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Triaxial Apparatus for Field Laboratories

Appareil triaxial pour laboratoires de chantier

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Summary

Triaxial compression equipment designed primarily for operation at the construction site, tests samples up to 15 cm in diameter under 25 kg/cm² pressure and 10,000 kg load. Lightweight for economical transportation; the apparatus does not depend on electric power; can be operated by one man. Owing to its simple and rugged construction, only a minimum of servicing and maintenance is required.

Introduction

Economy of testing large samples right at the construction site has resulted in the development of light, readily transportable triaxial compression apparatus suitable for specimens up to 15 cm in diameter. First unit of this type, designed by the writer in 1956, was installed at the site of an earth dam¹ in 1957 in the field laboratory of an engineering firm² on the recommendation of A. Casagrande³, consultant on the project. A second unit was built in 1957 at the request of the Office of the Chief of Engineers, U.S. Army, for the use of the Corps of Engineers⁴, and has been selected here to serve as an example of equipment of this type. Additional units have been constructed for several regional division laboratories of the Corps of Engineers. The apparatus consists of three major components: loading machine, compression chamber, and control unit; each of which will be briefly described. In addition certain experiences with service behavior will be mentioned, and latest improvements listed.

Loading Machine

For the development and measurement of load a hydraulic ram and an elastically deformable tube are mounted at the lower and upper ends of a sturdy rectangular frame (Fig. 1). For the measurement of compression a separate and independent light frame supports a concentric dial indicator.

Load frame.—Constructed of thin walled rectangular steel tubes, the load frame is held together at each corner by only four bolts that can be easily knocked out for dismantling, or replaced for re-erecting. Net working clearance is 60 cm horizontally and 100 cm vertically.

Hydraulic ram.—Having a capacity of 20,000 kg, or twice the rated capacity of the loading machine, in the usual test-load ranges this ram responds to finger-pressure control exercised by the operator through a remotely actuated manual pump. As the only connection between the pump and the loading machine is a flexible hose, no mechanical

Sommaire

Cet appareil, adapté à l'usage de laboratoire de chantier, est capable d'essayer des échantillons jusqu'à un diamètre de 15 cm sous une pression de 25 kg/cm² et une charge de 10.000 kg. D'une construction légère permettant un transport économique, l'appareil n'emploie pas d'énergie électrique et peut être manipulé par un seul homme. Grâce à sa construction simple et solide un minimum d'entretien est nécessaire.

vibrations are transmitted. The hydraulic system is completely filled with oil, hence, upon the yielding of the specimen near failure, the load automatically and instantly relaxes, saving the shear pattern from needless destruction. The manual pump assures complete independence for the apparatus from electric power. If desired, the ram can be operated with a motor driven pump, but in field use to date this has not been required.

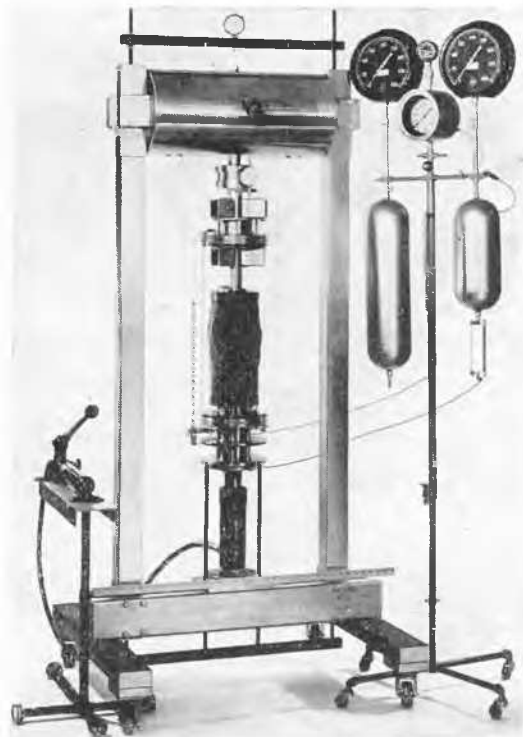


Fig. 1 Triaxial Apparatus for 15 cm Diameter Specimens
Appareil triaxial pour échantillons de 15 cm de diamètre

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² Bechtel Corporation, Engineers & Constructors, Vernon, Calif.

³ Prof. of Soil Mechanics and Foundation Eng'g. Harvard University.

⁴ U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Load sensitive tube.—Similar in action to a proving ring or load ring, but different in shape, this tube on top of the load frame is stretched vertically by the load, and its consequent horizontal contraction is measured and indicated by a laterally mounted dial indicator. The lateral deformation of the 27 cm diameter aluminum tube, 60 cm long, under a vertical load of 1 kg is 1 micron. As this 1 : 1 load-deformation ratio remains constant within ± 1 per cent over the lower third of the tube's capacity, which is the most frequently used working range, for practical purposes the dial readings are direct, in kg. Direct load readings are a definite help to the operator in the efficient conduct of the test. In the middle and upper third of the total load range, and when maximum accuracy is desired, the exact load corresponding to a reading can be looked up in a calibration chart. Internal ball bearing movement and jeweled bearings in the dial indicator combine to keep the load tube sensitive to a load of 1 kg through its entire range of 10,000 kg.

