# Use of Shale in Highway Embankments

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## INTRODUCTION

Poor performance of midwestern shales in highway embankments has led to a substantial research effort at Purdue University, sponsored by the Indiana State Highway Commission and the Federal Highway Administration. Any embankment must be built to avoid slope failures and excessive settlement. Both problems are exaggerated by the non-durability of the shale, which causes the shale pieces to break down (slake) under wetting and drying cycles in the embankment.

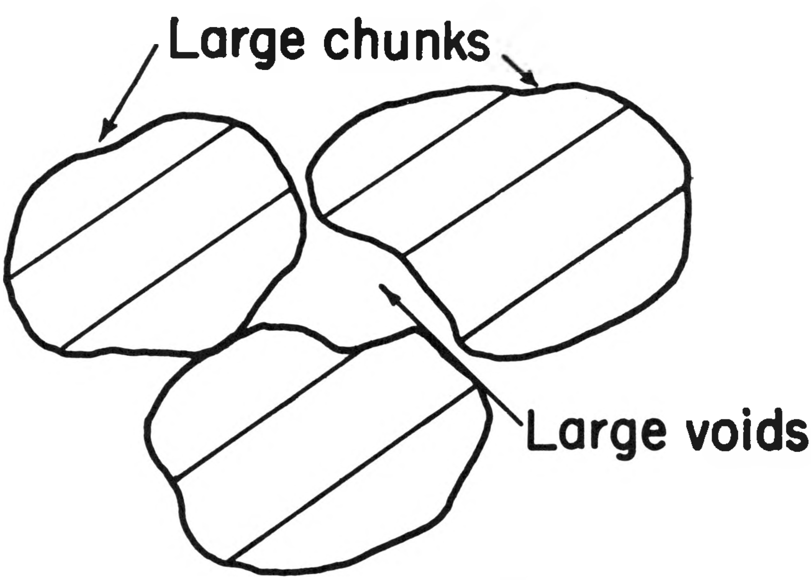


Figure 1. Non Durable Chunks Break Down (Slake) and Fall into Voids

The best procedure with such shales is to break them down thoroughly and compact them in thin soil-type lifts. However, due to the hardness of many of these shales there is a temptation to allow the piece to be large and the layers to be thick. Figure 1 illustrates this situation. Large chunks of shale produce large voids between them. When the shale slakes, the slaked material falls into these voids, and the embankment may settle greatly. This settlement will produce a rough pavement and may even lead to slope failures (i.e., I-74 in southeastern Indiana). Conversely, if the pieces are small, the voids are small, and the shale simply remains in place when slaked.

## DURABILITY RATING

The first testing to be undertaken is rating the durability of the shale proposed for embankment use. Three tests have emerged as "most useful" for this purpose (1, 2, 3, 4), these are slake durability, Atterberg limits, and point load strength. When the shale is relatively "soft," the slake durability and Atterberg limits tests should be used; when the shale is relatively "hard," the tests should be slake durability and point load strength.

The slake durability test was developed about 10 years ago in England by John Franklin. With this test, the shale is placed inside a mesh drum which is rotated in a water bath. The slaked pieces fall through the drum openings, and the durability is rated by the weight retained inside the drum.

The point load strength device (shown in Figure 2) has been extensively used in rock mechanics. It is particularly suitable for shales, since chunks of material can be used. (It is very difficult to cut a cylindrical sample of intact shale.)

John Franklin has worked out classification of shales, using these three tests, for Ontario, Canada. It is being worked on for Indiana shales in current research.

## DEGRADATION RATING

Nondurable shales must be broken down and placed in thin, tight, "soil-fill" lifts, but when the shale is hard, special construction attention is required. Degradation of the shale is measured by change in average aggregate size due to compaction. The percentage change in average aggregate size is called the "index of crushing" (3, 4). The harder the shale, the smaller is the reduction in average size due to compaction (the smaller the index of crushing). Or, to state it another way, the harder

