APPENDIX E
LABORATORY CONSOLIDOMETER TESTS

E-1. General. The following laboratory tests are described which may be used to evaluate consolidation parameters of compressible soils. The Step Load (SL) and Rapid Load (RL) tests are normally recommended. The Constant Rate of Deformation (CRD) and Controlled Gradient (CG) tests were developed to reduce the time required to complete the test relative to the SL test.

E-2. Step Load Test (SL). This test described in Chapter VIII, EM 1110-2-1906, Laboratory Soils Testing, and ASTM D 2435, One-Dimensional Consolidation Properties of Soils, may be performed with fixed or floating ring consolidometers, Figure E-1. A uniform vertical loading pressure is applied on the loading plate in increments to a thin specimen. The specimen should not be less than 2.00 inches in diameter by 0.5 inch in height. The decrease in height of the specimen following axial drainage of water from the specimen for each pressure increment is monitored with time. The duration of each pressure increment is usually 24 hours. Lateral strain is prevented by the specimen ring.

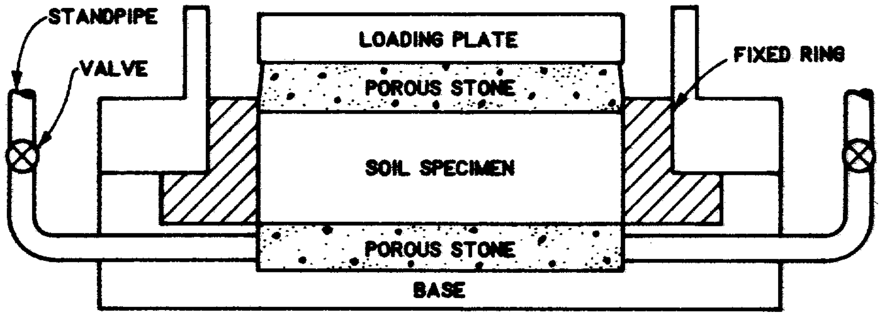
a. Specimen Preparation. Undisturbed specimens shall be trimmed in a humid room to prevent evaporation of soil moisture. A glass plate may be placed on top of the specimen and the specimen gently forced into the specimen ring during the trimming operation. A cutting tool is used to trim the specimens to accurate dimensions. The top and bottom surfaces of the specimen are trimmed flush with the specimen ring. Compacted specimens may be compacted directly into a mold which includes the specimen ring.

b. Test Procedure. The specimen and specimen ring are weighed and then assembled in the loading device, Figure E-1. An initial dial indicator reading is taken. The seating pressure from the top porous stone and loading plate should not exceed 0.01 tsf. The specimen is inundated after a pressure of 0.25 tsf is applied to the specimen; additional load increments should be applied if the specimen swells until all swelling ceases. Loading increments are applied to the specimen in increments of 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 tsf. Each load increment should remain a minimum of 24 hours or until primary consolidation is completed. The data may be plotted as illustrated in Figure 3-17.

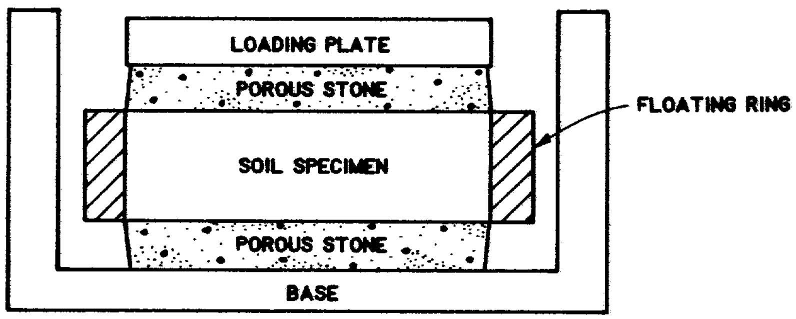
c. Possible Errors. Sources of error in consolidation results include sample disturbance, specimen not completely filling the ring, too low permeability of porous stones, friction between the specimen and specimen ring, and unsatisfactory height of the specimen.

(1) Friction. Side friction may be reduced by using larger diameter specimens, thinner specimens, or lining the consolidation ring with teflon.

(2) Specimen height. The specimen thickness determines how clearly the break in the consolidation-time curve represents completion of primary consolidation. Specimens that are too thin may cause the time to 100 percent consolidation to be too rapid. The break in the curve indicating end of primary consolidation may be obscured by secondary compression if the specimen is too thick.



a. FIXED-RING CONSOLIDOMETER



b. FLOATING-RING CONSOLIDOMETER

Figure E-1. Schematic diagrams of fixed-ring and floating-ring consolidometers

d. Time Requirements. A properly conducted test may take several weeks or months and may be especially time consuming for soft or impervious soil.

E-3. Rapid Load Test (RL). The RL test is similar to the SL test except much larger pressure increment ratios may be used and the duration of each pressure increment is restricted. The time duration is usually limited to allow only 90 percent of full consolidation as evaluated by Taylor's square root of time method, Table 3-11. Refer to item 47 for further details.

a. Time Requirements. This test may be performed in a single day.

b. Accuracy. Accuracy is similar to the SL procedure.

c. Pressure Increments. Large pressure increments exceeding those of the SL test for applied pressures exceeding the maximum past pressure reduces the amount of secondary compression contained in the void ratio-logarithm time curve, Figure 3-17.

