APPENDIX VIIIA:

SWELL AND SWELL PRESSURE TESTS

1. INTRODUCTION. Swell is the process of imbibing available moisture to cause an increase in soil volume until the pore water pressure increases to an equilibrium determined by the environment. The amount of swell to satisfy the new pore pressure equilibrium depends on the magnitude of the vertical loading and soil properties that include soil composition, natural water content and density, and soil structure. The rate of swell depends on the coefficient of permeability (hydraulic conductivity), thickness, and soil properties. Soils that are more likely to swell appreciably include clays and clay shales with plasticity indices greater than 25, liquid limits greater than 40, and natural water contents near the plastic limit or less.

The presence of capillary stress or negative pore water pressure arising from molecular forces in swelling soils causes available moisture to be absorbed. The vertical confining pressure required to prevent volume expansion from absorbed moisture is defined as the swell pressure.

The swell and swell pressure are generally determined in the laboratory with the one-dimensional consolidometer (Appendix VIII, CONSOLIDATION TEST). Swell is determined by subjecting the laterally confined soil specimen to a constant vertical pressure and by giving both the top and bottom of the specimen access to free water (usually distilled) to cause swell. The swell pressure is determined by subjecting the laterally confined soil specimen to increasing vertical pressures, following inundation, to prevent swell.

2. APPARATUS, CALIBRATION OF EQUIPMENT, AND PREPARATION OF SPECIMENS. The apparatus is essentially the same as that listed in paragraph 2, Appendix VIII, CONSOLIDATION TEST.

Smoothly ground porous stones should be used in the consolidometer to minimize seating displacements. Filter paper should not be used because it is compressible and contributes to displacements. The equipment is calibrated and the sample prepared in the same manner as described for the consolidation test.

3. PROCEDURE.

a. Swell Test. (1) Record all identifying information for the specimen, such as project number, boring number, and other pertinent data, on the data sheet (Plate VIII-J, p VIII-18, is a suggested form); note any difficulties encountered in preparation of the specimen. Measure and record the height and cross-sectional area of the specimen. Record weight of specimen ring and glass plates. After the specimen is prepared, record the weight of the specimen plus tare (ring and glass plates), and from the soil trimmings obtain 200 g of material for specific gravity and water content determinations. Record the weight of the material used for the water content determination on the data sheet.

(2) Fit an air-dried, smoothly ground porous stone into the base of a dry consolidometer. Place the ring with the specimen therein on top of the porous stone. If the fixed-ring consolidometer is used, secure the ring to the base by means of clamps and screws.

(3) Place the top air-dried, smoothly ground porous stone and loading plate in position. The inside of the reservoir should be moistened to promote a high-humidity environment. The reservoir and loading plate should subsequently be covered with a sheet of impervious material such as plastic film or moist paper towel to inhibit loss of moisture.

(4) Place the consolidometer containing the specimen in the loading device.

(5) Attach the dial indicator support to the consolidometer, and adjust it so that the stem of the dial indicator is centered with

respect to the specimen. Adjust the dial indicator to allow for both swell and consolidation measurements.

(6) Adjust the loading device until it just makes contact with the specimen. The seating load should not exceed about 0.01 ton per sq ft.

(7) Read the dial indicator and record the reading on a data sheet (Plate VIII-2, p VIII-19, is a suggested form). This is the initial reading of the dial indicator.

(8) Depending on the particular design considerations, a specific load (e.g. overburden plus design load) is applied to the specimen. After a period of at least 5 min but less than 30 min (to avoid shrinkage from drying), record the dial reading on the data sheet (Plate VIII-2) and inundate the specimen.

(9) Inundate the specimen by filling the reservoir, within the inundation ring that surrounds the specimen, with water (distilled, tap, or field pore water, actual or reconstituted). Cover with the plastic film, and moist paper towel or equivalent. If a fixed-ring device is used, a low head of water should be applied to the base of the specimen and maintained during the test by means of the sandpipe.