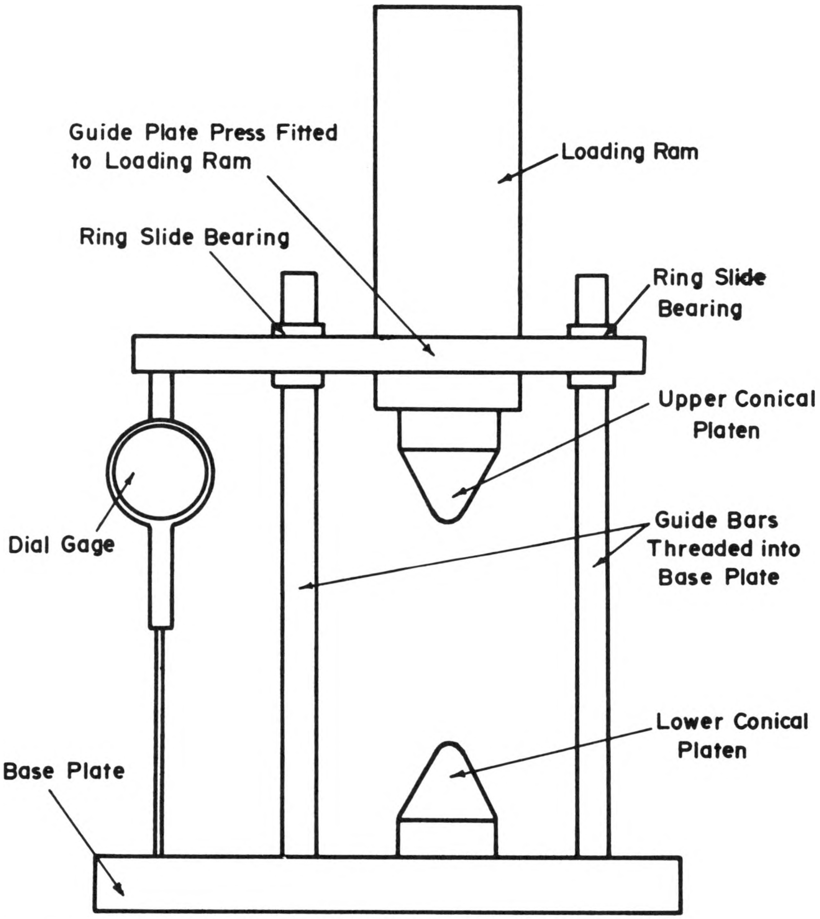


Figure 2. Diagram of Point Load Strength Test Apparatus

the shale, the more compaction is required to produce a given reduction in average size.

Degradation can be visually rated in the field during the rolling process, but it is difficult to measure in the field, even in a controlled test pad. Accordingly, a laboratory compaction test in a CBR mold has been developed for this rating. Figure 3 shows data for a sample of the

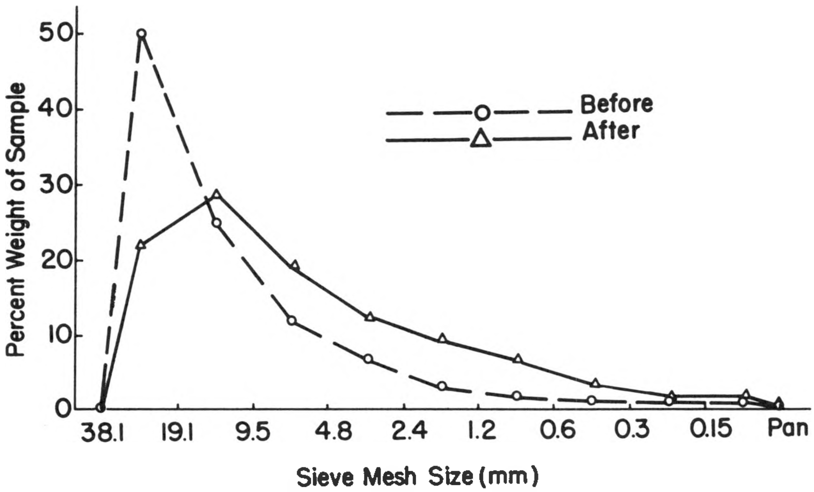


Figure 3. Aggregate Size Distributions for New Providence Shale

New Providence shale. While the values of the laboratory test are not correct for field rolling, the index of crushing values should indicate the hardness of one shale with respect to another. When the index value is relatively low, project engineers are forewarned of difficulty in getting thin tight lifts. The problem can also be recognized (in a visual way) in a test pad.

