Waterways Experiment Station Large Triaxial Apparatus

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● A SERIES of investigations in connection with studies of the distribution of stresses and strains in soil masses has led to the development of the large triaxial apparatus which is the subject of this paper. These investigations are being conducted by the Waterways Experiment Station of the Corps of Engineers.

The apparatus was not built primarily for testing soil specimens, but to provide a substantially known stress condition in a mass of sand. This was needed in connection with a study of pressure cell action. Pressure cells are used to measure stresses in soil masses, but it is known that difference in stiffness between the soil and the cell can lead to improper registrations. The large triaxial apparatus was developed to help study this problem.

The triaxial loading was dictated by a need for controlled and known stress conditions; the size of specimen, by a need to install pressure cells within the triaxially loaded mass (the Waterways Experiment Station pressure cell presently used is 6 in. in diameter and 1 in. thick); and the use of sand as a sample medium, by a need to interpret more precisely a large number of measurements made in sand under an earlier phase of the program.

Details of the large triaxial apparatus and its operation and use are given in this paper. Comments on the preliminary results are included as a matter of interest. Since vacuum was used for confinement and only one soil, and that dry, was tested in the apparatus, any results bearing on the triaxial testing of soils, generally, are limited in scope.

DESCRIPTION OF THE APPARATUS

The Waterways Experiment Station large triaxial apparatus uses a specimen 70 in. tall and 35.68 in. in diameter (see Figures 1, 2, 3 and 4). This diameter gives a cross-sectional area of 1,000 sq in. The specimen is confined within a rubber membrane between a head and base plate and evacuated to gain lateral load from normal air pressure. The headplate is rigidly made of sections of ½-in. steel plate welded together. In addition to its faceplate and circumferential plate, it has both radial and tangential stiffening ribs and a partial top plate. The base plate is of porous concrete set in a welded steel pan. This base is pierced by an access port to accommodate pressure cell cables. The specimen is evacuated through the porous concrete base and its access port. The membrane is of 1/32-in. black rubber. Membranes have been made of sheet rubber by vulcanizing longitudinal seams. Soft white rubber membranes were tried but proved to be too fragile, becoming pierced repeatedly at the top of the forming jacket during specimen construction operations. This occurred despite the fact that a sheet metal rim was used to protect the membrane at this critical point.

During construction, the triaxial specimen is confined within a forming jacket consisting of three 120-deg segments. These segments were built up by welding together parts formed from sheet steel. They consist of the main curved sheet of ¼-in. steel, reinforced vertically at the edges with ⅜-in. ribs and horizontally by six curved ⅜-in. steel ribs. The three segments are bolted together to provide a cylinder. Rubber gaskets are placed between segments so that vacuum may be applied between the forming jacket and membrane during sample construction. Experience has indicated that this feature probably is unnecessary.

The entire device is seated on a heavily reinforced concrete base 6 ft square and 10 in. thick. Load is applied by use of hydraulic jacks working against a heavy load-reaction truss. This is a truss built in the stress distribution shelter at the Waterways Experiment Station for use in loading full-scale test sections constructed beneath it. It

Figure 1.

has been described in an earlier publication (1). A hand winch and trolley crane mounted on the load-reaction truss provide the means of handling the headplate, forming jacket segments, and other heavy items.

Loads on the specimen are measured with a 50,000-lb capacity Baldwin, Type C SR-4 load cell. Vacuum is measured at both the top and bottom of the specimen. The vacuum is applied through buried pipes by a pump, and a cable outlet chamber is provided to permit electrical connections to pressure cells installed within the specimen.

