EVALUATION OF SHALE EMBANKMENT CONSTRUCTION CRITERIA

EXPERIMENTAL FEATURE FINAL REPORT

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ABSTRACT

A 1.5 mile section of the Coos Bay - Roseburg Highway in Oregon was reconstructed in 1983. The project was located in an area where degradable fine-grained siltstone and sandstone would be encountered in the through cuts. After the construction of the adjacent Slater-Mystic Creek section in 1974, it was recognized that significant settlement and stability problems were developing as a result of the use of these degradable rocks in the construction of embankments. The Oregon Department of Transportation (ODOT) completed a demonstration study described herein to evaluate the use of these materials for embankments and riprap revetment at nine structures.

The study concluded that use of visual classification, aided by slake-durability testing, was reliable in the selection of rock-like materials for use in slope revetments. Where rock was determined to be nondurable, it was physically broken down and placed and compacted as soil. The performance of the embankments in the five years following construction has been very good and no appreciable settlement is evident. The rock placed as revetment has performed as anticipated, with about 25 percent of the material degrading. This is attributable to limitations in sorting the durable and nondurable material during excavation. As a result of this demonstration study, ODOT has implemented a practical and effective embankment specification for selection and treatment of degradable rock materials in highway construction.

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ACKNOWLEDGEMENTS

This experimental features study was initiated and conducted by Tom Szymoniak, who at the time worked as a geotechnical specialist for the Oregon Highway Division. Overall project design was coordinated by Marty Havig, while the construction was managed by Ron Busey with support from Al Vohland and Larry Carson, all with the Oregon State Highway Division. Post-construction site evaluations were performed by the Region Geologist Jim Bilderback and Geotechnical Engineer George Machan. Barry Siel, FHWA, assisted with the final site inspection and helped summarize the findings of this study. Special thanks to the Oregon Department of Transportation Research Unit and Ron Chassie, Geotechnical Engineer, FHWA, for their continued support and review of this report.

INTRODUCTION

Statement of Problem

In the coastal areas of Oregon, interbedded sandstone and fine-grained sedimentary formations are encountered in highway cuts. The material from these cuts has been used in embankments and as slope revetment. When the interbedded sedimentary units are first excavated from the cuts they behave as rock. However, some of this material will slake to a soil upon exposure to air and water. Previous ODOT experience was that when such slakeable materials were placed in embankments and compacted using conventional rock fill placement methods (i.e., 3-foot thick lifts), short and long-term settlement of the embankment, pavement distortions, and slope instability has resulted.

Purpose of the Experimental Features Study

The purpose of this study was to implement recommendations from the Federal Highway Administration (FHWA) report RD-78-141. The FHWA report includes guidelines for testing, design, and construction to reduce the problems resulting from the construction of earth structures with degradable rock. The guidelines also aid in the selection of durable rock for use as riprap revetment and drain rock. These guidelines were developed primarily for shales in Indiana; therefore, this Experimental Features Study needed to evaluate the appropriateness and relative success of applying these guidelines to other degradable rocks, such as siltstone and friable sandstone.

Project Tasks

Four general tasks listed below were completed during the course of this study to evaluate the use of interbedded sedimentary rock as embankment fill and revetment. The first task, although not a part of the Experimental Features Study but included in the design phase of the project, is included in this report because of its importance to the overall evaluation.

1) This first task included preparing special benching and drainage designs and earthwork specifications for the construction of the embankments.
2) The second task was the selection and identification of durable and non-durable rock materials. Preliminary identification was made by evaluating the subsurface conditions disclosed by the exploration borings. During construction, selection was accomplished by use of several simple laboratory and field tests, supplemented by visual identification in the field.
3) The third task was to evaluate different compaction methods for construction of embankments using degradable rock. This was done by constructing several test pads at structure approach embankments. The test pad criteria and requirements were set forth in the contract specifications.
4) The fourth task was to conduct a post-construction investigation of the test pad embankment materials by testing undisturbed samples from the embankments and monitoring settlement with field instrumentation. It was decided to modify the fourth task to evaluate embankment performance on a long-term visual basis.