(10) Observe and record on the data sheet (Plate VIII-2) the deformation as determined from dial indicator readings after various elapsed times. Readings at 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 8.0, 15.0, and 30.0 min, and 1, 2, 4, 8, 24, 48, and 72 hr are usually satisfactory. A timing device should be located near the consolidometer to ensure accurately timed measurements. Allow the load increment to remain on the specimen until it is determined that the primary swell is completed. Time to complete the primary swell of heavy clay soils and clay shales often requires three or more days. Plot the dial reading versus time data on a semilogarithmic plot as shown in Plate VIIIA-1 to ascertain the completion of primary swell. The completion of

primary swell is arbitrarily defined as the intersection of the tangent to the curve at the point of inflection, with the tangent to the straight-line portion representing a secondary time effect as shown in Figure 1. This is similar to the procedure in paragraph 5j, Appendix VIII, CONSOLIDATION TEST.

(11) Although a falling-head permeability test may be performed at this point of the swell test (see paragraph 8, Appendix VII, PERMEABILITY TESTS), the specimen may not be fully saturated and the permeability results consequently affected. After primary swell is complete,† the load should be removed in decrements according to the procedure in paragraphs 5l and 5m, Appendix VIII, CONSOLIDATION TEST. The final load should be the seating load.

b. Swell Pressure Test. The procedure of this test is identical with the preceding swell test through (9). Following (9), increments of load are applied as needed to prevent swell. Variations from the dial reading at the time the specimen is inundated with water should be kept preferably within 0.0002 in. and not more than 0.0005 in. Following 24 hr after the specimen exhibits no further tendency to swell, a falling-head permeability test may be performed (see paragraph 8, Appendix VII, PERMEABILITY TESTS) and the final load (which is also the swell pressure) should be removed in decrements according to the procedure in paragraphs 5l and 5m, Appendix VIII, CONSOLIDATION TEST. The final load should be the seating load.

4. COMPUTATIONS. The computations for the swell tests are similar to those presented in paragraph 6, Appendix VIII, CONSOLIDATION TEST.

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† After primary swell is complete, the loading pressure may be increased to consolidate the specimen until the void ratio is less than the initial void ratio under the overburden pressure; thereafter, loads may subsequently be removed to determine rebound characteristics. This procedure permits an alternative measure of the swell pressure, defined as the total pressure required to reduce the void ratio to the initial void ratio.