A three-leg pipe frame is placed around the specimen to provide support for deflec-

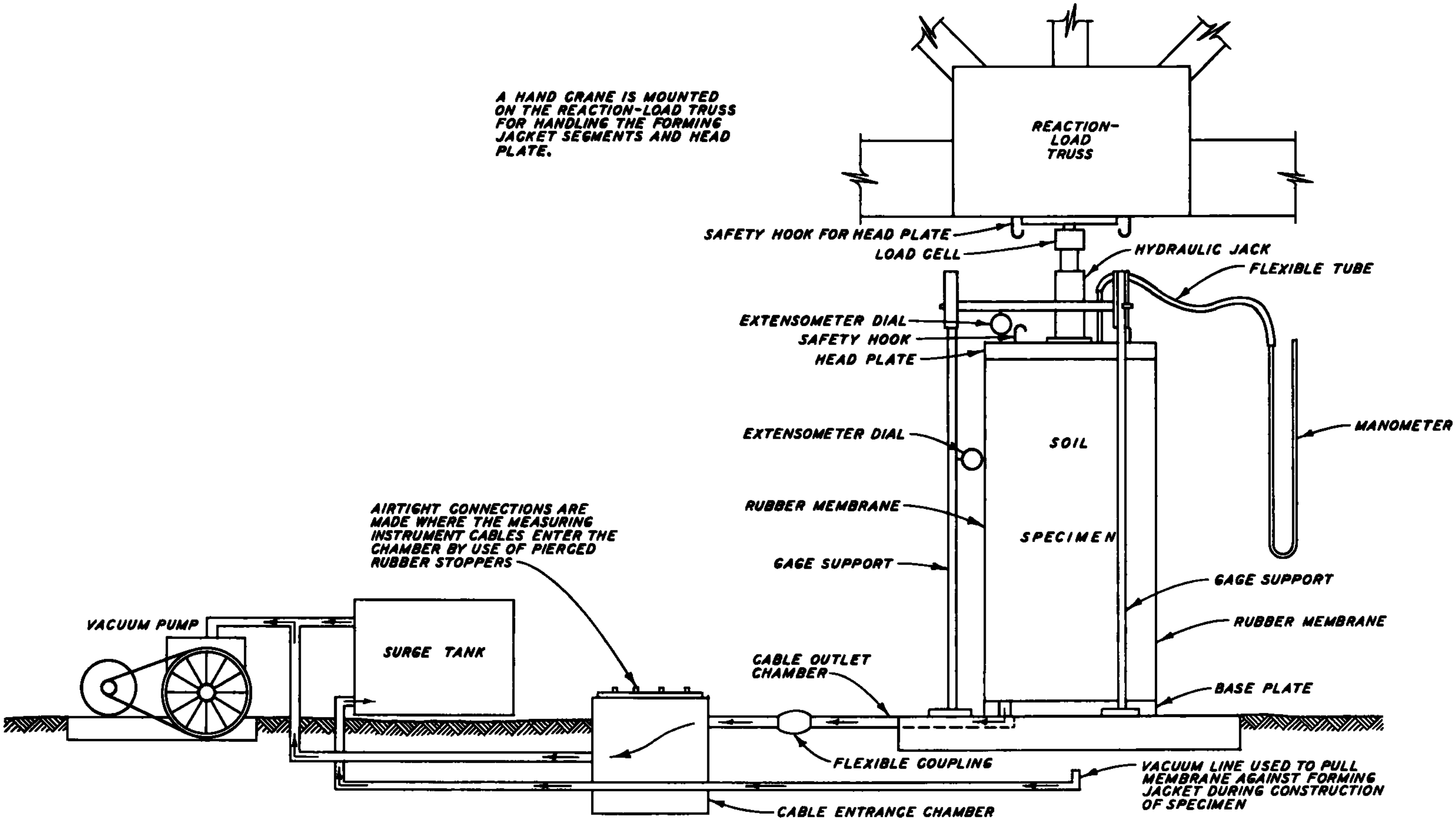

Figure 2. Large triaxial apparatus.

