

Chapter 3 Laboratory Testing

3-1. General

a. Reference should be made to EM 1110-1-1906 for current soil testing procedures, and to EM 1110-2-1902 for applicability of the various shear strength tests in stability analyses.

b. Laboratory testing programs for levees will vary from minimal to extensive, depending on the nature and importance of the project and on the foundation conditions, how well they are known, and whether existing experience and correlations are applicable. Since shear and other tests to determine the engineering properties of soils are expensive and time-consuming, testing programs generally consist of water content and identification tests on most samples and shear, consolidation, and compaction tests only on representative samples of foundation and borrow materials. It is imperative to use all available data such as geological and geophysical studies, when selecting representative samples for testing. Soil tests that may be included in laboratory testing programs are listed in Table 3-1 for fine-grained cohesive soils and in Table 3-2 for pervious soils, together with pertinent remarks on purposes and scope of testing.

Table 3-1
Laboratory Testing of Fine-Grained Cohesive Soils

Test	Remarks
Visual classification and water content determinations	On all samples
Atterberg limits	On representative samples of foundation deposits for correlation with shear or consolidation parameters, and borrow soils for comparison with natural water contents, or correlations with optimum water content and maximum densities
Permeability	Not required; soils can be assumed to be essentially impervious in seepage analyses
Consolidation	Generally performed on undisturbed foundation samples only where: <ul style="list-style-type: none"> <i>a.</i> Foundation clays are highly compressible <i>b.</i> Foundations under high levees are somewhat compressible <i>c.</i> Settlement of structures within levee systems must be accurately estimated <p>Not generally performed on levee fill; instead use allowances for settlement within levees based on type of compaction. Sometimes satisfactory correlations of Atterberg limits with coefficient of consolidation can be used. Compression index can usually be estimated from water content.</p>
Compaction	<ul style="list-style-type: none"> <i>a.</i> Required only for compacted or semi-compacted levees <i>b.</i> Where embankment is to be fully compacted, perform standard 25-blow compaction tests <i>c.</i> Where embankment is to be semi-compacted, perform 15-blow compaction tests
Shear strength	<ul style="list-style-type: none"> <i>a.</i> Unconfined compression tests on saturated foundation clays without joints or slickensides <i>b.</i> Q triaxial tests appropriate for foundation clays, as undrained strength generally governs stability <i>c.</i> R triaxial and S direct shear: Generally required only when levees are high and/or foundations are weak, or at locations where structures exist in levees <i>d.</i> Q, R, and S tests on fill materials compacted at appropriate water contents to densities resulting from the expected field compaction effort

Table 3-2
Laboratory Testing of Pervious Materials

Test	Remarks
Visual classification	Of all jar samples
In situ density determinations	Of Shelby-tube samples of foundation sands where liquefaction susceptibility must be evaluated
Relative density	Maximum and minimum density tests should be performed in seismically active areas to determine in situ relative densities of foundation sands and to establish density control of sand fills
Gradation	On representative foundation sands: a. For correlating grain-size parameters with permeability or shear strength b. For size and distribution classifications pertinent to liquefaction potential
Permeability	Not usually performed. Correlations of grain-size parameters with permeability or shear strength used. Where underseepage problems are serious, best guidance obtained by field pumping tests
Consolidation	Not usually necessary as consolidation under load is insignificant and occurs rapidly
Shear strength	For loading conditions other than dynamic, drained shear strength is appropriate. Conservative values of ϕ' can be assumed based on S tests on similar soils. In seismically active areas, cyclic triaxial tests may be performed

3-2. Classification and Water Content Determinations

After soil samples have been obtained in subsurface exploration of levee foundations and borrow areas, the first and essential step is to make visual classifications and water content determinations on all samples (except that water content determinations should not be made on clean sands and gravels). These samples may be jar or bag samples obtained from test pits, disturbed or undisturbed drive samples, or auger samples. Field descriptions, laboratory classifications, and water content values are used in preparing graphic representations of boring logs. After examining these data, samples of fine-grained soils are selected for Atterberg limits tests, and samples of coarse-grained soils for gradation tests.

