Shrink-Swell Potential of Soils*

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ABRIDGMENT

•THIS IS a report on a laboratory method for determining the shrink-swell potential of soils. In a recent study by the Bureau of Public Roads, a new test procedure has been developed. The purpose of the study was to develop a rapid, reliable method for measuring the potential volume change of soils subjected to alternate wetting and drying.

The results of most test procedures for measuring volume change characteristics of soils are affected by the molding moisture and density condition of the test specimen. For example, dense dry soils swell more than loose wet soils when soaked, while loose wet soils shrink more than dense dry soils when dried. Thus, tests measuring either shrinking or swelling alone are not suitable for determining a soil's shrink-swell potential since the test results are dependent on the initial moisture and density condition.

In an attempt to find a suitable method for determining shrink-swell potential, 2 other types of tests were examined: (a) the Georgia volume-change test, and (b) a rapid cyclic wetting and drying procedure based on Porter's work in Texas.

Tests were first made by the Georgia method. This method for determining volume change measures both swell and shrinkage. Briefly, the procedure consists of compacting two identical specimens, then one is soaked while the other is dried. The test value is determined from the combined volume change of the two specimens. In some of the Public Roads tests by the Georgia method it was noticed that some medium to low plasticity soils exhibited high swell characteristics when soaked, evidently due to the compaction of the specimen. Also, some high plasticity soils swelled much more during a second soaking than during the normal first soaking period. Both of these occurrences suggested that an approach based on Porter's studies would be more logical.

Consequently, another test procedure was devised to determine whether alternate wetting and drying, as suggested in Porter's studies, would achieve an equilibrium condition of shrinking and swelling regardless of initial moisture and density condition. In this procedure, three 2-in. diameter specimens of soil were molded to cover a wide range of initial moisture and density conditions. After molding, the three specimens were subjected to 4 cycles of alternate wetting and drying under a ¼-psi surcharge. Figure 1 shows the molds, surcharges and dial indicator for measuring changes in height.

Using the cyclic wetting and drying procedure, tests were made on 12 soils having a wide range of shrink-swell potential. They ranged from a silt having a PI of 4 (low shrink-swell potential) to a bentonite having a PI above 300 (very high shrink-swell potential). Wet-dry cyclic changes in height for two of the soils having quite different volume-change characteristics are shown in the next two figures.

Figure 2 shows the changes in height for Cecil soil which has a low shrink-swell potential. During the first soaking, the height change of the specimen compacted air dry was much more than occurred in the specimen which was compacted at optimum moisture content. However, after drying, the height change of these two specimens during the second soaking is more nearly the same. After 2 more cycles, the height change is approximately equal for all three specimens.

Figure 3 shows the changes in height for Iredell soil, which has a high shrink-swell potential. As occurred in the Cecil soil, the greatest differences in height changes

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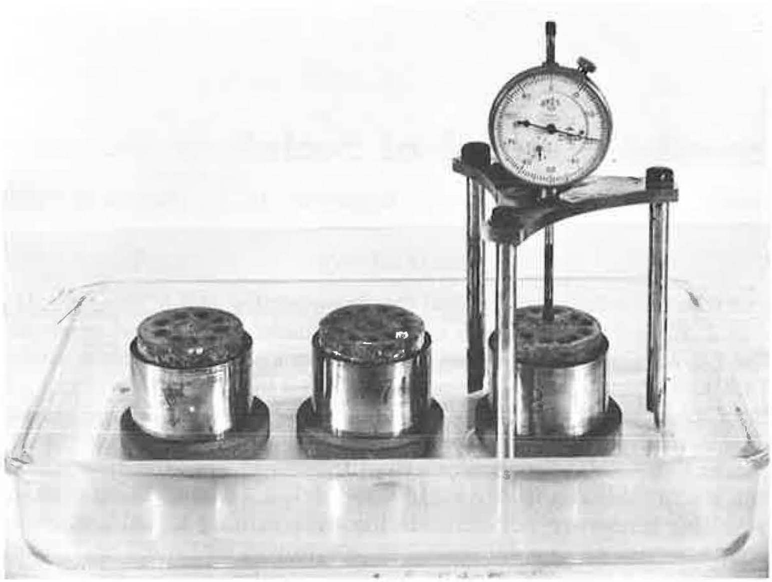

Figure 1. Apparatus for cyclic wetting and drying test.