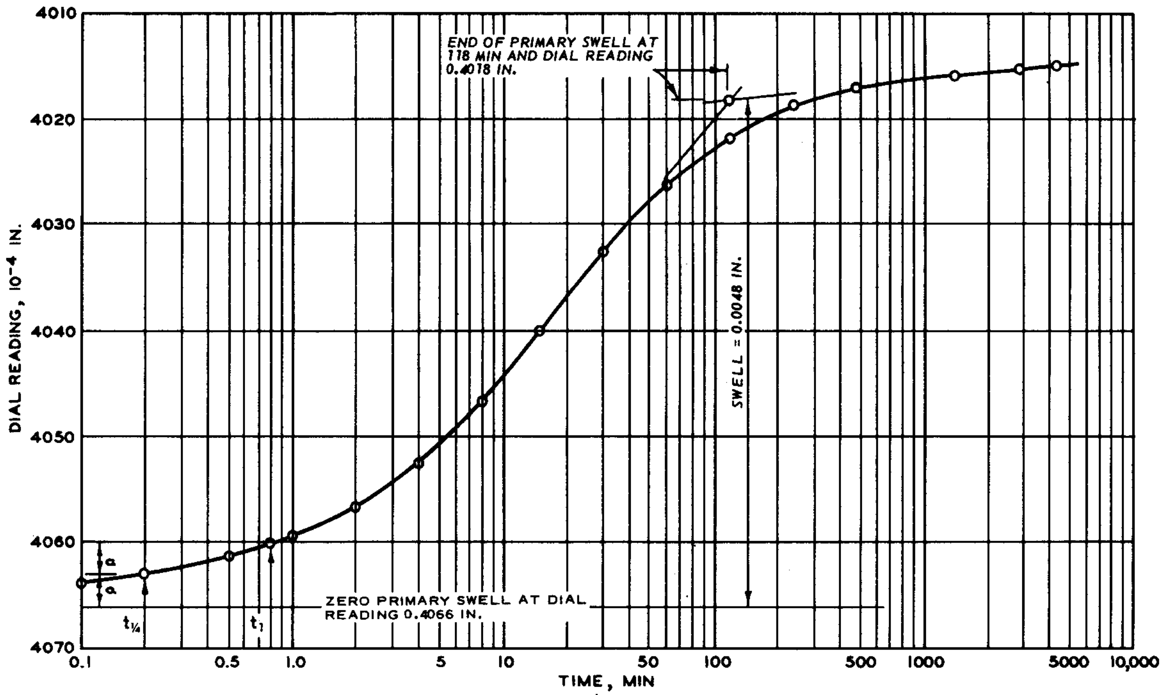

Figure 1. Time-swell curve

5. PRESENTATION OF RESULTS. The results of the swell tests shall be summarized on report forms, Plates VIIIA-1 and VIIIA-2. The data shall be shown graphically in terms of time-swell curves on the form shown as Plate VIIIA-1 and in terms of void ratio-pressure curves on the form shown as Plate VIIIA-2. To obtain the void ratio-pressure curve, the void ratio, e, is plotted on the arithmetic scale (ordinate) and the corresponding pressure, p, in tons per square foot on the logarithmic scale (abscissa) as shown in Figures 2 and 3. The overburden pressure, p_o, swell pressure, p_s, swell index, C_s, and swell at p_o, $\Delta H/H$, shall be determined and shown on the report form (Plate VIIIA-2). The determination of the overburden pressure is normally made by design engineers.

The swell pressure, p_s, is determined as in Figure 3. The swell pressure by the alternative definition in the footnote of paragraph 3