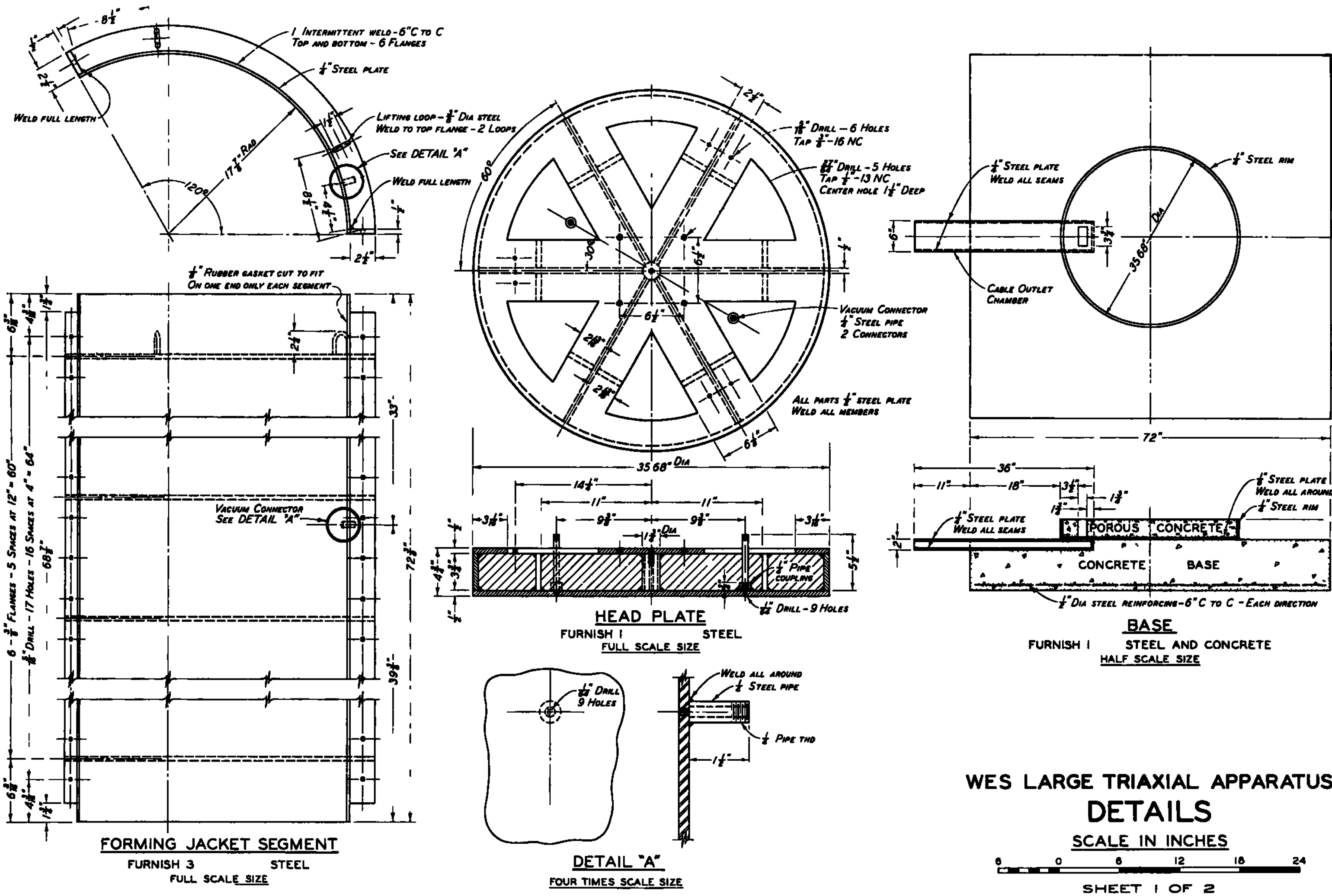
1 Intermittent weld-6" C to C
Top and bottom - 6 Flanges
Weld full length
Lifting loop
Weld to top flange - 2 Loops
See DETAIL "A"
Weld full length
Rubber gasket cut to fit
On one end only each segment
Vacuum Connector
See DETAIL "A"
FORMING JACKET SEGMENT
FURNISH 3 STEEL
FULL SCALE SIZE
Vacuum Connector
2 Connectors
All parts steel plate
Weld all members
35.68" Dia
Pipe coupling
HEAD PLATE
FURNISH 1 STEEL
FULL SCALE SIZE
Drill - 9 Holes
Weld all around
Steel pipe
Pipe thd
DETAIL "A"
FOUR TIMES SCALE SIZE
Steel plate
Weld all seams
Steel rim
Cable Outlet
Chamber
35.68" Dia
72"
Weld all around
POROUS CONCRETE
CONCRETE BASE
BASE
FURNISH 1 STEEL AND CONCRETE
HALF SCALE SIZE
WES LARGE TRIAXIAL APPARATUS
DETAILS
SCALE IN INCHES
6 0 6 12 18 24
SHEET 1 OF 2

Figure 3.