## COMPACTION CONTROL

The compaction control curve can be generated in either the laboratory or in the field, but for shales, a field test pad is definitely preferred. A test pad is provided for each shale, and the density growth curve is generated for a selected roller, roller weight, and water content. See Figure 4. The density value is selected at a reasonable number of passes, and with the observation that a thin tight lift is being compacted. The compaction specification can be stated in terms of either (a) an end result, or (b) a combination of procedure and end result. Generating the control in this manner generally improves the

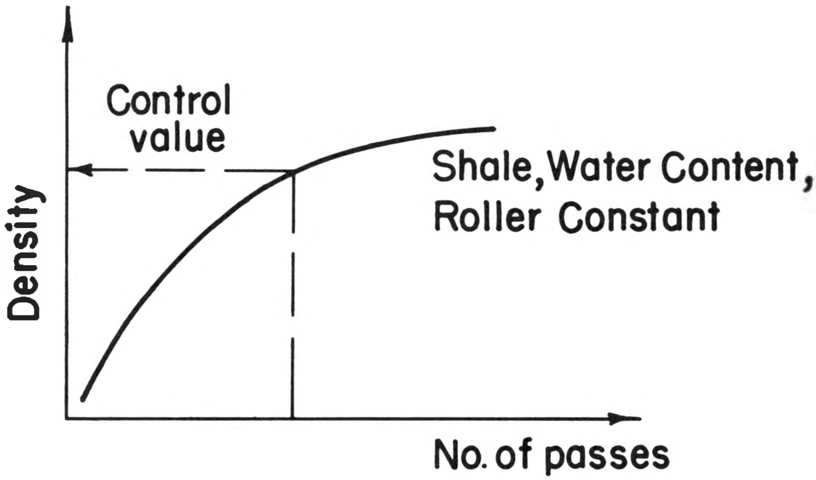


Figure 4. Density Growth Curve

contractor-engineer relationship, since both know that the specification has a practical and realistic origin.

If a laboratory control curve is used, there will be problems of oversize, slaking of the shale when water is added, the necessity for curing periods after adding water, and the generation of somewhat irregular moisture-density curves. Techniques for minimizing these problems are described in 4 and 5.

## COMPRESSIBILITY AND STRENGTH

The modes of potential embankment trouble are settlement and shear failure, as shown in Figure 5. Intact samples for the needed tests

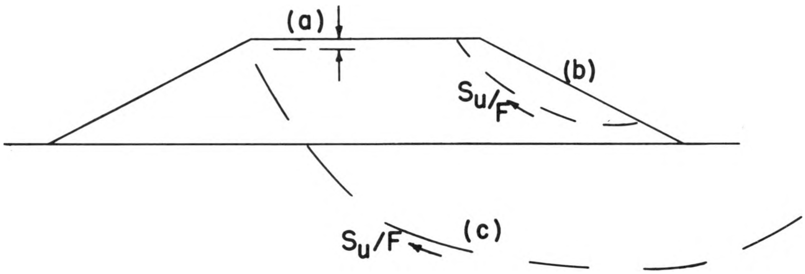


Figure 5. Modes of Potential Trouble
(a) Excessive Settlement
(b) Slope Fixture
(c) Bearing Capacity Failure

may be taken from test pads or compacted in the laboratory. The former are preferred and should be as large as test equipment will allow. If prepared in the laboratory, the samples should have moisture-density values which meet the compaction specification. This will almost certainly be defined by the AASHTO (impact type) control curve. However, it is recommended that the samples be prepared by a compaction mode which better approximates field rolling, e.g., kneading (5, 6). This technique requires that the kneading foot pressure be varied to fit the control curve (Figure 6).

