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EVALUATION OF SOIL MECHANICS LABORATORY EQUIPMENT. REPORT NO. 1--ETC(U)
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EVALUATION OF SOIL MECHANICS LABORATORY EQUIPMENT REPORT NO. 1. WARLAM TRIAXIAL APPARATUS FOR 6-IN.-DIAMETER SAMPLES

ARMY ENGINEER WATERWAYS EXPERIMENT STATION,
VICKSBURG, MISSISSIPPI

NOVEMBER 1958

EVALUATION OF SOIL MECHANICS LABORATORY EQUIPMENT

WARLAM TRIAXIAL APPARATUS FOR 6-IN.-DIAMETER SAMPLES

CWI ITEM NO. 516

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Report 1

November 1958

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

PREFACE

This investigation was conducted for the Office, Chief of Engineers as directed in letter dated 5 February 1957, ENGWE, subject "New Civil Works Investigation Project." The project was numbered CWI-516.

The work was performed by personnel of the Soils Test Section, Waterways Experiment Station, under the general direction of Messrs. W. J. Turnbull and W. G. Shockley. The assistance of Dr. A. A. Warlam, Consultant, in the assembly, calibration, and preliminary testing of the equipment is gratefully acknowledged. This report was prepared by Mr. J. E. Mitchell, Chief, Soils Test Section.

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SUMMARY

The apparatus described in this report is of relatively new design. Its compactness, independence from electrical power, and light weight make it suitable for use in temporary field laboratories. The large sample size, 6-in. diameter by 12-in. long, allows it to be used on soils containing gravels. The high chamber pressure permits testing at pressures encountered in earth dams of 200 to 300 ft in height.

The equipment is generally satisfactory for the testing intended. The lucite chamber was not adequate for the maximum chamber pressure given by the manufacturer. Repeated loadings and brittleness with age make its operation hazardous at the manufacturer's 150-psi maximum pressure.

The load applying and measuring part of the apparatus is very reliable. The proving ring, made of a thin aluminum alloy tube, is very sensitive and accurate. The chamber with sample is of such weight that it can be lifted and placed in position by one man.

WARLAM TRIAXIAL APPARATUS FOR 6-IN.-DIAMETER SAMPLES

PART I: INTRODUCTION

1. Source. The equipment was designed and manufactured by Apparatus Specialties, 209 Villard Avenue, Hastings-on-Hudson, New York, Dr. A. A. Warlam, owner.

2. Cost. Compression chamber with cap and pedestal for 6-in.-diameter by 14-in.-long samples, lucite cylinder for 150 psi and aluminum cylinder for 400 psi lateral pressure, hydraulic loading press with 20,000-lb proving ring, air pressure control unit and pore and intergranular pressure indicator (complete) $6642

Adapters, cap and pedestal with necessary spacers for 4-in.-diameter and 2.8-in.-diameter samples . . . . . $ 245

Compaction mold for 5.6-in.-diameter specimens, sponge-rubber lined (granular materials) . . . . . $ 250

Compression chamber only with specimen caps and pedestals for 6-, 4-, and 2.8-in.-diameter samples (without loading press or air control unit) - approximate cost $3200

Since this apparatus is custom made, the purchaser should expect minor changes and improvements in design, and consequent slight differences in cost. A photograph of the complete apparatus purchased is attached.

3. Application. The apparatus tested in this project is relatively new in design. Its light weight and compact construction make it convenient for use and shipment. The large sample size, 6-in. diameter by 14-in. long, makes it suitable for testing soils containing gravels. (Small samples are not satisfactory for such materials.) The high chamber pressure permits testing at pressures encountered in earth dams 200 to 300 ft in height.

PART II. DESCRIPTION OF APPARATUS

4. Sample size. The equipment was designed primarily to test specimens 6 in. in diameter by 14 in. long. Smaller specimens can be accommodated by the use of proper spacers and end caps. Auxiliary spacers and end caps were purchased for 4-in.-diameter by 9-in. long and 2.8-in.-diameter by 6- to 8-in.-long specimens. These proved to be very useful and extended the versatility considerably.

5. Equipment weight. The total weight of apparatus set up for use without sample or water in chamber is 395 lb, itemized as follows:

Chamber (aluminum cylinder)	61 lb
Air control unit, complete	30 lb
Frame, ram, proving ring, and hydraulic pump	304 lb

The complete apparatus and accessories, packed for shipment, weighs 700 lb.

6. Mobility. The loading frame and air control unit are mounted on rubber-tired casters, making the unit very easily moved by one man. If the distance is appreciable, the hand hydraulic pump must first be placed on the frame, as it is not mounted on casters. The chamber with 6-in. sample in place is of such weight that one man can place it in the loading frame unassisted.