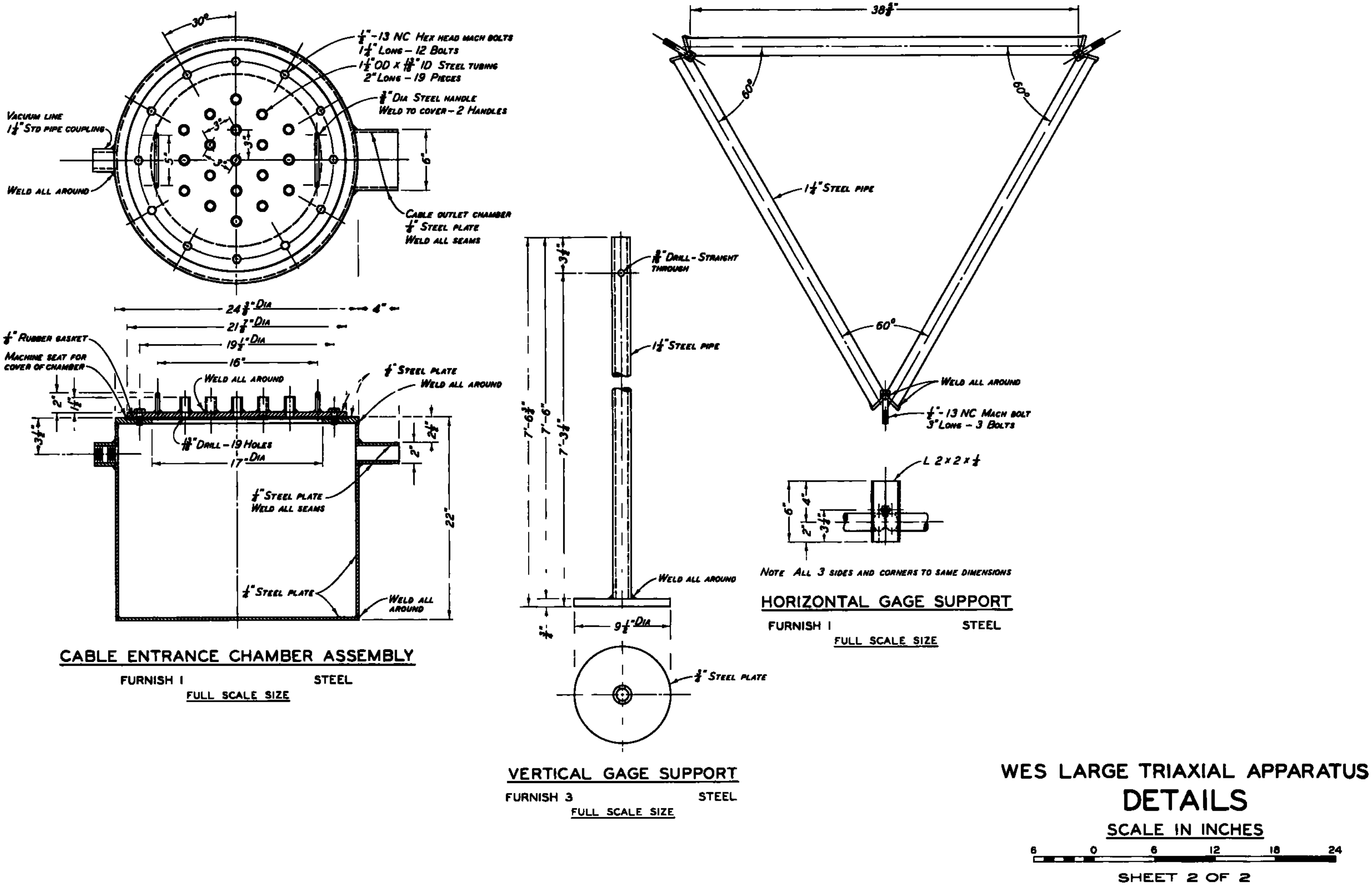
CABLE ENTRANCE CHAMBER ASSEMBLY
FURNISH 1
STEEL
FULL SCALE SIZE
VACUUM LINE
WELD ALL AROUND
CABLE OUTLET CHAMBER
WELD ALL SEAMS
RUBBER GASKET
MACHINE SEAT FOR COVER OF CHAMBER
STEEL PLATE
VERTICAL GAGE SUPPORT
FURNISH 3
STEEL
FULL SCALE SIZE
STEEL PIPE
WELD ALL AROUND
HORIZONTAL GAGE SUPPORT
FURNISH 1
STEEL
FULL SCALE SIZE
NOTE ALL 3 SIDES AND CORNERS TO SAME DIMENSIONS
WES LARGE TRIAXIAL APPARATUS
DETAILS
SCALE IN INCHES
SHEET 2 OF 2