Section I

Fine-Grained Soils

3-3. Use of Correlations

Comparisons of Atterberg limits values with natural water contents of foundation soils and use of the plasticity chart itself (Figure 3-1), together with split-spoon driving resistance, geological studies, and previous experience often will indicate potentially weak and compressible fine-grained foundation strata and thus the need for shear and perhaps consolidation tests. In some cases, in the design of low levees on familiar foundation deposits for example, correlations between Atterberg limits values and consolidation or shear strength characteristics may be all that is necessary to evaluate these characteristics. Examples of correlations among Atterberg limits values, natural water content, shear strength and consolidation characteristics are shown in Figures 3-2 and 3-3. Correlations based on local soil types and which distinguish between normally and overconsolidated conditions are preferable. Such correlations may also be used to reduce the number of tests required for design of higher levees. As optimum water content may in some cases be correlated with Atterberg limits, comparisons of Atterberg limits and natural water contents of borrow soils as shown in Figure 3-4 can indicate whether the borrow materials are suitable for obtaining adequate compaction.

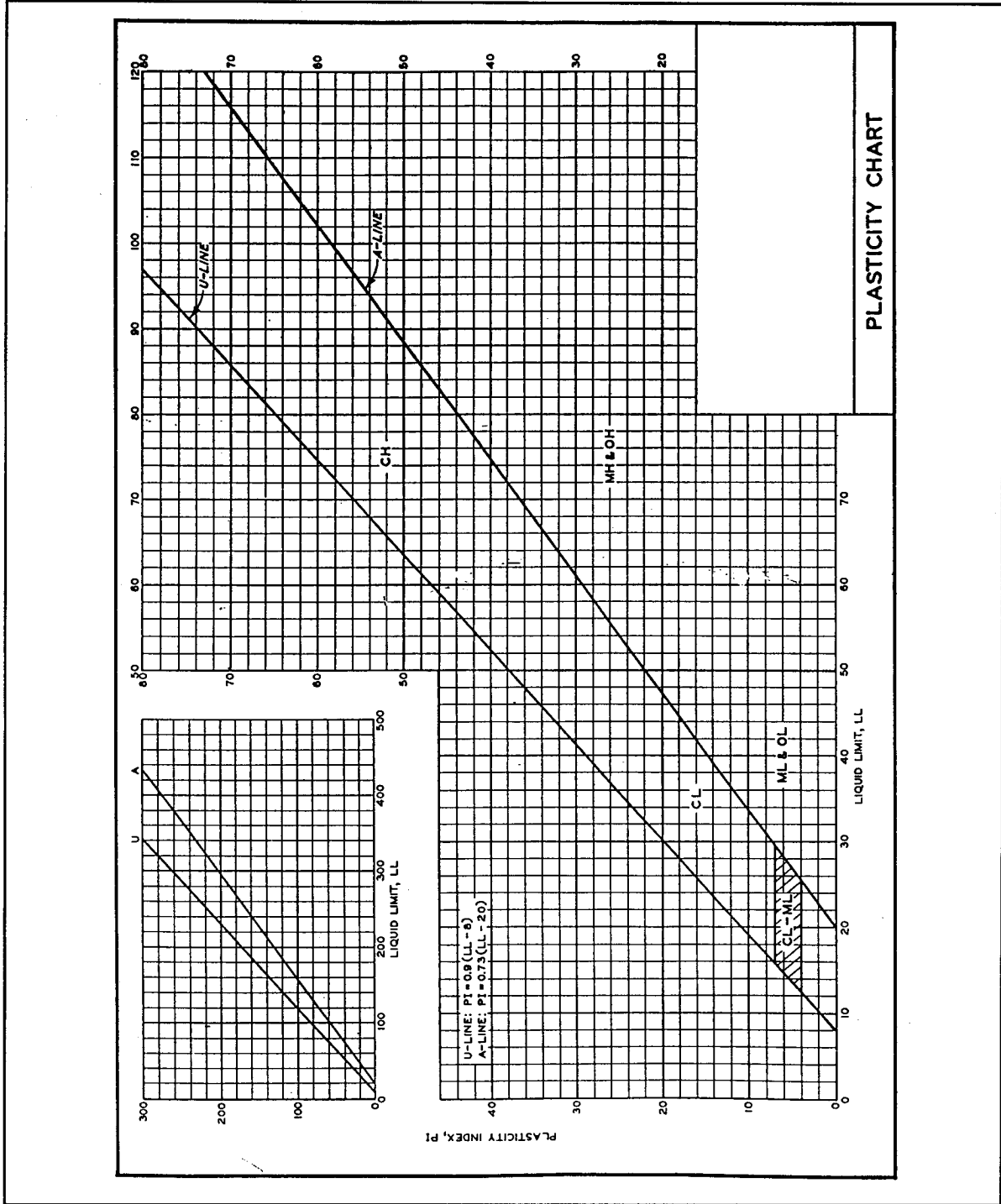


Figure 3-1. Plasticity chart (ENG Form 4334)