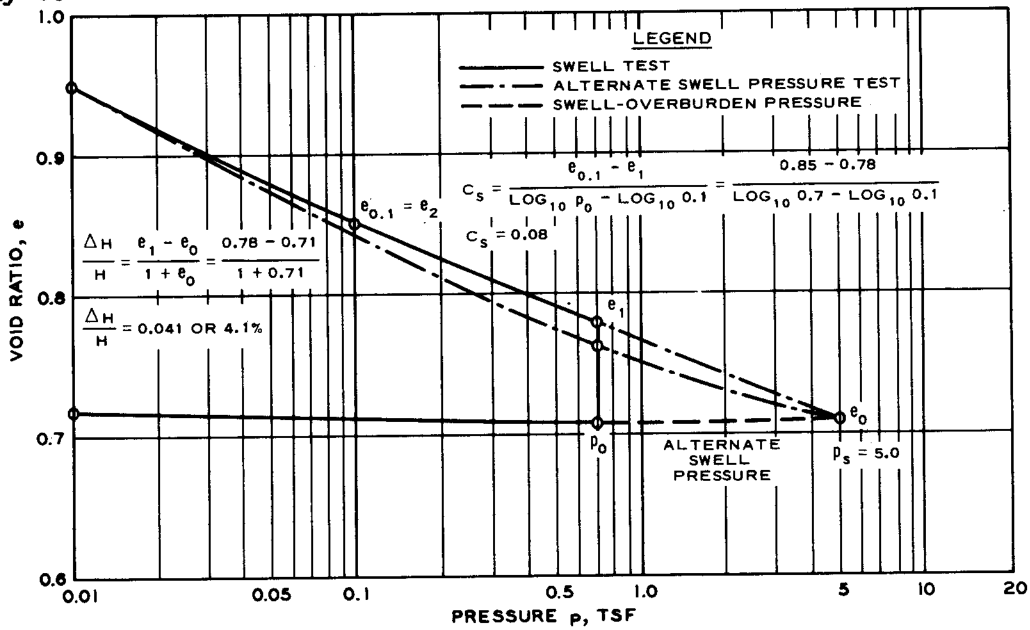

Figure 2. Void ratio-pressure curve of swell test

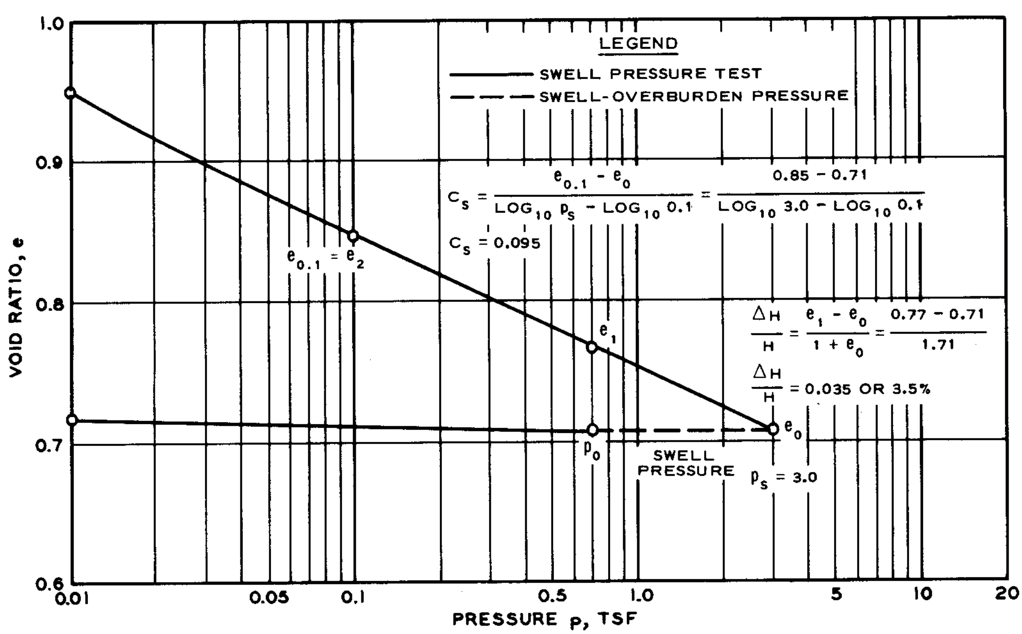

Figure 3. Void ratio-pressure curve of swell pressure test

may also be determined from the results of the swell test (Fig. 2) and recorded on Plate VIIIA-2. The initial void ratio is the void ratio determined following placement of the overburden pressure.

The swell index is defined by the equation

$$C_s = \frac{e_2 - e_1}{\log_{10} p_1 - \log_{10} p_2}$$

where p_1 and p_2 are selected pressures from a straight-line portion of a void ratio-pressure rebound curve, and e_1 and e_2 are the corresponding void ratios. The swell index is a measure of the ability of the soil to swell. Example computations of C_s are shown in Figures 2 and 3.

The swell is defined by the equation

$$\frac{\Delta H}{H} = \frac{e_1 - e_0}{1 + e_0}$$

where e_1 is the void ratio following swell, and e_0 is the void ratio prior to swell. Example computations are shown in Figures 2 and 3 for swell at the overburden pressure p_o.

If permeability tests are performed in conjunction with the swell tests (see Appendix VII, PERMEABILITY TESTS), the coefficient of permeability determined for each void ratio during rebound shall also be plotted in the form shown as Plate VIIIA-2.

A brief description of undisturbed specimens should be given on the report form. The description should include color, approximate consistency, and any unusual features (such as stratification, fissures, shells, roots, sand pockets, etc.). For compacted specimens, give the method of compaction used and the relation to maximum density and optimum water content.

6. POSSIBLE ERRORS. In addition to the possible errors discussed in paragraph 8, Appendix VIII, CONSOLIDATION TEST, the following may also cause inaccurate determination of swelling characteristics:

a. Displacements caused by seating of the specimen against the surface of the porous stones may be significant, especially if swell displacements and loading pressures are small. Thus, smoothly ground porous stones are recommended.

b. Filter paper is highly compressible and contributes to the observed displacements and hysteresis in displacements on loading and rebound. Filter paper is consequently not recommended.

c. The compressibility characteristics of the consolidometer and the test procedures influence the swell pressure results. Because very small expansions in volume greatly relieve swell pressures, the stiffness of the consolidometer should be as large as possible, and variations in displacements that occur during determination of the swell pressure should be as small as possible.

d. Swelling characteristics determined by consolidometer swell tests for the purpose of predicting heave of foundation and compacted soils are not representations of many field conditions because:

(1) Lateral swell and lateral confining pressures are not simulated.