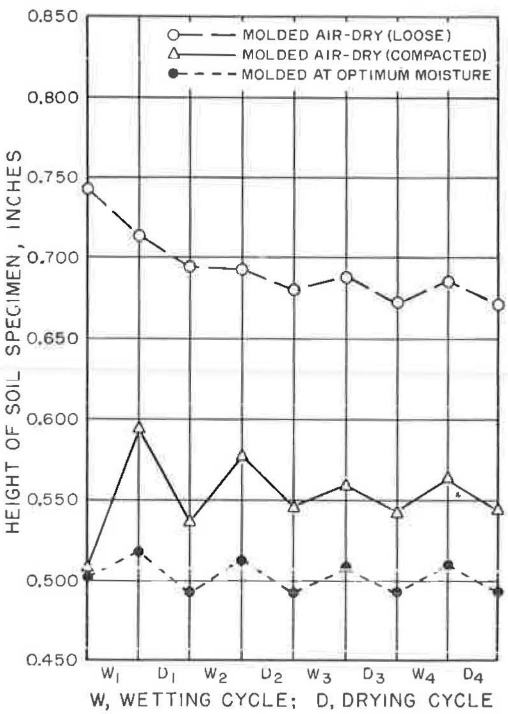

Figure 2. Height change of 3 specimens of Cecil soil when alternately wetted and dried under a 0.25-psi surcharge.

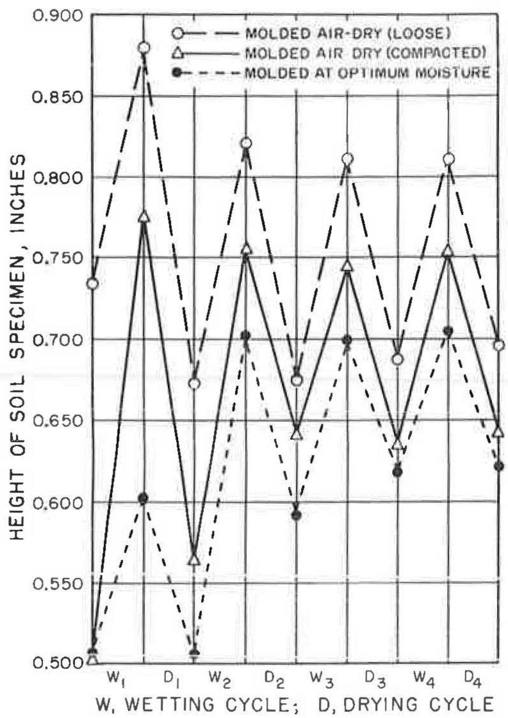

Figure 3. Height change of 3 specimens of Iredell clay when alternately wetted and dried under a 0.25-psi surcharge.

between the 3 specimens occurred during the first soaking. However, for both soils, the height change of all specimens was essentially consistant after several cycles of wetting and drying. At this point, the effects of the initial moisture and density condition appear to have been minimized and an equilibrium shrink-swell condition achieved by this procedure. The shrink-swell potential for each soil was then taken as the volume change which occurred during the drying in the 4th cycle. The volume of the specimens before drying was calculated from their measured height and diameter, while the volume of the specimens after drying was measured by mercury displacement.

Up to this point, the study led to a method for determining shrink-swell potential uninhibited by molding moisture and density. However, this cyclic wetting and drying method requires one or more weeks to complete a test. In an effort to shorten the time required to obtain an estimate of shrink-swell potential, it was hoped that shrink-swell potential could be related to some other test requiring less testing time. For this reason, in the second part of the study, the same 12 soils were tested by 8 other volume change or swell pressure tests and the results of the tests compared to the shrink-swell potential.

The 8 other tests were plasticity index, shrinkage limit, AASHO T 190 (expansion pressure), CBR volume change, AASHO T 116 (volume change of soils), the Georgia volume change method, total surface area and linear shrinkage.

Summarizing this second part of the study: the results of the 8 other tests were related to shrink-swell potential with varying degrees of success. Table 1 indicates the general quality of the relationships and presents possible reasons as to why certain soils did not readily conform. Four of the tests, PI, Georgia volume change, surface area and linear shrinkage, appear to be closely related to shrink-swell potential. The Georgia method requires the longest testing time (2 days). Surface area measurements require the next longest time (from 1 to 2 days). The PI and linear shrinkage tests both require from 16 to 24 hours.

Based on the good correlation with shrink-swell potential (Fig. 4) and ease of testing, linear shrinkage was selected as the best substitute for the slower cyclic wetting and drying method.

In conclusion, most previously developed test methods for measuring shrinking and swelling characteristics of soils are influenced by the molded moisture and density of the test specimen.

The objective of this laboratory study, to develop a method to evalute a soils' shrink-swell potential independent of its molding moisture and density, appears to have been reasonably well achieved with the development of a new test method employing cyclic wetting and drying.

Although from 1 to 100 weeks are required to complete a shrink-swell potential test, comparisons of the results obtained by this test to 8 "standard" tests for a wide range of soil types indicate that the linear shrinkage test has real potential as a substitute for the very time-consuming cyclic wetting and drying method.

The relationship of linear shrinkage to shrink-swell potential was very good for the linear shrinkage test method described in the Appendix. However, further investigations, not reported here, were devoted specifically to factors influencing the linear shrinkage test. The primary purpose of these investigations was to find a modified procedure that would provide an even better correlation. Results obtained by an alternate procedure, devised as a result of the supplementary studies, did not correlate as well with shrink-swell potential as those obtained by the test method herein described. The study, however, did show the variables and their quantitative effect on linear shrinkage test results. A limited supply of an informal report on the supplementary study is available. Interested researchers may obtain copies without cost by addressing requests to the Bureau of Public Roads, Washington, D. C., 20235, attention: Materials Division, Office of Research and Development.