7. Load capacity.

a. Frame. The frame is made of rectangular and square steel tubing welded and bolted together. The bolted assembly allows it to be easily dismantled for convenience in packing for shipment. Total load capacity for the frame is 25,000 lb.

b. Proving ring. The 23,000-lb-capacity aluminum tube proving ring is of unique design, being made of an aluminum alloy tube 23-1/2 in. long, 10-1/2-in. diameter, and .365-in. thick. This long length and large diameter with relatively thin walls provides sensitivity at small loads and yet gives a large total capacity. The ring is held to the frame at the bottom by four machine screws. The load is transmitted through the ring by an aluminum piston which

is held in place by bearings arranged similar to those on the chamber piston. The ring operates in tension. The load-indicating dial is connected to the ring through an adjustable lever which makes it possible to have the dial readings in direct units of load.

c. Hydraulic ram. The load application is by means of a standard Blackhawk Jack, Model P-76, and a Blackhawk Ram, Model RC-251, capacity 20 tons.

d. Pressure system. The various components are rated as follows:

(1) Air tanks, 400 psi

(2) Tubing, valves, couplings, 400 psi

(3) Lucite chamber cylinder, 150 psi

(4) Aluminum chamber cylinder, 400 psi

(5) Piston seal, 400 psi

(6) Lucite expansion tank, 300 psi (located below right-hand air tank)

(7) Pressure gauges, chamber pressure (right-hand gauge) 400 psi; effective chamber pressure (lower center gauge), 200 psi (used where pore pressure measurements are made); pore pressure (center upper gauge) 0 to 200 psi, varies depending on gauge used.

e. Strain measurements. The strain measurements are taken from a dial gauge mounted on an arm on the piston or a dial gauge mounted on a separate strain-measurement frame on top of the proving ring. The second system is to be used for accurate measurements of strain on brittle samples at small amounts of strain.

f. Specimen chamber. The chamber has two cylinders; one of lucite for low pressures and one of aluminum for high pressures. The top and bottom are held by locking dogs which expand into grooves in the cylinder. Leakage is prevented by an "O" ring seal. The aluminum piston moves on two sets of three each radially spaced ball bearings (see photograph). The friction is very low because of this construction and does not increase with eccentric loading on the piston. The piston seal is by means of a 2-in. triaxial membrane supported by a tapered knit nylon sleeve. This permits piston travel but not rotation. To keep the seal properly placed it is necessary to have 4 to 5 psi pressure in the chamber before the piston is moved. There is no piston friction in this type of seal, even after standing for long periods of time. This makes the equipment ideal for long-time drained tests.

PART III: PERFORMANCE OF THE APPARATUS

8. Axial loading system. The application of deviator stress as mentioned previously is by means of a hand-operated Blackhawk jack and ram. There is some pulsation in loading by means of a single piston pump. However, the observed load on the proving ring can, with reasonable care, be kept either constant or increasing at a uniform rate. Test results on duplicate samples with the load applied at a uniform rate by a Baldwin-Southwark testing machine checked with those obtained using the hand pump. The maintenance of a uniform load during pore pressure measurements was satisfactory using the hand pump.

9. Axial load measuring system. The aluminum proving ring is very accurate and reliable for measuring the axial load. The lever arm connecting the load dial gauge to the proving ring is very convenient in allowing adjustments so that the units of load can be read directly. Little or no hysteresis was observed in the ring, even after stressing to capacity load.

10. Lateral and pore pressure systems.

a. Chamber pressure is applied from the right-hand air tank and read on the right-hand gauge. The large 400-psi gauge supplied was satisfactory for the higher lateral pressures but a more sensitive gauge was substituted when low pressures were to be used. The lucite chamber is rated at 150 psi, but in operation the bottom edge broke at the locking groove at 130 psi. The working pressure for the lucite cylinder has since been limited to 100 psi and no further trouble has been experienced. The valve at the bottom of the chamber for admission of water leaked under the higher loads and needed to be replaced. No water reservoir for filling the chamber is provided and must be added by the user. The bleeder valve (radiator drain cock) on the chamber pressure system leaked at the higher pressures and was replaced with a needle valve.

b. Pore pressure is measured by balancing it with air pressure and reading on a Bourdon gauge (top center). Provisions are made for reading the pore pressure from the top or bottom of the sample, or both. Capillary plastic tubing (bore 0.04") is used on the pore pressure lines. The saturation and