Figure 4.

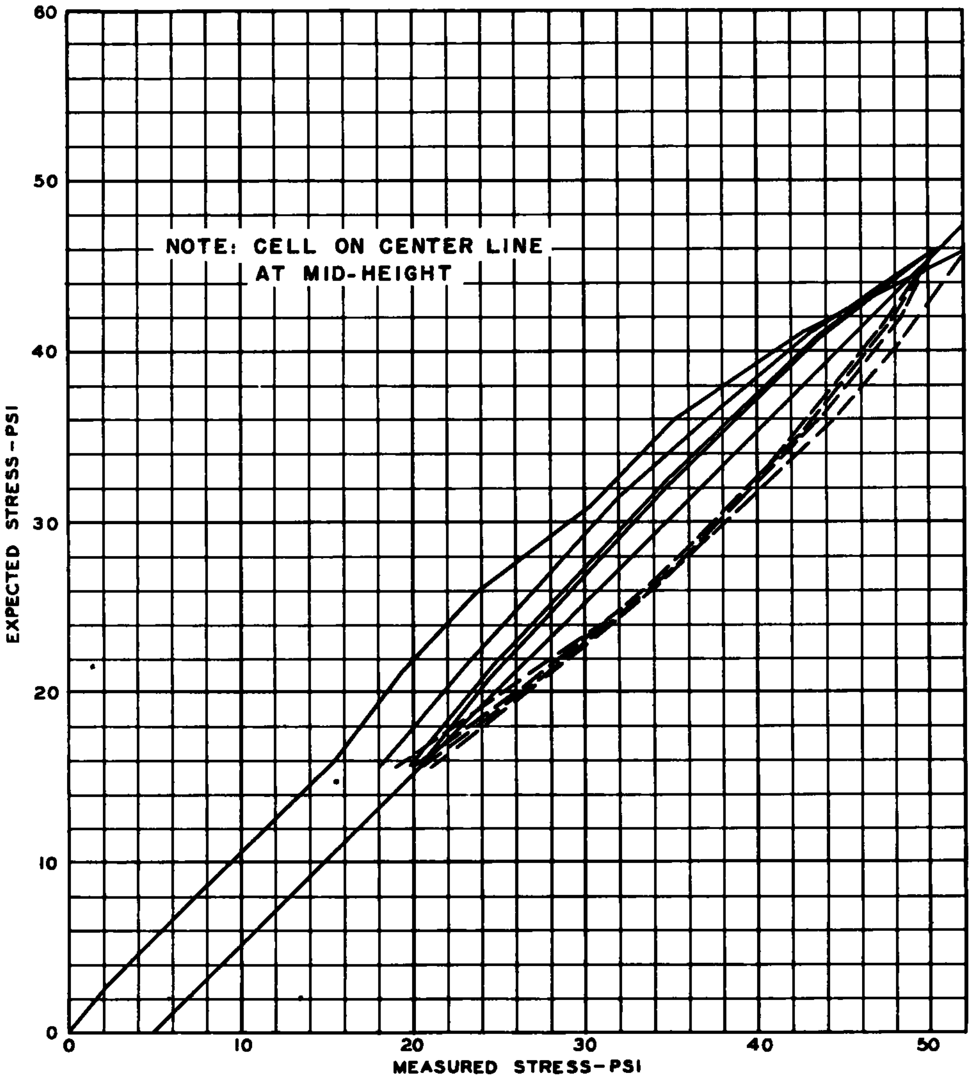

Figure 5. Typical vertical stress plot.

tion gages. Vertical gages are placed 120 deg apart at the edge of the headplate, and horizontal gages can be placed at any desired height along the three legs of the pipe frame.

A uniform sand is the only soil thus far used in the Waterways Experiment Station large triaxial apparatus. It is a processed mortar sand, substantially all of which falls between the 10- and 200-mesh sieves, and which has about 50 percent passing the 40-mesh sieve. In all cases the sand was air dry.

As has been mentioned, Waterways Experiment Station pressure cells were installed in the large triaxial specimens to measure stresses. These cells are 6 in. in diameter and 1 in. in thickness. They have a 100 percent sensitive face and use a mercury-filled pocket beneath the faceplate to transmit strain to a sensitive diaphragm. Details of this cell are not sufficiently pertinent to this paper to warrant further description here, but the cells are described in detail in another reference (2). In addition to the pressure cells, a number of soil strain gages were installed in several specimens.

These gages utilize differential transformer elements to measure relative displacement of reference diaphragms. The particular gages used were developed at the Ohio River Division Laboratories of the Corps of Engineers and are described in some detail in another reference (3). Figure 4 shows a typical plot of some of the data being collected.

FINDINGS OF INTEREST

The project has not progressed to the point that comprehensive results can be presented, but certain preliminary or tentative findings can be stated, as follows:

1. Considerable variation exists between magnitudes of stresses at various points within a triaxially loaded sand mass.
   a. At mid-height, vertical stresses near the center are appreciably greater than those at the edge of the specimen.