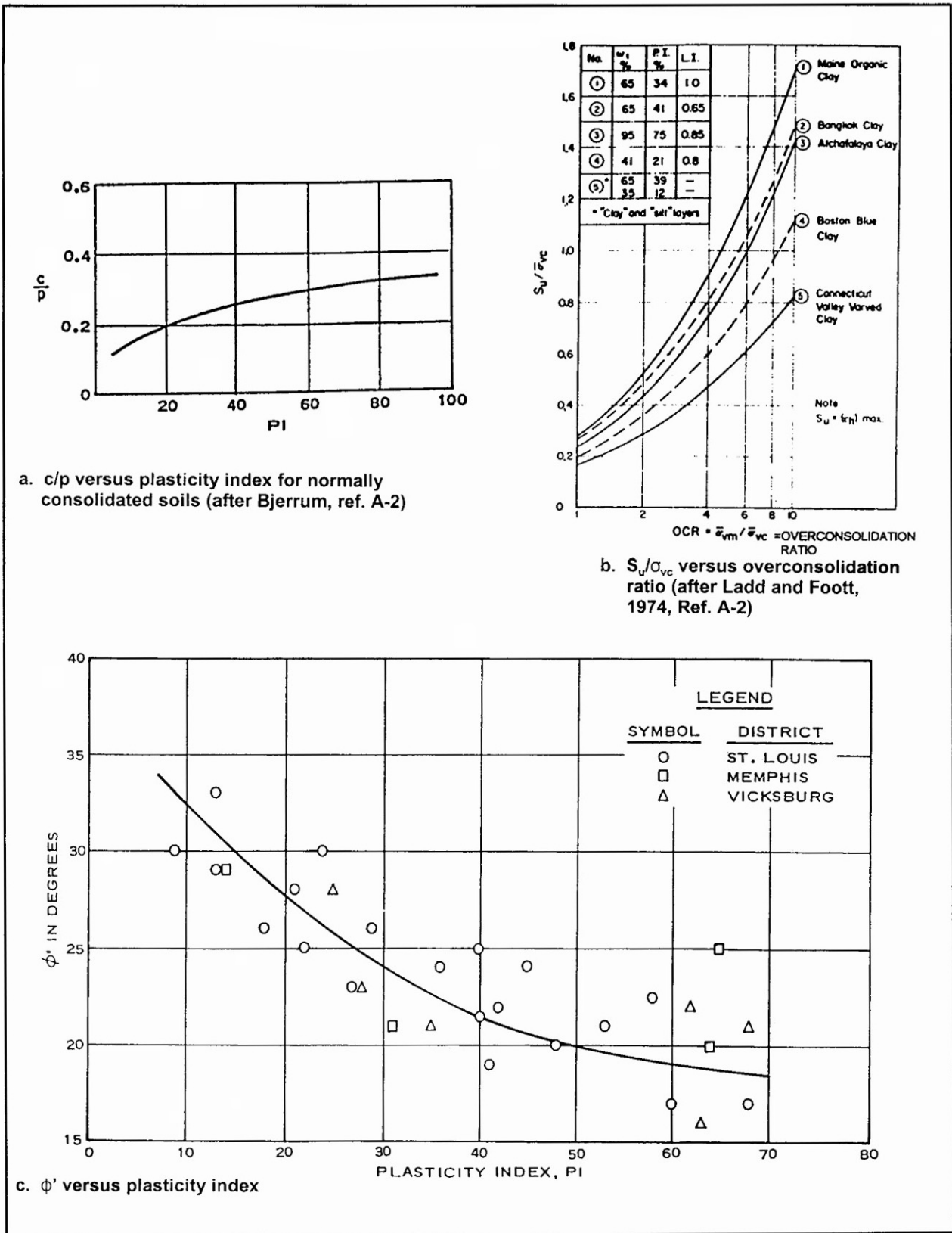
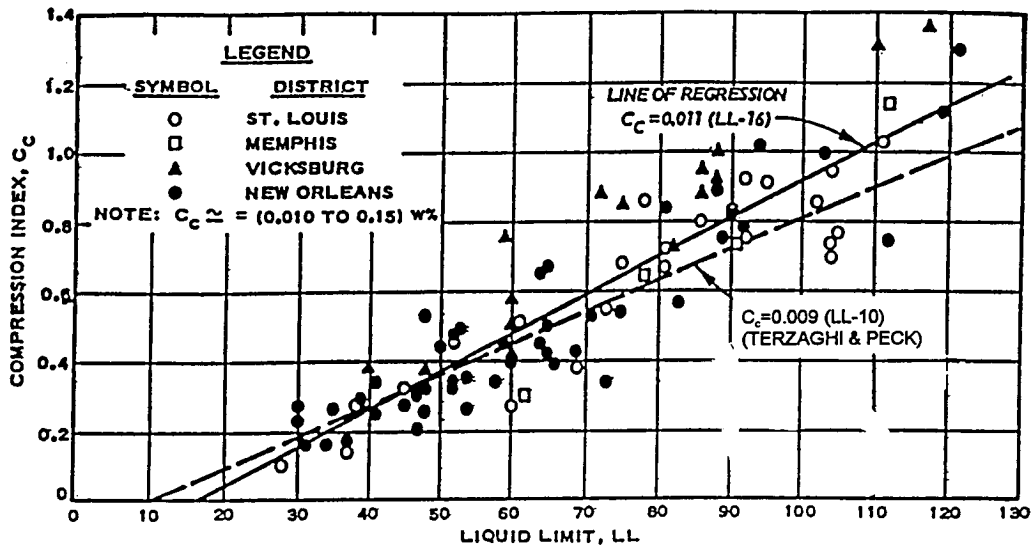
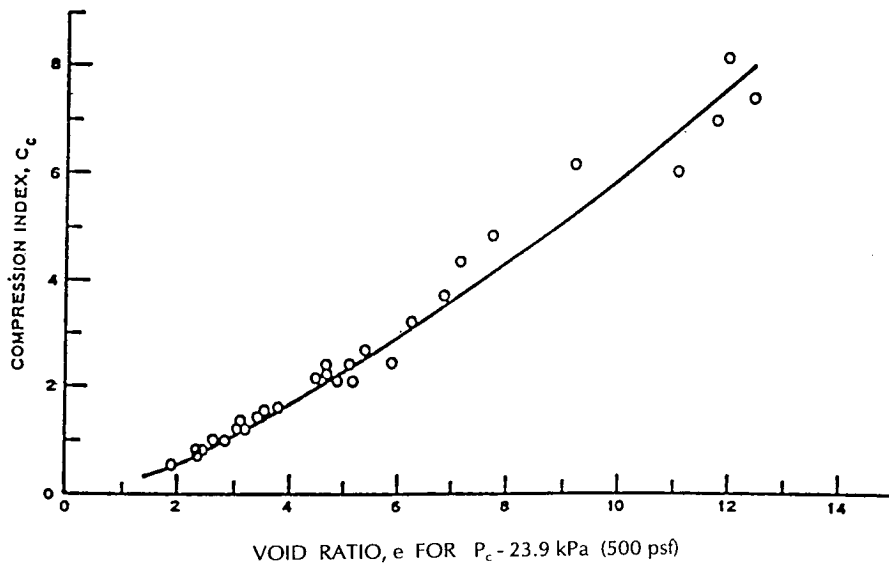


Figure 3-2. Example correlations of strength characteristics for fine-grained soils

