APPENDIX D

DREDGED MATERIAL CONSOLIDATION TEST PROCEDURES

D-1. General. The accuracy of any calculation of the consolidation behavior of fine-grained dredged material is only as good as the soil parameters used. It is therefore very important that the necessary time and resources be allocated to field sample testing and interpretation of the results. Procedures for obtaining sediment samples are found in Chapter 2. This appendix describes methods of consolidation testing, recommended oedometer test procedures for dredged material, and test data interpretation.

D-2. Consolidation Testing. There are essentially three methods of conducting consolidation tests on fine-grained dredged material. They are the self-weight settling test, the controlled rate of strain test, and the oedometer test. Each of these methods has its advantages and disadvantages, and a combination is usually desirable.

a. Self-weight Settling Test. The self-weight settling test is advantageous in determining the void ratio-effective stress relationship at very low levels of effective stress. However, to cover the range of stresses encountered during the consolidation of a prototype dredged fill deposit, the settling column height must equal that of the prototype. If the settling column height equals that of the dredged fill layer, then the time required to complete the test could be on the order of years for typical layers. This is not practical in most situations; so for efficiency, the settling test should be supplemented with one of the other type tests for the higher effective stresses.

b. Controlled Rate of Strain Test. A large-strain controlled rate of strain device specifically for the purpose of testing fine-grained dredged material is now under development. When such a device is available, it is recommended that it be routinely used to define consolidation properties at the high void ratios common to dredged fill.

c. Oedometer Test. The most common type of consolidation testing currently available is the oedometer test. The apparatus required by this test is found in all well-equipped soils laboratories, and the test has been used successfully on numerous dredged materials. Disadvantages of the test include:

(1) The fact that void ratio-effective stress relationships at very low (<0.005 tons per square foot) levels of effective stress are generally not possible.

(2) The fact that the time required between load increments may sometimes be 2 weeks or more.

(3) The fact that large strains during a given load increment add to the uncertainties of test data analysis for coefficients of consolidation and permeabilities.

(4) The question of whether a thin oedometer sample with no initial excess pore pressure when subjected to a sudden load increment reacts the same as an underconsolidated thick sample whose excess pore pressure is slowly decreased. Regardless of the disadvantages, the fact that it is the most common and readily available test is an advantage that makes the oedometer test the most attractive for dredged material today.

D-3. Recommended Oedometer Test Procedure.

a. Oedometer testing of very soft dredged fill materials is accomplished essentially as specified in EM 1110-2-1906 for stiffer soils. The major difference is in the initial sample preparation and the size of the load increments. The majority of dredged fill samples will be in the form of a heavy liquid rather than a mass capable of being handled and trimmed.

b. Before testing begins, both accurate and buoyant weights of the top porous stone and other items between the sample and dial gage stem should be determined because this will be a major part of the seating load. The force exerted by the dial indicator spring must also be determined for the range of readings initially expected because this will constitute the remainder of the seating load and will be considered the first consolidating load applied to the sample. The dial gage force is determined using a common scale or balance. Samples are prepared for testing by placing a saturated bottom porous stone, filter paper, and consolidometer ring on the scale and then recording their weights. Without removing this apparatus from the scale, material is placed in the ring with a spatula. The material is placed and spread carefully to avoid trapping any air within the specimen. After slightly overfilling the ring with material, the excess is screeded with a straightedge, with care being taken not to permit excess material to fall onto the scale. After a level surface flush with the top of the ring is obtained, the ring top is wiped clean and a final weight recorded.

c. The ring with bottom stone is next assembled with the remainder of the consolidometer apparatus. Care must be taken not to jar or otherwise disturb the sample during this process. Once the consolidometer is ready, it is placed on the loading platform, and assembly is completed. As soon as the seating load is placed, the water level in the consolidometer should be brought level with the top of the top porous stone and held there through at least the first three load increments or until the difference in the actual weight and buoyant weight of the seating load is insignificant. Thereafter, the level of the water is not important so long as the sample is kept inundated.