BACKGROUND

The Coos Bay - Roseburg Highway (State Route 42) in southwestern Oregon is being reconstructed through a series of projects over several years. After the construction of the Slater-Mystic Creek section in 1974, it was recognized that significant settlement and stability problems were developing as a result of using degradable rocks in embankment construction. To reduce the amount of cut and fill on the next reconstruction section, Mystic Creek to Camas Valley, the alignment was lowered to follow the North Umpqua River. This change required construction of nine bridges with up to 30-foot high abutments. Because of the past experiences in using the interbedded sandstone/siltstone, it was decided to implement and evaluate the design and construction guidelines set forth in the FHWA publication RD-78-141 Design and Construction of Compacted Shale Embankments.

Project Geology

The geology along this alignment is dominated by the Lookingglass Formation. The Lookingglass Formation is the renamed middle member of the Umpqua Formation and is early to middle Eocene in age. It was deposited by an advancing sea that occupied the southern part of the Oregon Coast Range. The Lookingglass Formation consists of basal beds of conglomerate which grade upward to sandstone and siltstone beds with minor amounts of shale. The quality of the sandstone beds ranges from fair to poor, with the finer sandstones sometimes being degradable. The siltstone and shale materials are commonly degradable.

Embankment Materials

Fine-grained sedimentary rocks are sometimes collectively referred to as "shale" because of similar behavior. Shale is characterized by a finely laminated structure or fissility and normally contains an appreciable content of clay minerals. Whereas, other potentially degradable sedimentary rock types include mudstone, claystone, siltstone, sandstone and tuff. Because of similar degradable behavior, the technology developed for shales could be extended to other degradable sedimentary rocks. Fine-grained sedimentary rocks vary greatly in their properties and behavior. The difficulty is in determining the long-term durability. Durable materials can be constructed using rock placement/compaction techniques (2-to 3-foot thick lifts) and nondurable materials must be placed and compacted in thinner lifts (8 to 12 inches thick), like soil.

DESIGN CONSIDERATIONS

The successful use of nondurable rocks in embankment construction requires sufficient drainage, to prevent harmful saturation of the embankment materials, and adequate gradation and compaction of each fill lift. The design considerations conducted under the first task included the identification of groundwater in the cut/fill transitions and the development of special details and specifications for embankment construction.

Identification of Groundwater

The breakdown or slaking of rock is very dependent on the presence of moisture. Since the new alignment was near a major river, understanding the seasonal river fluctuations and levels of groundwater was critical during both the design and the construction stages of this project. Groundwater information was obtained primarily from two sources. The first and most important sources are the drill log records produced during subsurface exploration. This information contains the levels at which groundwater was encountered during drilling as well as subsequent levels in holes left open or in which piezometers were installed. The other source of information was a complete visual reconnaissance by the ODOT Region geologists and the project geotechnical engineer. The reconnaissance identified springs and wet areas.

Benching and Drainage

Included in the plans for this project was a typical drawing outlining benching and drainage treatment for embankments, as shown on Figure 1. The design consists of providing 10-foot wide benches in the original slopes where embankments are to be built. Bench construction served two purposes: 1) to integrate the new embankment with the existing ground, and 2) to intercept and direct groundwater from flowing into the new embankments. The drainage systems consisted of 8-inch drain pipe surrounded by gravel drain material wrapped with geotextile. Control of groundwater through drainage minimizes the wet/dry cycles in the embankment and therefore minimizes the breakdown or slaking of the degradable materials in the embankment.