E-4. Constant Rate of Deformation Test (CRD). A thin, cylindrical soil specimen similar to that of the SL test is saturated at constant volume under a back pressure and loaded vertically without lateral strain at a constant rate of vertical strain. Drainage is permitted only from the upper surface of the specimen. A general purpose consolidometer capable of this test procedure is shown in Figure E-2.

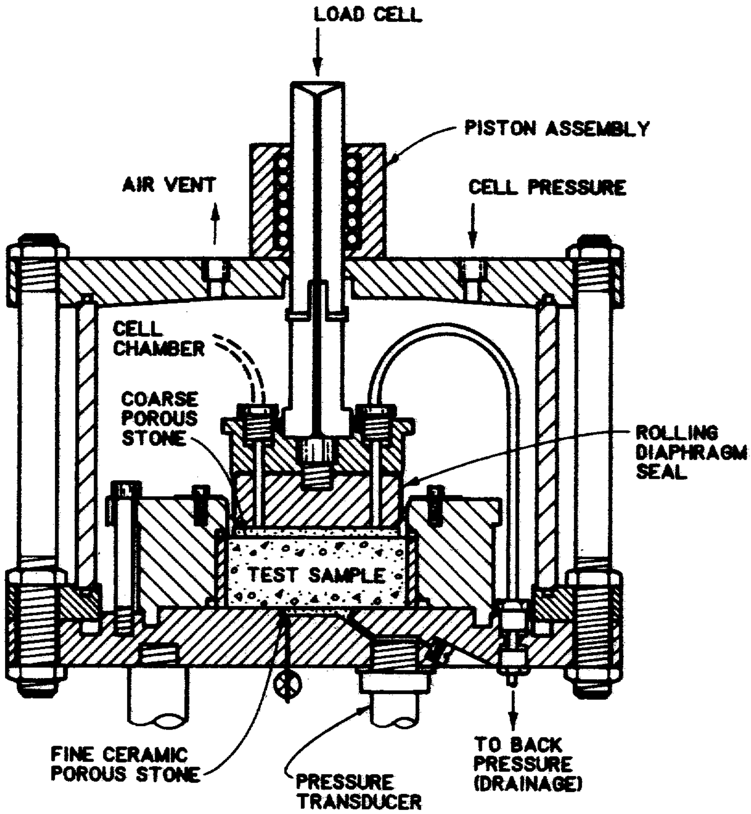


Figure E-2. General purpose consolidometer. Reprinted by permission of the American Society of Civil Engineers from the Journal of the Soil Mechanics and Foundations Division, Vol 97, 1971, "Consolidation at Constant Rate of Strain", by A. E. Z. Wizza, J. T. Christian, and E. H. Davis, p 1394

a. Evaluation of Maximum Past Pressure. The maximum past pressure determined by this procedure is dependent on the rate of strain and increases with increase in strain rate. The strain rate should be consistent with expected field rates. Typical field strain rates are about 10^{-7} per minute.

b. Evaluation of Coefficient of Consolidation. c_v should be evaluated by (item 67)

$$c_v = \frac{h^2 \bullet \log_{10}\frac{\sigma_2}{\sigma_1}}{2 \bullet \Delta t \bullet \log_{10}\left[1 - \frac{u_h}{\sigma_a}\right]} \qquad \text{(E-1)}$$

where

h = average thickness of drainage path (specimen thickness), in.
σ_1 = total vertical stress at time t_1, psi
σ_2 = total vertical stress at time t_2, psi
Δt = $t_2 - t_1$, minutes
u_h = average excess pore water pressure at the bottom of the specimen over the time interval t_1 and t_2, psi
σ_a = $(\sigma_1 + \sigma_2)/2$, average total vertical stress over time interval t_1 and t_2, psi

The coefficient of consolidation c_v determined by this method appears comparable with that of the SL test.

c. Evaluation of Void Ratio-Logarithm Pressure Relationship. The void ratio-logarithm pressure relationship may be obtained by determining the void ratio and effective stress at any time during the test.

(1) The change in void ratio Δe over a pressure increment is $(1 + e_1)\varepsilon$ where e_1 is the void ratio at the beginning of the pressure increment and ε is the strain over the pressure increment.

(2) The average effective stress over a pressure increment is $\sigma_a - u_h$.

(3) The excess pore water pressure u_h is measured at the bottom of the specimen, Figure E-2.

d. Assumptions. This method assumes that the coefficient of consolidation and compression index are constant for the soil.

E-5. Controlled Gradient Test (CG). This test is similar to the CRD test except that the applied vertical pressure is adjusted so that the pore water pressure at the bottom of the specimen remains constant throughout the test (item 38). This restriction requires a feedback mechanism that significantly complicates the laboratory equipment.

a. Evaluation of Coefficient of Consolidation. The coefficient of consolidation may be estimated by

$$c_v = \frac{\Delta\sigma \bullet h_a^2}{\Delta t \bullet 2u_h} \qquad \text{(E-2)}$$

where

$\Delta\sigma$ = change in total pressure between time increment t_2 and t_1 , psi
Δt = $t_2 - t_1$, minutes
h_a = average height of specimen between time t_2 and t_1 , in.
u_h = excess pore water pressure at bottom of the specimen, psi

b. Evaluation of Void Ratio-Logarithm Pressure Relationship. The void ratio-logarithm pressure relationship is evaluated similar to the above procedures. The excess pore water pressure at the bottom of the specimen should be kept as small as possible to maintain a nearly uniform void ratio within the specimen.

c. Assumptions. This method assumes that the coefficient of consolidation and coefficient of volume change are constant. The coefficient of volume change is the change in strain divided by the change in total vertical stress.