and then released. The plug in the bottom of the testing mold is then removed and the testing orifice ring substituted (see Fig. 74A). Marks are made on the cylindrical steel piston in place so that 3 in. may be measured in ¼ in. increments from the top of the mold

Load is then applied to the piston at such a rate that it moves vertically downward at the rate of one inch per minute. As each mark on the plunger comes even with the top of the mold the total load required to remove the piston is recorded as the load for the distance downward displaced.

SWELL TESTS

Swell tests are used to determine the volume increase accompanying the absorption of water by soil samples not already saturated. The consolidometers which may also be used for this purpose,

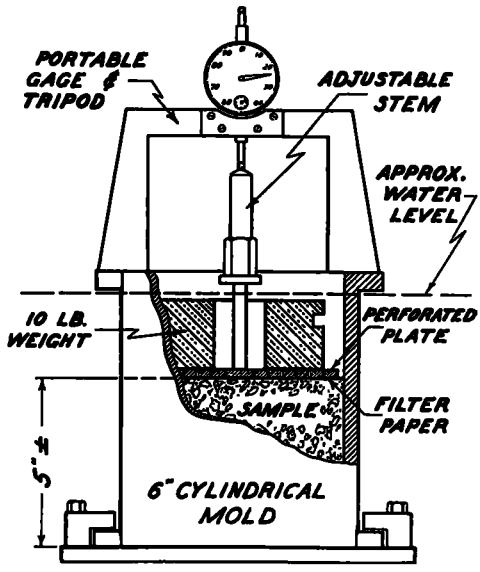

Figure 81. Expansion Test for Determining the Swell of Bearing Value Specimens. Stanton.

TABLE 8

SWELL TESTING DEVICES

State	Organization	Apparatus	Contributor
California	California Div. of Highways	California	T. E. Stanton, Jr.
Dist. of Col.	George Washington University	Proctor Mold	C. A. Hogentogler, Jr.
Idaho	Idaho Dept. of Public Works	California	R. M. Jewell
Idaho	Idaho, University of	California	Prof. A. S. Janssen
Michigan	Michigan Highway Dept.		Prof. W. S. Housel
Missouri	Missouri, University of		Dr. H. F. Winterkorn
Nebraska	Nebraska Dept. of Roads & Irri.		R. E. Bollen
Oklahoma	Oklahoma Highway Comm.	Proctor Mold	C. R. Reid
Dist. of Col.	Public Roads, U. S. Bureau of	Proctor Mold	C. A. Hogentogler
Texas	Texas Highway Department		W. H. Wood
Utah	Utah Road Commission	Proctor Mold	Levi Muir

are in the section on consolidation tests.

The swell testing devices reported by various laboratories are listed in Table 8.

T. E. Stanton, Jr.: A sample which has been compacted and tested for bearing value is loosened, reconsolidated, and placed in a tank of water after noting the height. During the soaking period, the sample is confined within the mold by a porous disk and a 10-lb. weight, which represents the surcharge of a pavement (see Fig. 81). After the specimen has soaked for 4 days the swell is recorded and the bearing value again determined.

Prof. W. S. Housel: The equipment used in the swell test consists of a brass cylinder 4 in. in diameter and 5 in. high, in which samples of an oil coated aggregate are compressed at a pressure of 2000 lb. per sq. in., using a perforated brass plate as a piston. A briquette approximately 2 in. thick is formed, which is removed from the mold, reversed in position, and replaced, with the tamped surface down. Five hundred

cc. of water are then poured in the upper part of the cylinder and allowed to stand for 24 hours, after which the swell is measured by an Ames dial to thousandths of an inch.

Dr. H. F. Winterkorn: For measuring the swelling capacity of soil fines and soil colloids we avail ourselves of the apparatus described by Hans F. Winterkorn and L. D. Baver in "Sorption of Liquids by Soil Colloids," *Soil Science*, Vol. 38, No. 4 (1934), pp. 291–298. The apparatus was constructed upon the principle of measuring the intake of liquids by powdered colloids through a soil is lightly packed with a pestle, the tube placed on the moist filter disk of the apparatus and the apparatus closed with a stopper. A glass capillary through the stopper, and another one at the end of the burette provide equal pressures at both surfaces of the sorption liquid, and, at the same time, render negligible the loss of liquid from evaporation.