d. Since some consolidation will normally occur very rapidly when the seating load is placed, it is important that this first load is placed very quickly, to include the dial gage. If all induced settlement is not accounted for, later calculations may be inconsistent. It may be necessary to use a table level or some other measuring device to check the height of the top of the porous stone above the sample ring at some time during this first load increment. Of course, the thickness of the top porous stone and filter paper must have been previously measured. In this way, a reconciliation between deformation recorded by the dial gage and actual deformation can be made.

e. After the sample has been subjected to the seating load, dial gage readings are taken at times 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 8.0, 15.0, and 30.0 minutes; 1, 2, 4, 8, and 24 hours; and daily thereafter until primary consolidation is complete as determined by the time-consolidation curve. The first series of readings is valid for determination of the first point of the e-log-σ' curve and may be used in coefficient of consolidation or permeability determinations if the seating load is placed quickly and in a manner so as not to induce extraneous excess pore pressures.

f. Consolidation of the sample is continued according to the following recommended loading schedule: 0.005, 0.01, 0.025, 0.05, 0.10, 0.25, 0.50, and 1.00 tons per square foot. Exactly what the first load increment will equal depends on the weight of the top porous stone, loading column, and dial gage force. To keep the dial gage force relatively constant throughout testing, the dial gage may have to be reset periodically. If so, it should be reset just before the next load increment is placed and not during a load increment. If consolidation behavior at loads much greater than about 1.0 ton per square foot is required, it is recommended that samples which have been preconsolidated to 0.5 ton per square foot be used, since most typical dredged fill samples will have undergone more than 50-percent strain by the time the above loading schedule is completed. Experience has shown that extrapolation of the e-log-σ' curve produced from the recommended loading schedule to lower void ratios should yield reasonably accurate results, providing that the void ratios through the extrapolated range are greater than about 1.0.

g. When primary consolidation Is completed under the final load of the schedule, the difference between the tops of the top porous stone and the top of the sample ring should again be determined by a table level or other measuring device as a second check on final sample height as determined from dial gage readings. This check is considered important, since the dial gage will probably have been reset several times during the loading schedule. Before the dial gage is removed, the sample should be unloaded and allowed to rebound under the seating load and dial gage force only. When the sample is fully rebounded, a final dial gage reading is made, and the sample is removed for water content and weight of solids measurements.

h. The preceding recommended test procedure is not meant to replace the more comprehensive treatment of EM 1110-2-1906 or other soils testing manuals. Its purpose is merely to point out where the conventional procedure must be modified or supplemented to handle extremely soft dredged fill material. A final recommendation is that a specific gravity of solids test always be accomplished for the actual material consolidated, since calculations are very sensitive to this value and typical estimated values may lead to significant error.

D-4. Calculation of Permeability. Since the conditions of the oedometer test correspond very closely with those assumed in small strain consolidation theory when data are analyzed for each load increment, there is probably no advantage in using the more complicated finite strain theory in deducing permeability. Then the expression can be written:

$$k = \frac{T_u \bar{H}^2 \gamma_w \bar{a}_v}{(1 + \bar{e})t} \qquad \text{(D-1)}$$

where

k = coefficient of permeability, centimetres per second

T_u = time factor for specified percent consolidation

$\bar{H}$ = effective specimen thickness, centimetres

a_v = coefficient of compressibility, square centimetres per gram

e = void ratio

t = time required to reach specified percent consolidation, second

The bar indicates average values during the load increment. If 50-percent consolidation is assumed to occur simultaneously with 50-percent settlement, the equation can be written:

$$k = \frac{0.197 \bar{H}^2 \alpha_w \bar{a}_v}{(1 + \bar{e})t_{50}} \qquad \text{(D-2)}$$

where t_{50} is the time required for 50-percent settlement from the compression-time curve for the particular load increment. The values for k are then plotted versus e , and a smooth curve drawn through the points.