Test frame.—A separate frame, supporting the compression dial indicator, remains free from distortions even when the load frame is under maximum strain. Moving with the chamber base, this frame makes it possible for the concentric compression dial indicator to respond almost exclusively to compression that develops in the chamber. Once the apparatus compression is deducted from the readings, the remainder is dependable specimen compression.

Mobility.—Fitted with ball bearing casters, the loading machine can easily be rolled out of the way when not needed. Its total weight, including the pump on a separate stand, is 138 kg.

Compression Chamber

The chamber is light in weight, accepts specimens up to 15 cm in diameter, 35 cm long; its piston transmits loads practically with no friction; it can be pressurized with water, or at low pressure even with air.

Chamber construction.—Efforts to make the entire triaxial apparatus operable by one man have resulted in a chamber of relatively light construction. Weighing 25 kg it can be lifted by one operator, unassisted, if in good physical condition. To achieve this light weight the often employed tie rods are omitted, and the usually large cylinder cover plates are replaced by small plugs, or closure discs, which are held in place with internal locks projecting into cylinder grooves (Figs. 1, 2). With the tie rods out of the way, a 360° unobstructed view of the specimen is obtained. Operation is fairly simple. On opening, the chamber separates into two parts only: one the base with the specimen, the other the cylinder and head. On closing, the superstructure is lowered over the specimen, and the locks engage automatically. Freedom from leaking is insured by rubber O rings. Pressure capacity of the chamber with plain transparent plastic cylinder is 7 kg/cm², with rim reinforced transparent plastic cylinder 10 kg/cm², with aluminum cylinder 25 kg/cm². Size of the chamber is 23 × 90 cm.

Pedestals and caps.—To accommodate 15 × 35 cm specimens the chamber is equipped with 16 cm diameter pedestal and cap. If a specimen of smaller size is to be tested, the 16 cm pedestal and its short spacer can be quickly removed, and a smaller pedestal on a longer spacer attached. As the chamber has been found practical for the testing of specimens as small as 10 × 22, or even 7 × 16 cm, pedestals and caps 10 1/2 and 7 1/2 cm in diameter are standard accessories. The pedestals and caps are normally made of acrylic or phenolic plastics, with the exception of those in the 16 cm size that must stand up in heavy duty service

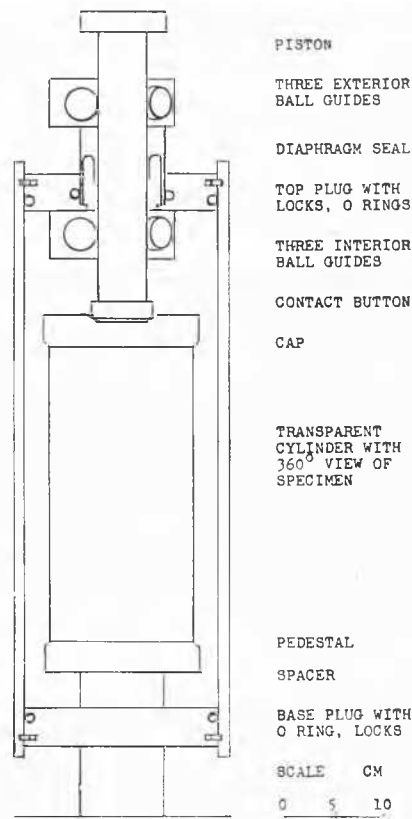


Fig. 2 Compression Chamber.
Chambre de compression.

such as triaxial crushing tests on broken stone under high pressure. These are made of aluminium. The pedestals and caps are drained through porous stainless steel filters and plastic tubing.

Piston.—Friction free movement of the piston is insured by ball guides (Fig. 2). This design is a result of a long development dating back to 1944 when the writer first constructed ball guides⁵ for a triaxial chamber, measured the friction caused by lateral components of eccentric vertical loads, and found that the friction of a piston guided by balls was only one tenth of the friction of a piston not so guided. These measurements having demonstrated the great advantage of ball guides, the writer has employed them in over a dozen triaxial chambers of several types, large and small. The piston of the chamber now being described, with its ball guides represents a forward step in the development of friction free load transmission equipment. In this design the ball guides are the only chamber components with which the periphery of the piston is in firm contact. Due to this arrangement sliding friction can not be generated. Sealing is effected by a flexible diaphragm of very slight motion resistance. The piston restraint caused by this resistance and by the internal drag in the ball bearings is practically constant, and amounts only to about 0.2 kg even under capacity load and pressure.