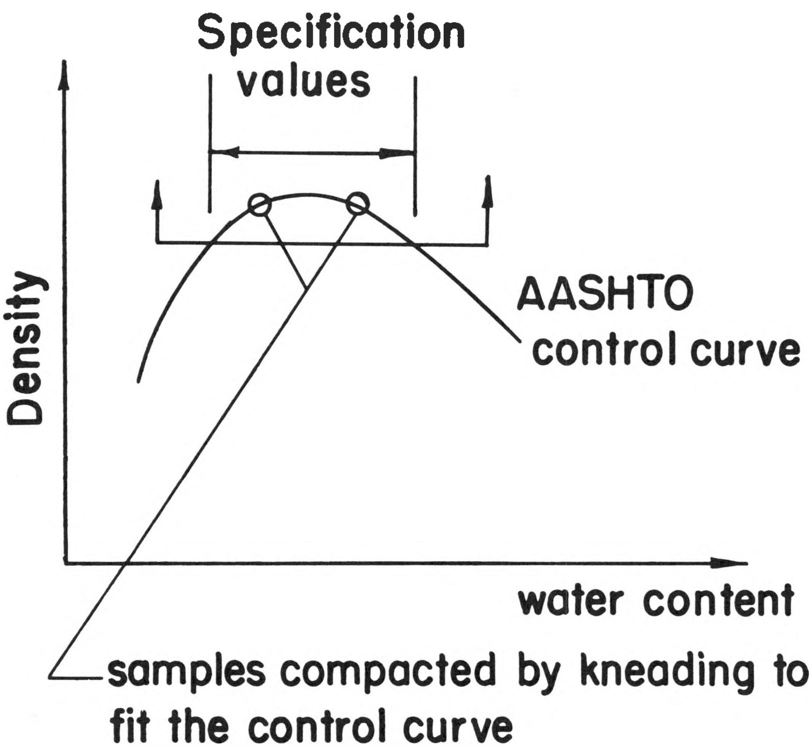


Figure 6. Laboratory Preparation of Strength and Compressibility Samples

One dimensional compression tests are run to produce estimates of settlement. As shown in Figure 7, a prestress is created by the rolling process. When the embankment stresses are less than the prestress (7a), there is little settlement; when the embankment stresses are greater than the prestress (7b), there is appreciable settlement. The prestress value increases with the roller pressure and increases with decreasing compaction water content (5).

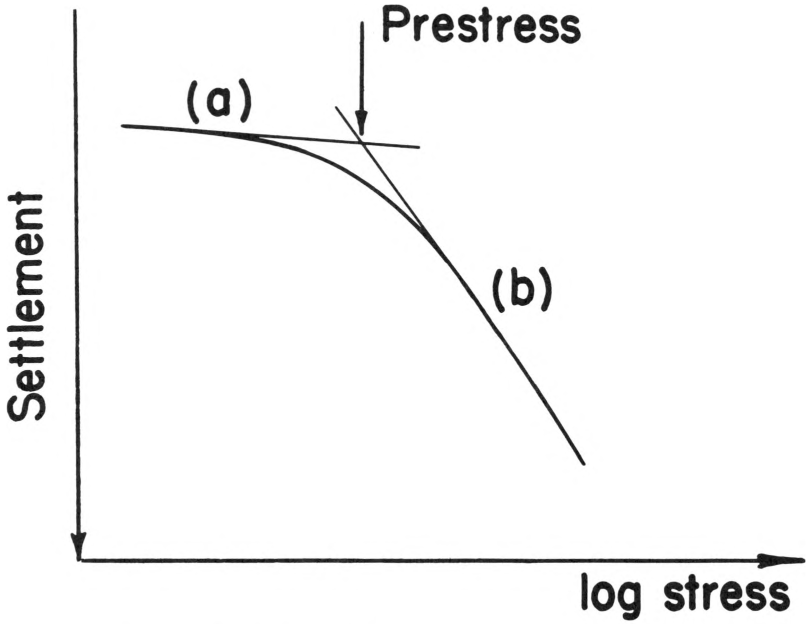


Figure 7. Prestress Established by Rolling

The embankment settlement of primary interest is that occurring when the embankment is wetted and dried in service. This behavior is approximated by saturating compacted samples under a simulated embankment confinement. The settlement shown in Figure 8 increases