pore pressure lines are continuous plastic tubing, facilitating the elimination of air bubbles from the system. A calibration chart was made to make it possible to correct for the small volume change in the plastic tubing when very accurate pore pressure measurements were to be made. The error in neglecting the correction would not be significant in routine work. The bleeder valve (radiator drain cock) on the pore pressure system leaked under high pressure and was replaced with a needle valve. An ingenious arrangement allows the effective lateral pressure on a sample to be read directly (bottom center gauge). This is accomplished by encasing a standard Bourdon gauge in a cell to which the pore pressure is admitted. The Bourdon gauge is connected to the lateral pressure line. The result of this arrangement is that the Bourdon gauge (lower center) reads the lateral pressure minus the pore pressure. This is particularly convenient when a positive pressure is applied to the pore water to fully saturate the sample. All gauges used for the measurement of pressure were calibrated using a dead load gauge tester. The pore pressure measurements in all tests were made from the bottom of the sample. Some difficulty was encountered from plugging by powdered mica of the porous stainless steel disk at the bottom of the sample. The powdered mica (100 mesh) was used on the specimen cap and base to facilitate drainage of the samples. No particular care was taken to keep it off the porous disks and, as a result, they became plugged. Porous aluminum oxide stones are considered to give less trouble from plugging.

c. The pore pressure tube on the 2.8-in. specimen cap was connected by means of a taper joint and, while no difficulty arose, a more sturdy connection is preferable. Practically all the pressure connections on both the chamber and pore pressure systems were made using 1/8-in. OD plastic tubing and brass compression tube fittings, with the sleeve replaced with two rubber "O" rings. This method gives positive leakproof connections, even at high pressure. Care must be exercised, however, because the tube will be constricted if the nuts are too tight.

11. Chamber. The chamber is extremely light weight for the size sample and lateral pressures used. This made it very convenient for one-man operation in setting up the apparatus for testing. It is imperative that the locking dogs which secure the top and bottom to the cylinder be fully seated. Lack of complete seating of one dog may have been the cause

of failure of the lucite cylinder at the bottom groove when under 130 psi. The "O" rings on top and bottom made effective seals and did not impose compressive stresses in the lucite as flat-gasket and tie-bolted construction does. It is not possible to fill the chamber completely with water, due to the construction of the piston roll seal and the ball bearings. This makes it impossible to measure volume change of the sample by measuring the volume change of water in the chamber.

12. Tests performed. Approximately 30 complete tests (3 specimens per test) were performed in the evaluation of the apparatus. Lateral pressure was from 1/2 ton per sq ft to 20 tons per sq ft. Unconsolidated-undrained (UU) and consolidated-undrained (CU) tests, with and without pore pressure measurements, were made. The materials tested were silty sand, lean clay, and fat clay. Test results from duplicate samples run in the Warlam apparatus and conventional equipment compared favorably.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

13. The following conclusions and recommendations are made:

a. The equipment is satisfactory for the performance of triaxial tests on 6-in.-diameter by 12-in.-long specimens at high (400 psi) lateral pressures.

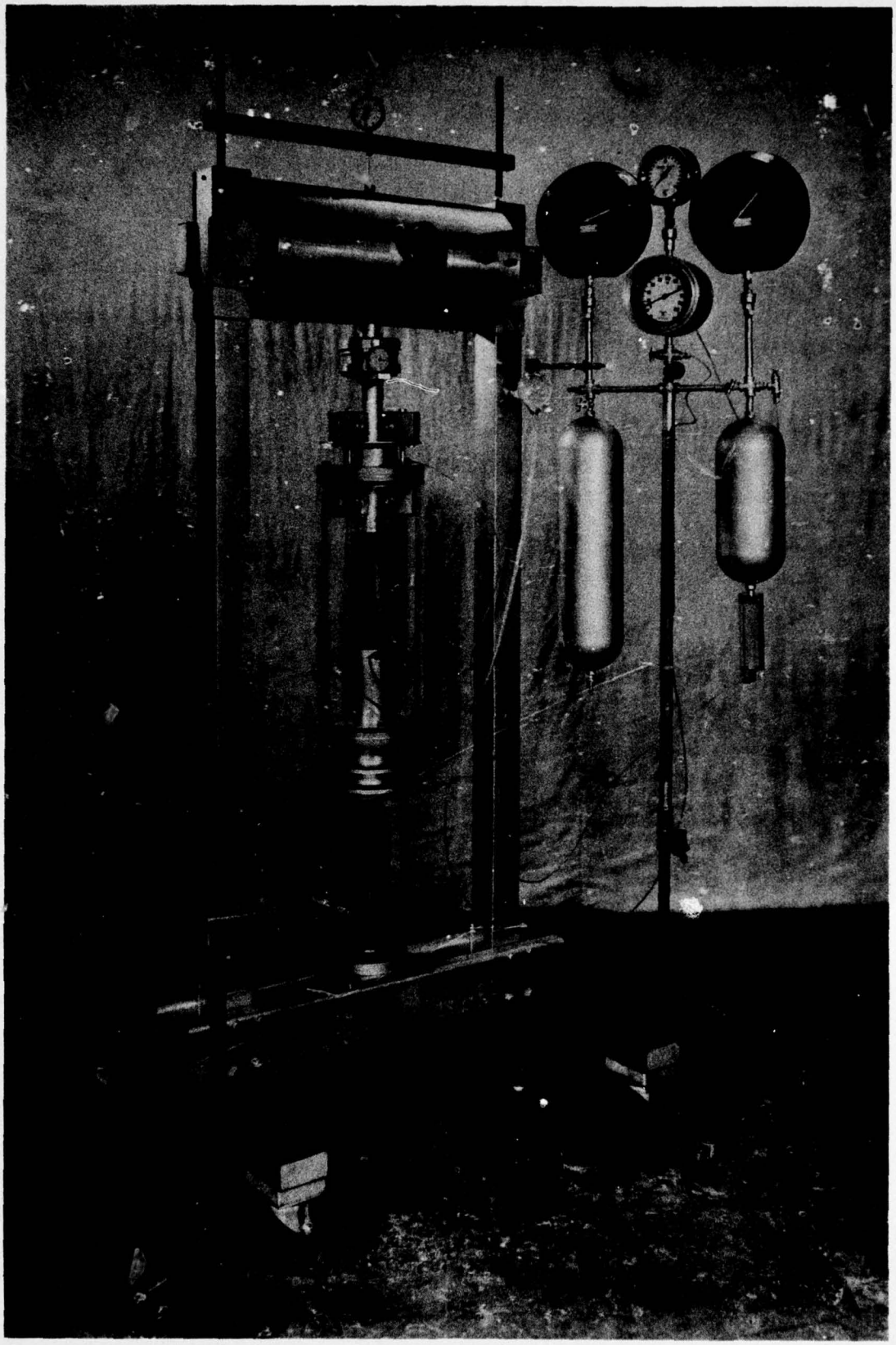
b. The load measuring and applying system is very accurate and reliable.