R. E. Bollen: For use in the swell test apparatus shown in Figure 82 enough soil is moistened to make a sample 2-in. thick for a prescribed moisture content and density. The base plate is securely fastened to the swell cylinder while one

Figure 82. Four-inch Diameter Swell Test Apparatus. Bollen. 1. Perforated base plate. 2. ½-in. porus disc (3$\frac{1}{16}$-in. dia.) 3. 4-in. swell test cylinder. 4. 3-in. thick steel disc. 5. 1-in. thick steel disc. 6. ½-in. thick perforated steel disc. 7. Special depth gauge. 8. Electrical contact indicator. 9. Connections for contact indicator. 10. 1-in. porous disc (3$\frac{1}{16}$ in. dia.).

porous membrane while avoiding a positive or negative liquid pressure head. The apparatus most frequently used consists of a Jena glass tube with a fused in glass filter disk which is connected with a microburette by a small glass tube. The microburette has a capacity of 1 cc. and can be read to 0.002 cc. With substances that swell greatly a three-way stopcock connected with a water reservoir can be inserted between microburette and a glass filter tube.

In using this apparatus a weighed amount of soil material is poured into a calibrated glass tube, 1 cm. in diameter and about 2 cm. long, closed at the bottom with a fine silk cloth. Then the of the perforated steel discs is in the bottom of the cylinder. This is done to avoid deforming the mold.

A 4-in. by 1-in. Norton disc is placed in the bottom of the mold and the required quantity of the wet soil is placed on the disc in the mold and leveled off. The piston which is used in compacting the bituminous cylinders in the 4-in. Hubbard-Field mold is used to compact the specimens. The load required to compact the sample to the specified density is recorded.

After the sample is properly compacted, the piston is removed and a one-half inch Norton disc placed on top of the molded specimen. The piston is

then placed on top of the Norton disc and a total load of 1215 lb. is applied and held for two minutes. The 4-in. by ½-in. perforated steel disc is then placed on top of the Norton disc.

The special depth gauge is fitted with the proper length rod to measure down to the steel ball on top of the perforated steel plate.

The swell test mold assembly containing the prepared specimen is placed in a large shallow pan. The initial reading

Figure 83. View of Unassembled Mold (Showing Piston, Pressure Pad, Measuring Device, Filter Paper and Soil Pat) Used in Making Swell Tests in Molds. Woods.

is taken and then water is poured over the perforated steel disc and the holes kept level full during the test. The temperature of the water is kept between 65° and 75°F.

Additional readings are taken at 6-hour intervals for the first 48 hours and at 12-hour intervals for the next 96 hours. An 8-in. diameter apparatus is also used.

C. A. Hogentogler: A modification of the Proctor mold which is described under consolidation tests is used for testing swell. The sample may be formed by the standard Proctor compaction method and the top section cut off, or formed by static compaction to the required depth.

W. H. Wood: We are making swell tests on samples of subgrade soil taken from underneath old concrete pavements. The procedure followed is that described for disturbed samples in "The Results of Tests to Determine the Expansive Properties of Soils" by Harold Allen and A. W. Johnson, as published in the Proceedings of the Sixteenth Annual Meeting of the Highway Research Board, 1936 (Vol. 16, p. 220). The equipment used for these tests is illustrated in Figure 83. The mold itself is made of bronze, the compacting cylinder of steel, and the pressure pad of zinc plated steel.

FIELD TESTS AND SAMPLING EQUIPMENT

Field tests are made on the soil in place. Some of the penetration devices described under Penetration and Extrusion tests are also used as field tests.

This section is devoted to additional contributions listed in Table 9.

Fred Burggraf: The apparatus shown in Figure 84 for measuring the resistance of road surfaces to lateral displacement is of the hydraulic type, and the manually operated power is attained through a hand wheel screw type pump mounted in a vertical position. An 8-in. diameter dial hydraulic pressure gauge graduated from 0 to 10,000 lb. is connected to one side of the base of the vertical hydraulic cylinder. A small hydraulic thrust cylinder having a 2-in. range of travel is connected to the opposite side of the vertical cylinder by a 24-in. piece of flexible rubber hose. To the rigid end of this thrust cylinder, parabolic shaped plates of different heights are attached, depending upon the depth of the layer to be tested. The plates used vary in height from 1½ to 6 in.