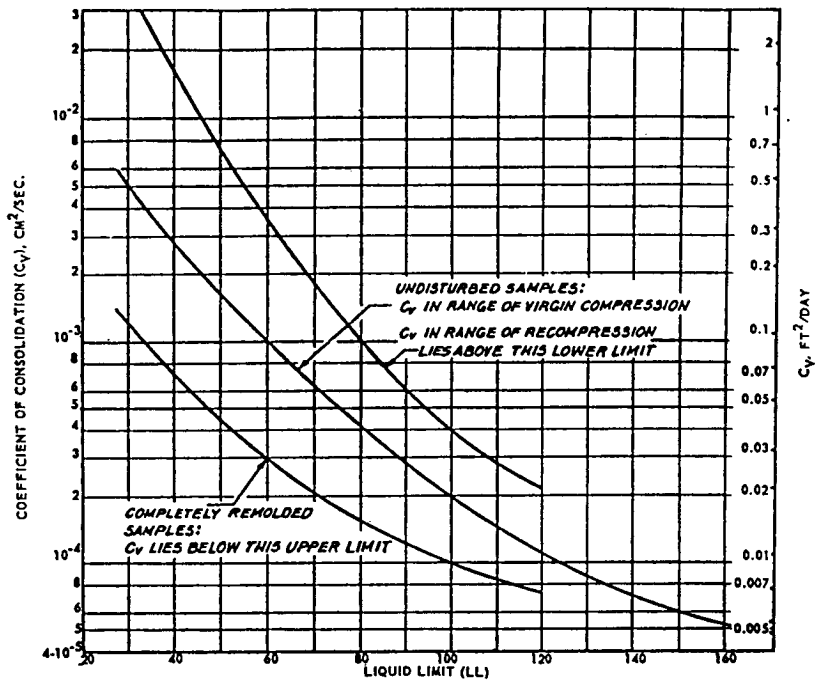


a. Compression index versus liquid limit for normally consolidated soils

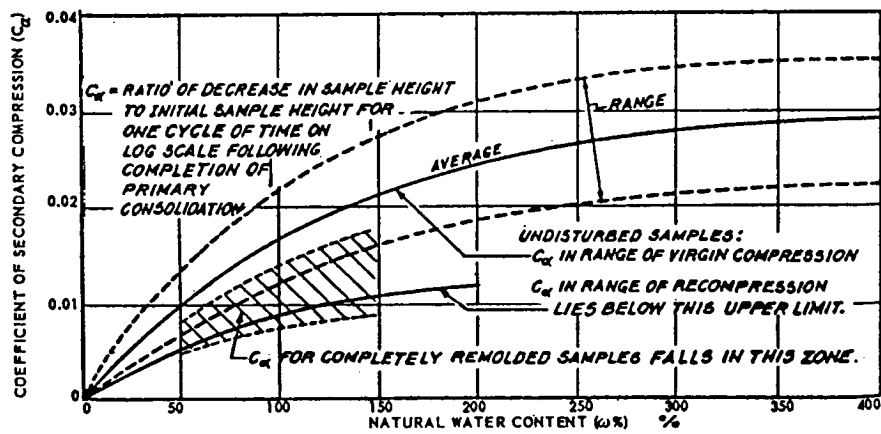


b. Compression index versus initial void ratio for tidal marsh

Figure 3-3. Example correlations for consolidation characteristics of fine-grained soils (after Kapp, ref. A-2)



c. Coefficient of consolidation versus liquid limit (from NAVFAC DM-7 ref. A-1)



d. Coefficient of secondary compression versus water content (from NAVFAC DM-7 ref. A-1)

Figure 3-3. (Concluded)