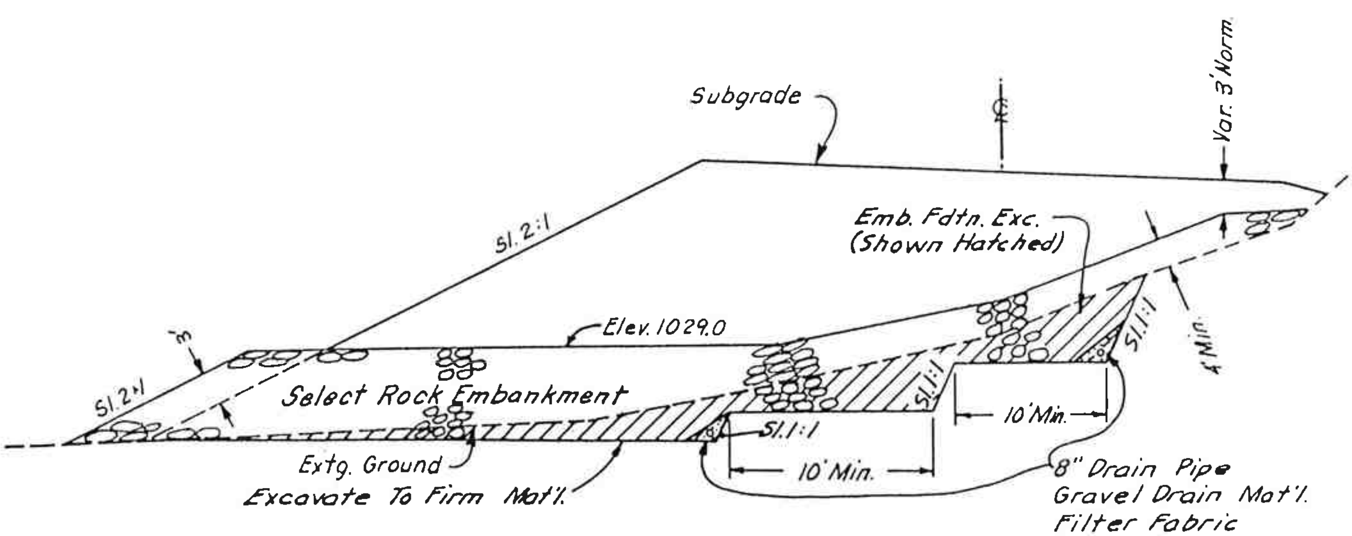

FIGURE 1: Benching and Drainage Detail

Slope Revetment

Slope riprap revetment was used for flood protection and general stability of the steep embankment slopes. The design considered that the available rock would be of variable quality. The excavated rock was to be sorted and the better quality sandstone used for riprap. However, it was recognized that the rock used in the revetment would also include some less-durable rock fragments, due to limitations in the sorting process. Therefore, the revetment thickness was made thicker than normal.

The 4-foot thickness allows for degradation of some of the rock fragments so that the remaining better quality rock would still perform long-term as a suitable revetment. The detail for the slope revetment is presented in Figure 2.

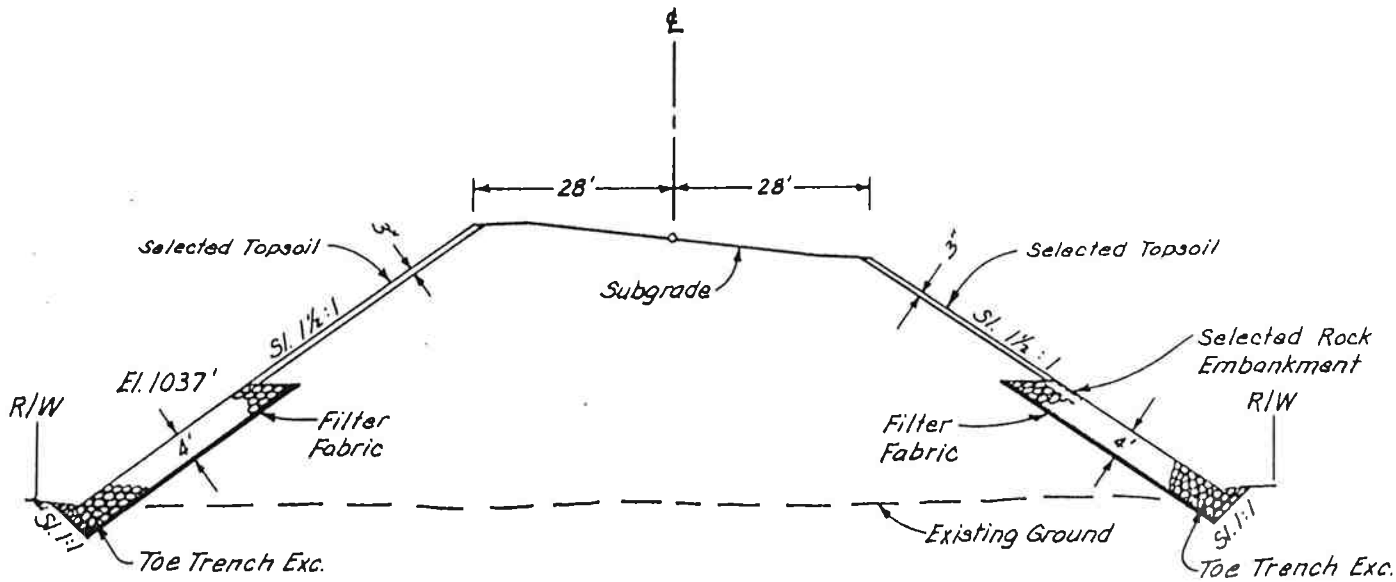

FIGURE 2: Slope Revetment Detail

Embankment Placement and Compaction

Since degradable siltstone material would be used for general embankment construction, specifications were developed to require breaking down the excavated rock to 6-to 12-inch size and placing in 12-inch maximum lifts. Repeated compaction passes would further pulverize the material, minimizing voids, thus reducing the concern for long-term slaking and degradation. Test pad construction was specified in order to evaluate different types of compaction equipment and to modify construction procedures, if necessary.