APPENDIX

SUGGESTED TEST METHOD FOR DETERMINING THE LINEAR SHRINKAGE OF SOILS

Definition

1. The linear shrinkage of a soil is that change in length of a bar of soil as determined in accordance with the following procedure.

TABLE 1

RELATIONSHIPS OF STANDARD TEST RESULTS TO SHRINK-SWELL POTENTIAL

Test Method or Measurement	Quality of Relationship to Shrink-Swell Potential	Remarks
Plasticity index	Good	May overestimate shrink-swell potential of soils containing iron oxides and inactive clays.
Shrinkage limit	Fair	Underestimates shrink-swell potential of bentonitic soils.
AASHO: T-190	Poor	Molding moisture and density conditions not suitable for prediction of shrink-swell potential.
CBR	Fair	Relationship with shrink-swell potential slightly improved for specimens molded to AASHO: T-180.
AASHO: T-116	Fair	May overestimate the shrink-swell potential of soils sensitive to method of compaction.
Georgia volume change test	Good	May overestimate shrink-swell potential of micaceous soils; method not suitable for bentonite soils.
Surface area	Good	May overestimate the shrink-swell potential of high-activity clays mixed with sands.
Linear shrinkage	Good	Test fairly rapid and easy to perform.

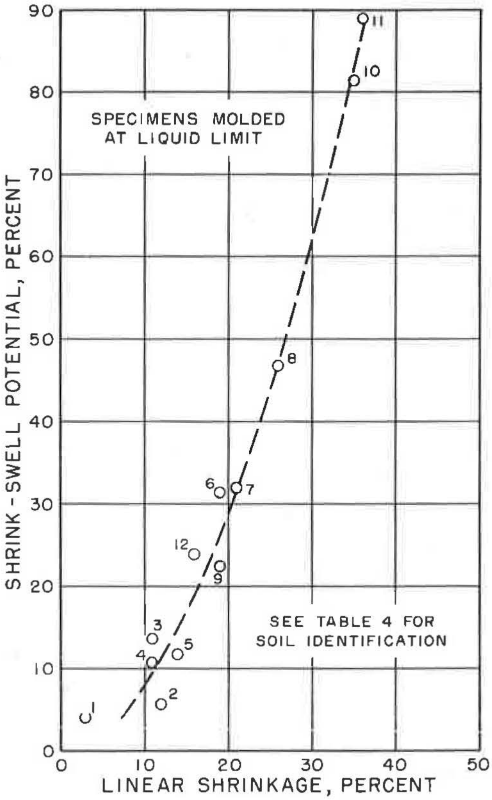

Figure 4. Relation of linear shrinkage to shrink-swell potential.

Apparatus

2. (a) Linear shrinkage mold - A Teflon mold 20 cm long and having a semi-circular cross-section of 2.54-cm diameter
   (b) Commercial petroleum jelly
   (c) Distilled water
   (d) Evaporating dish, about 4½ in. in diameter
   (e) Balance, 500-gm capacity, sensitive to 0.1 gm
   (f) Spatula, having a blade about 3 in. in length and about ¾ in. in width
   (g) Drying oven, 70 C ± 5 C
   (h) Scale, length 30 cm graduated to ½ mm

Sample

3. A sample of air dry soil weighing about 150 gm shall be taken from the thoroughly mixed portion of the material passing the No. 40 (420-micron) sieve.

Procedure

4. (a) The soil sample shall be placed in the evaporating dish and thoroughly mixed with 45 to 60 cc of distilled water by alternately and repeatedly stirring, kneading and chopping with a spatula. Further additions of water shall be made in increments of 3 to 8 cc until the soil is at or slightly above its liquid limit (see AASHO T 89-60). Each increment of water shall be thoroughly mixed with the soil as previously described before another increment of water is added.

(b) The mixture shall be placed in a linear shrinkage mold which has been previously lubricated with 0.30-g petroleum jelly. After firmly pressing the mixture into the mold with the spatula, excess material shall be removed by trimming with the straight edge of the spatula.

(c) The mold containing the mixture shall be placed in an oven at 70 C ± 5 C for 16 hours or until constant weight has been obtained.

Note 1: When the oven must be set at 100 C for other soil tests, linear shrinkage specimens may be dried at this temperature. However, the higher temperature will result in more cracking of the specimen and slightly lower test values.

(d) The soil specimen shall be removed from the oven, allowed to cool and then the length of both the top and bottom measured.

Note 2: For broken specimens, the lengths of the individual pieces should be marked and accumulated on a strip of paper; the total length can be determined directly by measuring the end points on the strip.

Calculation

5. The linear shrinkage of the specimen shall be expressed as follows:
Linear shrinkage (in percent) =

$$\frac{\text{Mold length} - \dfrac{\text{Top + bottom length of dried specimen}}{2}}{\text{mold length}} \times 100$$