sample in order that the entire surface area of the sample shall be uniformly compacted. The compactor shall be supplied complete with one 6-inch diameter (.0746 cu. ft.), one 12-inch diameter (.7854 cu. ft.) and one 18-inch diameter (2.6506 cu. ft.) molds including 2-1/2 inches high collar on each. Compactor to be operated from 110/220 volt, 60 cycle, single phase power source. The compactor shall be equipped with the following controls: (1) Pre-determining, reset type, 5-digit counter which can be easily set for required number of blows and will automatically stop process at end of set count. Both lapsed blows and blows remaining indicated so that original set count can always be determined. (2) "RUN"-"JOG" toggle switch in totally inclosed control box. In "RUN" position, motor drives compactor for pre-set count. "JOG" position permits clearing of hammer from mold at end of cycle or after mid-period stop. (3) "STOP" pushbutton will halt process at any time. Machine will complete set blows when "RUN" switch actuated.

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13. ABSTRACT

This report contains the results of a survey of existing apparatus capable of testing large-diameter specimens of compacted rock and earth-rock mixtures in laboratories not only of the Corps of Engineers (CE) but also of outside organizations.

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