   b. Near the head and base plates, vertical stresses near the center are appreciably lower than those at the edge of the specimen.
2. Considerable variation exists between magnitudes of strains at various points within a triaxially loaded sand mass. Vertical strains in the center of the specimen may be several times as large at mid-height as near the top and bottom.
3. Though only a single soil at a single moisture condition (dry) was used, specimens at various densities were tested. The pressure cell results indicate no effect of density on the distribution of stresses throughout the specimen.
4. Since the pressure cells were stiffer than the surrounding soil, they might be expected to yield readings somewhat too large. This was the case, though the magnitudes of over-registration have not yet been fitted to a neat pattern.
5. In comparing the results from the large apparatus and equivalent small tests, several trends can be noted:
   a. Large specimens showed average vertical strains less than those for the small laboratory specimens when subjected to the same external stresses.
   b. Similarly, the slopes of stress-strain curves (stress plotted vertically) were greater for the large specimens.
   c. The angle of internal friction, ϕ, for the dry sand when determined from large triaxial specimens was generally about a degree larger than when determined from the small laboratory specimens.

REFERENCES

1. Foster, C.R., and Fergus, S.M., "Stress Distribution in a Homogeneous Soil." Highway Research Board, Research Report No. 12-F, 1951.
2. Corps of Engineers, Waterways Experiment Station, Investigations of Pressures and Deflections for Flexible Pavements, Report No. 2, Pilot Tests on New Four-Gage Cell. Technical Memorandum No. 3-323, Vicksburg, Miss., October 1951.
3. Corps of Engineers, Ohio River Division Laboratories, Final Report on Development of Earth Strain Measuring Device. Mariemont, Ohio, June 1953.