(2) The actual availability of water to the foundation soils may be cyclic or intermittent. Field swell usually occurs under constant overburden pressure depending on the availability of water. The swell index, in contrast, is evaluated by observing swell due to decreases in overburden pressure while the soil specimen is inundated with water.

(3) Rates of swell indicated by swell tests are not reliable indicators of field rates of swell due to fissures in the mass soil and inadequate simulation of the actual availability of water to the soil.

(4) Secondary or long-term swell, which is not evaluated by these test procedures, may be significant for some clays and clay shales. These soils may not be fully saturated at the conclusion of the swell test.

(5) Chemical content of the inundating water affects results; e.g., when testing shales, distilled water may give radically different results than natural or reconstituted pore water.

SWELL TEST-TIME CURVES (TRANSLUCENT)		Date
Project		
Boring No.	Sample No.	Depth El

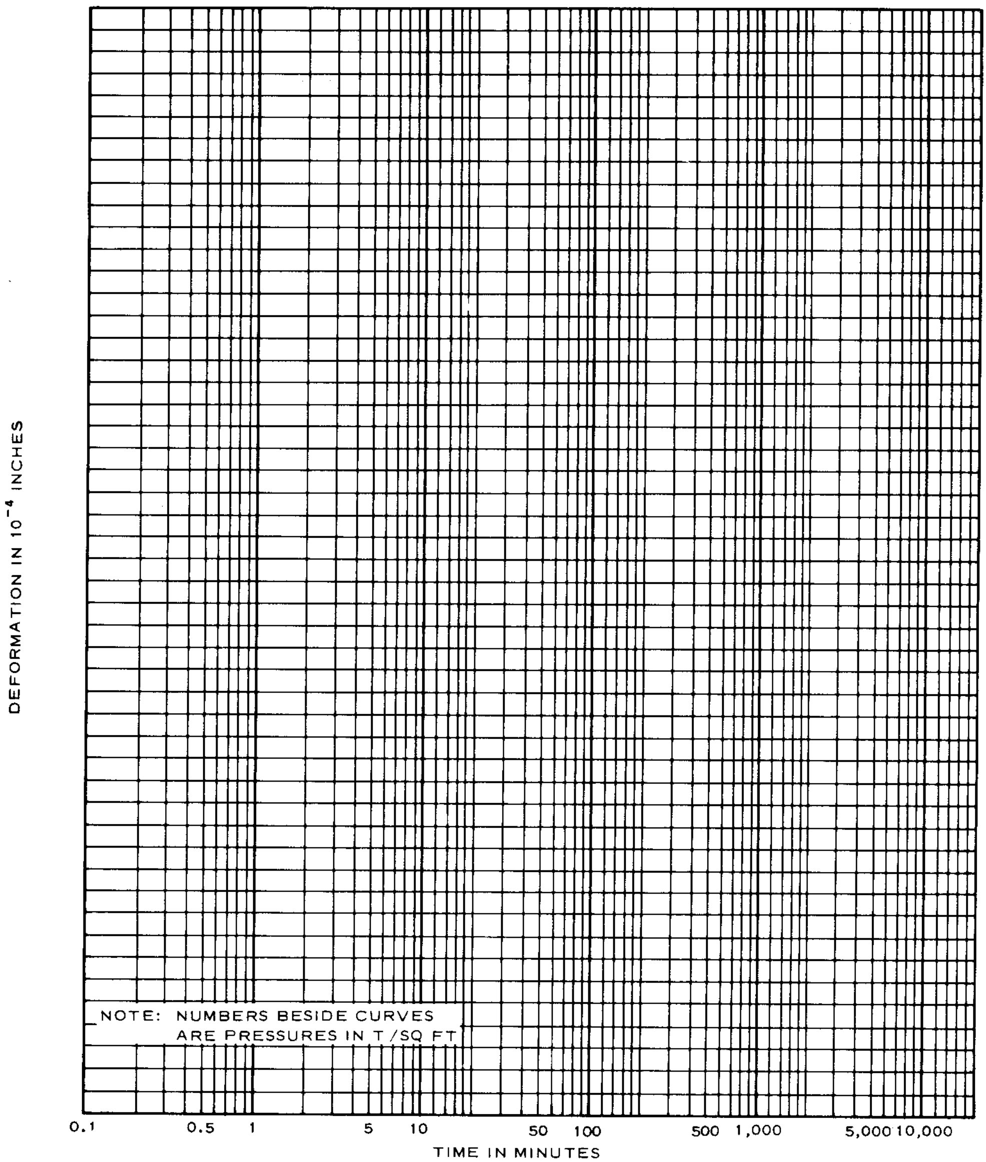

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PLATE VIIIA-1

SWELL TEST REPORT				Date
Project				
Boring No.	Sample No.		Depth El	
Type of Specimen		Type of Swell Test		
Diam in.	Ht in.	Before Test		After Test
Overburden Pressure, P_o	TSF	Water Content, w_o		w_o
Swell Pressure, p_s	TSF	Void Ratio, e_o at p_o	%	e_f
Swell Index, C_s		Saturation, S_o	%	S_f
Swell at p_o, $\frac{\Delta H}{H}$	%	Dry Density, γ_d	lb/ft^3	
Classification		k_{20} at p_o = x 10^- cm/sec		
LL	G_s			
PL	D_{10}			
Remarks				

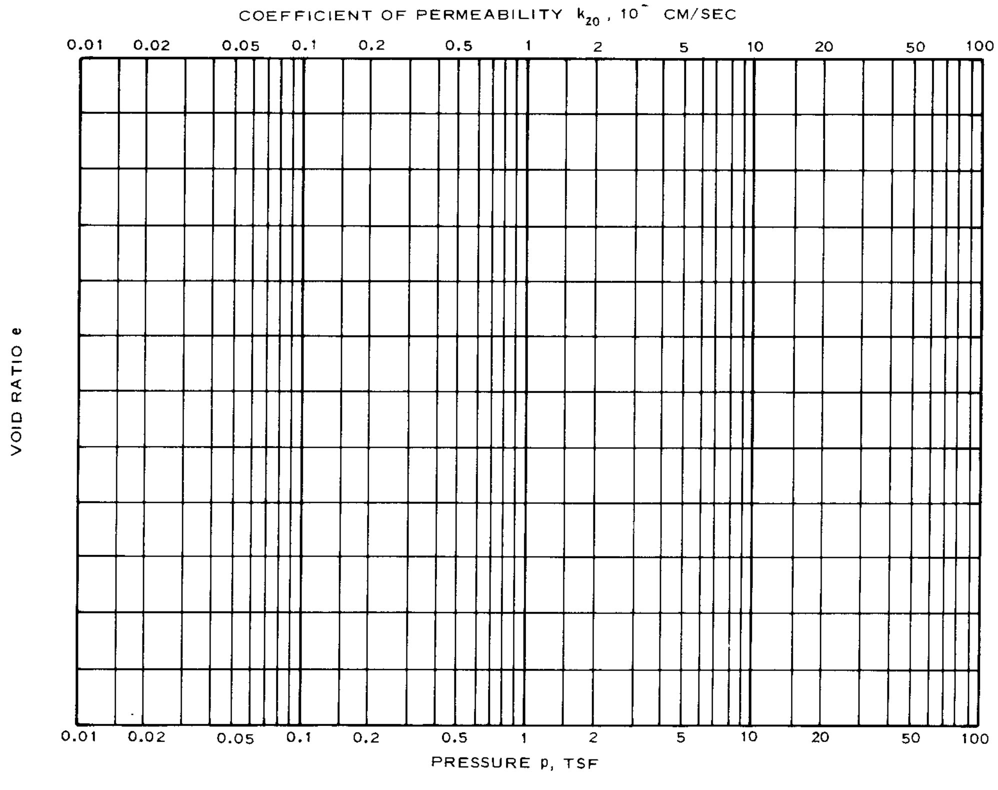

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PLATE VIIIA-2