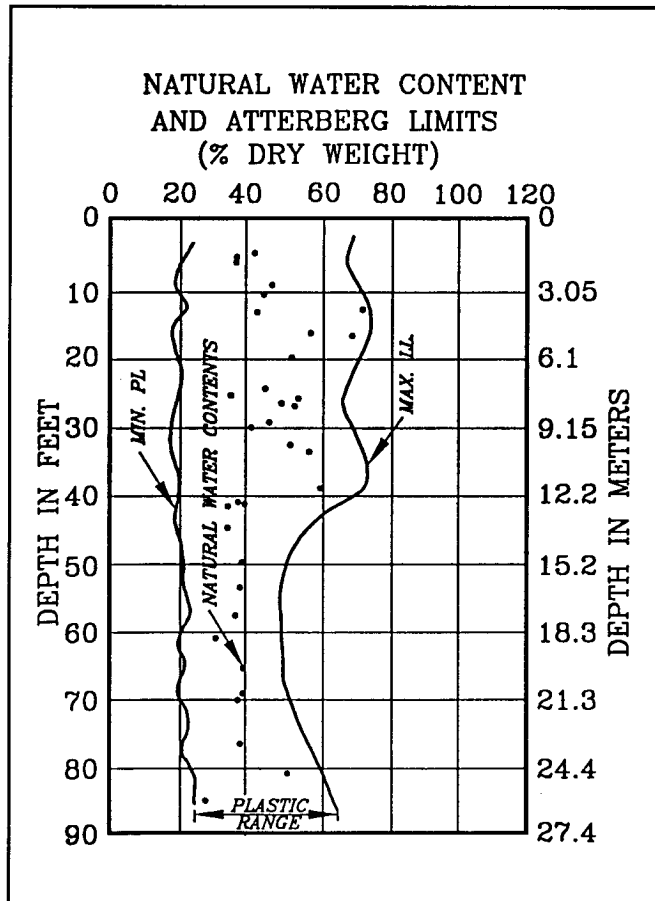


Figure 3-4. Comparisons of Atterberg limits and natural water contents

tions of liquid limit and natural water content with coefficient of consolidation, compression index, and coefficient of secondary compression can be used satisfactorily for making estimates of consolidation of foundation clays under load.

3-6. Permeability

Generally there is no need for laboratory permeability tests on fine-grained fill materials, nor on surface clays overlying pervious foundation deposits. In underseepage analyses, simplifying assumptions must be made relative to thickness and soil type of fine-grained surface blankets. Furthermore, animal burrows, root channels, and other discontinuities in surface blankets can significantly affect the overall effective permeability. Therefore, an average value of the coefficient of permeability based on the dominant soil type (Appendix B) is generally of sufficient accuracy for use in underseepage analyses, and laboratory tests are not essential.

3-7. Compaction Tests

The type and number of compaction tests will be influenced by the method of construction and the variability of available borrow materials. The types of compaction tests required are summarized in Table 3-1.

3-4. Shear Strength

Approximate shear strengths of fine-grained cohesive soils can be rapidly determined on undisturbed foundation samples, and occasionally on reasonably intact samples from disturbed drive sampling, using simple devices such as the pocket penetrometer, laboratory vane shear device, or the miniature vane shear device (Torvane). To establish the reliability of these tests, it is desirable to correlate them with unconfined compression tests. Unconfined compression tests are somewhat simpler to perform than Q triaxial compression tests, but test results exhibit more scatter. Unconfined compression tests are appropriate primarily for testing saturated clays which are not jointed or slickensided. Of the triaxial compression tests, the Q test is the one most commonly performed on foundation clays, since the in situ undrained shear strength generally controls embankment design on such soils. However, where embankments are high, stage construction is being considered, or important structures are located in a levee system, R triaxial compression tests and S direct shear tests should also be performed.

3-5. Consolidation

Consolidation tests are performed for those cases listed in Table 3-1. In some locations correlations

Section II
Coarse-Grained Soils

3-8. Shear Strength

When coarse-grained soils contain few fines, the consolidated drained shear strength is appropriate for use in all types of analyses. In most cases, conservative values of the angle of internal friction (ϕ) can be assumed from correlations such as those shown in Figure 3-5, and no shear tests will be needed.

3-9. Permeability

To solve the problem of underseepage in levee foundations, reasonable estimates of permeability of pervious foundation deposits are required. However, because of difficulty and expense in obtaining undisturbed samples of sands and gravels, laboratory permeability tests are rarely performed on foundation sands. Instead, field pumping tests or correlations such as that of Figure 3-5 developed between a grain-size parameter (such as D_{10}) and the coefficient of permeability, k , are generally utilized.