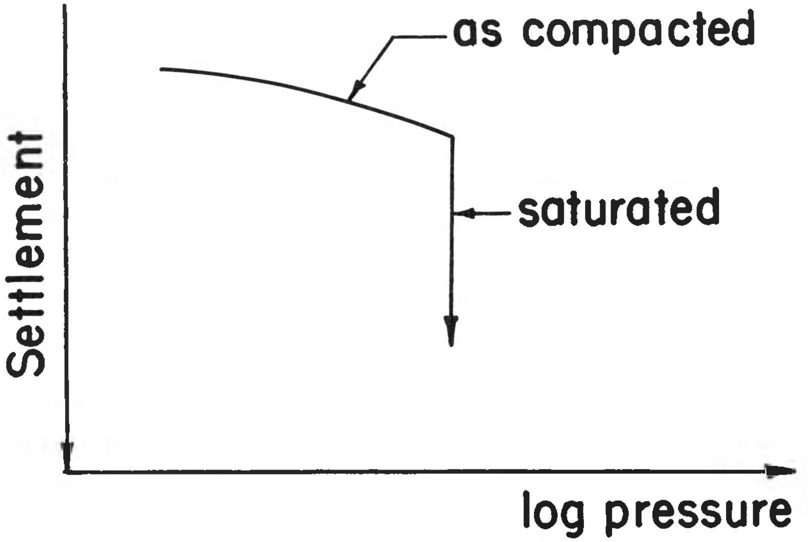


Figure 8. Settlement upon Saturation

with: (a) increasing confining pressure, (b) decreasing compacted density and (c) decreasing compaction water content.

Strength samples may also be obtained from test pads or compacted in the laboratory. The as-compacted strength is of much less interest than the saturated undrained one. Therefore, samples are saturated under simulated embankment confinements, and are sheared undrained. To define the effective strength parameters, shear induced water pressures are measured during the shear. Thus the three needed quantities ($c'$, $\sigma'$, $\phi'$,) may be experiementally defined (Figure 9). They would logically vary with the shale, the compaction water content, the compacted density, and the confining pressure. For a given shale, the c' and $\phi'$ values do not seem to be affected (6). However, the effective stress $\sigma'$ increases as: (a) the confining pressure decreases, (b) the com-

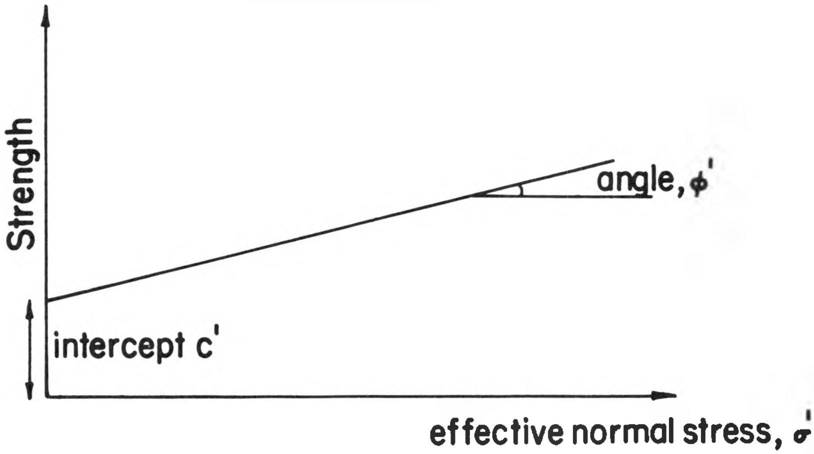


Figure 9. Effective Stress Strength

pacted density increases, and (c) the compaction water content increases.

Through testing of the kind described in this section it is possible to make reasonable predictions of both settlement and factor of safety against shear failure for shale embankments.

## SUMMARY

Through a research program extending over about ten years, technology has been developed which permits the Indiana State Highway Commission to do an efficient job of designing and building shale embankments.

The tests needed are: a) slake durability; b) point load strength or

Atterberg limits; c) compaction degradation; d) compaction control (field or laboratory); e) settlement upon saturation; and f) shear strength after saturation.

Draft standards for these tests have been written and will shortly be final edited by the ISHC.

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