RESEARCH PAYS OFF

Shale Handling Procedures Save Dollars

Problem

Highway embankments are normally built with soil and occasionally with rock. Adequate standards and specifications have been available for some time, enabling engineers to use both soil and rock with confidence. In southern Indiana there is an abundance of a sedimentary soft rock, called shale, that does not conform to either the soil or the rock classification. Some soft shales break up readily during excavation, hauling, and placement and can be treated like soil. Other shales appear more durable, suggesting that they can be used like rock, in large chunks, and placed in thick layers in embankment fills. When shale is placed in this way, large voids are created between the rock-like chunks (see Figure 1).

Embankments built with shales that appeared more durable were expected to perform satisfactorily on the basis of existing state-of-the-art construction procedures. These called for placing other materials between the shale layers (encasement), flattening side slopes, paying special attention to drainage, and using berms at the toe of slopes.

Unfortunately, early performance of shales fell far short of this goal. It was soon learned that although Indiana shales are mechanically hard they are not durable and tend to break down by slaking, a process by which a material disintegrates or crumbles into small pieces when exposed to moisture and drying conditions. When slaked material falls into the large voids, the embankments settle, causing rough pavements and slope failures that require costly repairs.

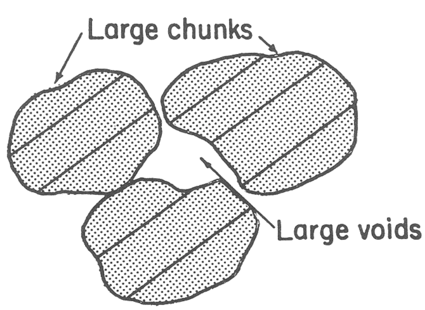


FIGURE 1 Nondurable shales used in rock fill embankments tend to crumble, filling voids between rock pieces and causing settlement that results in costly repairs.

Solution

In the late 1960s, embankment failures began to occur along Interstate 74 in the southern half of the state, highlighting the problems associated with the use of shales. Nevertheless, for economic reasons, a critical need still existed to use shales for the construction of embankments in certain locations in Indiana. Of particular concern in the 1960s and early 1970s was the construction of 123 miles of Interstate 64 (I-64) in southern Indiana, where such shales were common along many segments of the planned route. Consequently, the Indiana Department of Highways embarked on a research program to develop the necessary design standards and construction specifications for all Indiana shales. The research was a cooperative effort between Purdue University and three units of the Highway Department—the Division of Materials and Tests, the Division of Research and Training, and the Vincennes District. The results of several studies indicated that four areas needed to be evaluated in order to design and build shale embankments.

Durability Rating

Research revealed three tests to be useful for determining the durability rating. First, a slake durability test is performed. Shale is placed in a wire mesh drum and rotated in a water bath. The weight of the material remaining in the drum helps to determine its hardness. If it is soft and soil-like, the shale is further tested to calculate the Atterberg limits, measurements of the liquid and plastic properties of soils. If the shale is hard, pointload tests are conducted to determine overall strength. These test results provide factors to be used for designing embankments.

Degradation Rating

Research also confirmed that nondurable shale normally breaks down easily and can be placed in tight, soil-type layers, but hard shales need special compaction techniques. Degradation of shale is measured by the change in average aggregate size resulting from compaction. The percentage of change in the average aggregate size is called the "index of crushing." The smaller the index, the harder the shale, and the more compaction needed to produce the required reductions in average aggregate size.

Compaction Control

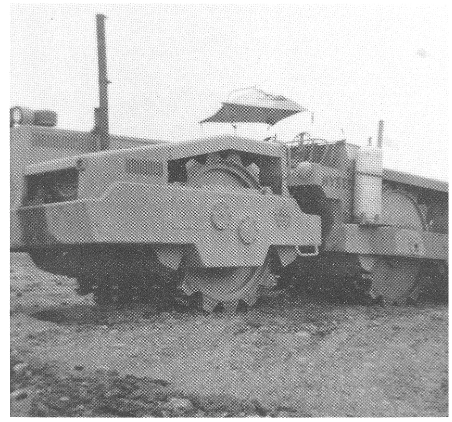
An important component of the research was the construction of test pads for a variety of Indiana shales, using selected compaction rollers of different configurations and weights (see photo for an example) along with different water contents of the compacted layers. Density curves were generated from which target density values could be selected. The density curves and target values were based on a reasonable number of roller passes and the visual indication that close contact was being obtained between aggregates. The variables studied here could be used later for controlling the quality of embankment construction operations.

Compressibility and Strength

Samples of the crushed shale material were taken from the field test pads. Because shale embankment problems are usually first discovered when settlement and shear failure (slides) occur, the samples were saturated under conditions that simulated the confining pressures of embankments and tested for their shear capacity in an undrained state. From the test results, it was then possible to predict both the potential settlement of embankments and the safety factors needed to prevent shear failures.

Application

The findings from the Indiana shale research program have led to the formulation of standard specifications that now allow placement of a variety of Indiana shales. The successful use of shales in embankments has resulted in substantial savings. It has reduced the amount of expensive fill materials imported for embankments without creating the potential for embankment failures and the need for subsequent repairs. Without the shale handling procedures, some road construction projects in the areas of the state where shale is located would be economically prohibitive.



Heavy test-pad roller compacting shale in the Vincennes District of Indiana.

Benefits

Although it is difficult to quantify benefits precisely, the cost of the shale research was approximately $500,000, with an estimated savings of at least $5 million in the construction of I-64 because special fill material was not required. Savings associated with other road construction projects have not been calculated because of the difficulty of examining past records and predicting future activity, but could easily account for much larger additional savings.

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Suggestions for "Research Pays Off" articles are welcome.

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