c. Pressure gauges need calibration before use.

d. Maximum lateral pressure should be reduced from 150 psi to 100 psi when the lucite cylinder is used.

e. The piston seal and bearings perform satisfactorily without leakage or friction, provided care is used in assembling and disassembling the apparatus.

f. No burettes are provided for measuring water changes in the sample. It is recommended that these be supplied to measure volume change during consolidation and water content change during saturation.



SUPPLEMENTARY SHEET 1

to paper given at 1958 Division Laboratories Conference
"Warlam Triaxial Apparatus for 6-in. Diameter Samples, CWI 516"

ADVANTAGES OF WARLAM TRIAXIAL APPARATUS

1. Working pressure of chamber is 400 psi for the aluminum cylinder, 100 psi for the lucite cylinder. (Specifications should limit proof testing of the chamber to not over 20% above the working pressure.)

2. The construction of the chamber is arranged to put the lucite chamber cylinder in tension only when the lateral pressure is applied.

3. The apparatus is capable of testing specimens 6 in. diameter by 14 in. length; 4 in. diameter by 9 in. length; and 2.8 in. diameter by 6 in. length.

4. Total weight of chamber with aluminum cylinder less sample does not exceed 70 lb; may be lifted by one man unassisted from the loading position to the testing position.

5. Piston seal is leakproof, has no increase in friction on long standing. Constructed so that friction does not increase with eccentric loading.

6. Pore pressure lines are continuous transparent tubing from outside chamber to cap and pedestal connections (making possible complete saturation of all lines).

7. Specimen cap and piston are arranged so that slight deviations of the sample ends from square will not cause concentrated loads nor bending of the sample.

8. Apparatus is provided with necessary gauges to read the following: air supply pressure; lateral pressure; effective lateral pressure (intergranular pressure).

SUPPLEMENTARY SHEET 2

to paper given at 1958 Division Laboratories Conference
"Warlam Triaxial Apparatus for 6-in. Diameter Samples, CWI 516"

PRECAUTIONS TO BE OBSERVED IN USE OF WARLAM TRIAXIAL APPARATUS

1. Operation of the chamber with the lucite cylinder should be with liquid only (never air alone).

2. The roll piston seal is so constructed that a chamber pressure of 4 or 5 psi is necessary before the piston is moved. A vacuum should not be applied to the chamber, as it will damage the piston roll seal.

3. Plastic lines with rubber ring seals are used for pressure. The fitting nuts should be tightened with care (with fingers only is usually sufficient) or constriction of the tubing will result.

4. Tolerances of fit on many of the pieces are quite close and care should be taken not to use excessive force in assembly.

5. The large rubber "O" ring seals on the chamber must be kept clean and free of grit and lightly lubricated with petroleum jelly or grease on assembly.

6. The porous disks in the specimen caps and bases become plugged easily. Care should be taken to clean out with air or water after using.

7. In assembly of the chamber, where locking dogs or rings are used in grooves to secure top and bottom, care should be taken the parts are fully seated before pressure is applied.