3-10. Density Testing of Pervious Fill

Maximum density tests on available pervious borrow materials should be performed in accordance with ASTM D 4253 so that relative compaction requirements for pervious fills may be checked in the field when required by the specification. Due to the inconsistencies in duplicating minimum densities (ASTM D 4254), relative density may not be used. Factors such as (but not limited to) site specific materials, availability of testing equipment and local practice may make it more practical to utilize methods other than ASTM D 4253 and ASTM D 4254 to control the degree of compaction of cohesionless material. The other methods used include comparison of in-place density to either the maximum Proctor density or the maximum density obtained by ASTM 4253 (if vibratory table is available).

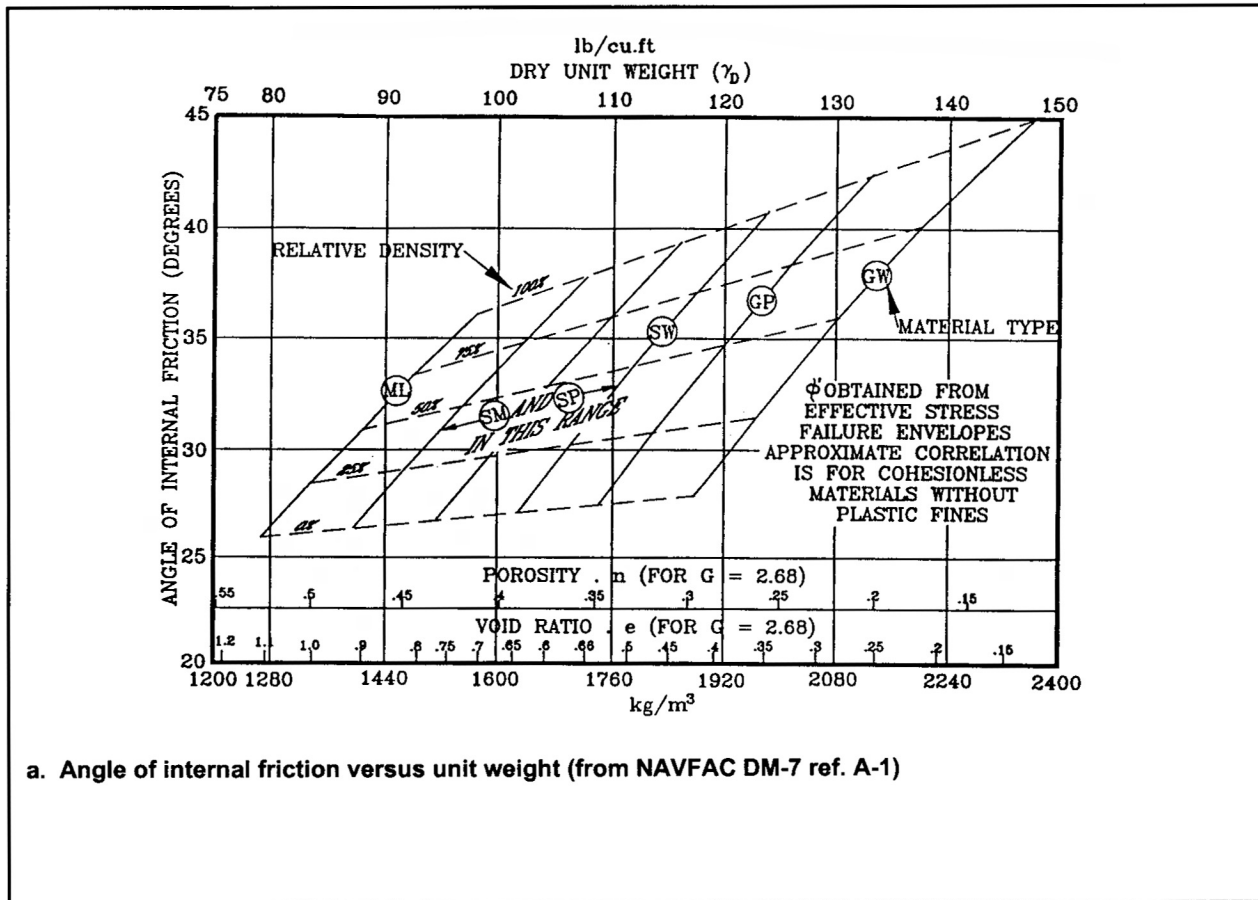
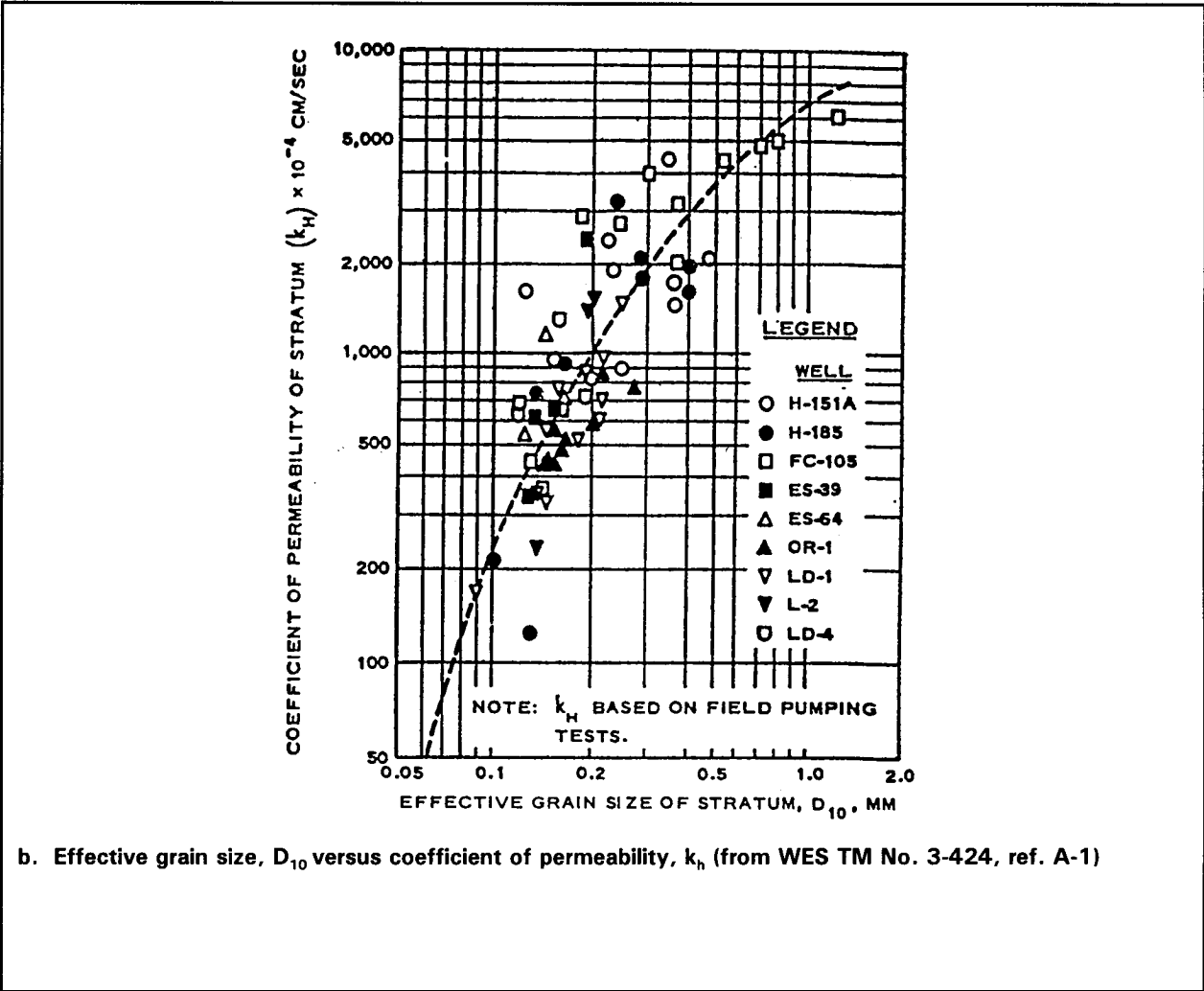


Figure 3-5. Example correlations for properties of coarse-grained soils



b. Effective grain size, D_{10} versus coefficient of permeability, k_h (from WES TM No. 3-424, ref. A-1)

Figure 3-5. (Concluded)