The diaphragm provides hermetic sealing, eliminates need for oil or glycerine, and requires no lubrication. A button fastened to the lower tip of the piston prevents it from being blown out, and presents a spherical contact surface to the cap. This surface with a conical recess in the cap tends to

⁵ "Stress-Strain and Strength Properties of Soils", by A.A. Warlam, Sc. D. Thesis, Harvard University, 1946; p. 25, Figs. 14, 30.

develop full seating, and once under load, allows no tilting. For the operator's convenience a dial indicator is attached to the piston to indicate piston motion relative to the cap. In routine tests this motion can often be accepted as specimen compression. In precise tests, compression is read off the concentrically mounted dial indicator.

Compaction mold.—Compacted specimens are prepared in a split mold fastened directly to the chamber base. This procedure eliminates handling of the specimen. The mold is lined with sponge rubber which helps to protect the impervious membrane from puncturing. In such a mold sharp crushed stone, 4 cm in size, has been compacted to a dry unit weight of 2.31 g/cc without injuring the membrane.

Control Unit

Support-equipment needed for the operation of the chamber is mounted on a mobile stand (Fig. 1) whose height is adjustable to suit the operator. The unit is fitted with compressed air cylinders to provide pressure, with gages to indicate pressures outside and inside the specimen, and with a capillary coil for back-pressure regulation. All components are readily accessible on all sides for examination, leak detection, adjustment. If a leak has sprung and can not be quickly located, the entire cylinder assembly may be lifted off the stand, and submerged in a water drum. The control unit weighs 15 kg.

Cylinders.—A large steel cylinder stores compressed air that can be fed into any of the other components. A smaller steel cylinder maintains pressure in the chamber. A transparent plastic cylinder receives overflow from the chamber.

Gages for external pressure.—Stored air pressure and chamber pressure are shown by two side gages. These are fitted with quick couplers and snubbers; can be uncoupled under full pressure, and replaced by others of different range.

Gages for internal pressure.—Magnitude of pressure in the interior of the specimen is indicated by the gages in the center. Pore water pressure or neutral pressure is shown by the upper gage. Intergranular, or effective pressure is indicated by the gage underneath. This gage, connected to the chamber, and placed inside a sealed case, operates in a neutral pressure atmosphere, and indicates only the difference between the chamber and neutral pressures. The gage is read through a clear plastic window, and can be easily replaced by another of different range. The sealed case also serves in the pore pressure balancing operation as a pneumatic cushion.

Capillary coil.—The back air pressure needed for preventing the escape of pore water is applied through a transparent plastic tube, 0.97 mm inside diameter. Convenience of the balancing operation calls for a long length of tube; for minimum pressure-head variation, however, the tube should be short. By coiling the tube a 120 cm path is provided for

the meniscus, with only a 30 cm maximum possible vertical elevation difference. With the meniscus at half height the total volume of water in the tube is 0.4 cc.

Service Behavior Experience

While experience with durability of these machines is limited due to the brevity of the period they have been in existence, they have successfully stood up under field conditions, and under intensive series of tests on difficult materials such as extremely angular glacial till, and tough siltstone. Some breakage of large acrylic pedestals and caps has been expected under high loads on coarse materials, but none has occurred in up to four years' use.

Easy transportability of the apparatus owing to simple and quick dismantling, reassembling, and light weight, have proven advantageous in several instances, such as shipment by air, on a few hours' notice, for a rush test program in 1959 from Mississippi to California. The diaphragm piston seal has proven capable of holding water and even air under pressure without leaking for long periods. A chamber pressurized with air was delayed in transcontinental transit for six weeks in 1958, but was found still pressurized on arrival.

Required service and maintenance consist mainly of keeping the equipment clean, the bearings oiled; replacing the diaphragm if it is accidentally damaged; and occasionally changing the hydraulic pump packing.

Late Developments

By changing from steel in a most recent model⁶ of the loading machine to a practically all aluminum construction, a 25 per cent saving in weight has been effected. The weight of the aluminum loading machine is only 93 kg.

Unusual pressure and load requirements by a government laboratory⁷ have been met with the design of a high capacity compression chamber. Its dimensions and weight do not differ significantly from those of the chamber described above, but by selecting for its component parts the strongest available alloys, pressure and load capacities have been substantially increased. This chamber has successfully withstood an internal pressure of 75 kg/cm², and a load of 35,000 kg.

A latest model⁶ control unit has been fitted with tanks for chamber water and saturation water; also with a burette for volume change measurement. Experiments in progress with a sensitive pneumatic pressure cell promise to render the indication of the effective pressure gage automatic, thereby relieving the operator from the tedious task of manual pore pressure monitoring.

⁶ U.S. Army Corps of Engineers, New England Division, Waltham, Mass.

⁷ U.S. Army Corps of Eng's., South Pacific Div. Lab., Sausalito, Cal.