MATERIAL IDENTIFICATION AND TESTING

It is important to distinguish durable rocks that can be placed as rock fill from nondurable rocks that must be placed and compacted using soil procedures. The identification and selection of excavated sedimentary rock to be used for revetment or common embankment construction were based on visual classifications made by the project geotechnical engineer, aided by laboratory and field classification tests. Some chemically nondurable rocks were easily identified by simple slaking tests (jar tests). Some rock units weathered rapidly just from air exposure as evidenced by rock core specimens that disintegrated shortly after being obtained and placed in the core boxes. Other sedimentary rocks that were visibly mechanically hard and durable were evaluated by their resistance to weathering in the field; ringing and resistance to breaking under hammer blows; and unchanging nature when subjected to slake-durability testing. However, mechanically hard but nondurable rocks are more difficult to identify without slake-durability testing.

Two tests, slake-durability and point-load, were conducted during construction to identify the durability of rocks. These tests were performed at the major cut areas to aid selection for use as rock embankment material, common embankment material, or riprap revetment material. The results of these tests are presented in Appendix A.

A total of 25 slake-durability tests were performed during construction. Each slake-durability test was performed on 10 oven dried rock pieces weighing 40 to 60 grams each. The samples were submerged and rotated in a wire drum cage (No. 10 screen) at 20 rpm for 10 minutes. The core material retained in the drum was then oven dried and the procedure repeated. The two-cycle Slake-Durability Index, I_D, is the percent (by weight) of oven dried material remaining after the test.

The FHWA report RD-78-141 recommends the following classification of materials based on slake-durability test results:

SLAKE-DURABILITY INDEX, I_D	CLASSIFICATION
<60%	Soil-like
60% to 90%	Intermediate
>90%	Rock-like

The slake-durability tests conducted in this ODOT study indicated 30 percent soil-like specimens, 30 percent intermediate, and 40 percent rock-like. This variability relates to the alternate bedding of harder sandstones and softer siltstones.

For the samples tested, the Slake-Durability Index, I_D, ranged from 13.0 to 98.8 % on materials ranging from siltstone to sandstone. The sandstone Slake-Durability Index ranged from 62.7 to 98.8%, with a mean of 89.3% (16 tests). If the questionable samples are excluded, those that were friable, coarse, or contained siltstone, then the Slake-Durability Index of the sandstone averaged 93.3%, with a minimum of 89.5%. Therefore, most of the visually competent sandstone was "rock-like." The siltstone, on the other hand, was significantly less durable with Slake-Durability Indexes of 13.0, 15.9, 47.6, 47.8 and 96.0%. The latter sample was observed to have been hard and could not be ripped. Therefore, most of the siltstone was "soil-like."
The point-load test is an index test for strength classification of rock materials. Eleven point-load tests were performed on eight rock fragments

obtained during excavation. The measured point-load strengths ranged from 13.4 to 90.0 psi. The intent of these tests was to improve the successful identification of durable and nondurable rocks by using the "Shale Rating Chart" (Reference 3, Figure 2). This chart compares the Slake-Durability Index with the point-load strength to arrive at a Shale Rating, R, on a scale of 0 to 9. The point-load data did not reflect any significant pattern or correlation, probably because of the limited number of tests. In addition, the orientation of the structure (joints and laminations) can affect the test results. This effect can be minimized by testing perpendicular to the joints/laminations.

Atterberg limits tests were conducted on five soil-like samples in conjunction with compaction testing. The Plasticity Index, PI, ranged from 6 to 15%, and the liquid limit ranged from 27 to 41%.

Visual identification and selection of "rock-like" and "intermediate" materials was made during excavation by the geotechnical engineer inspector. The relative success of these visual assessments is attributed to the technical understanding of the inspector and his hands-on experience with the slake-durability tests. Subsequent slake-durability tests confirmed that the visual determinations were usually correct.

TEST PAD CONSTRUCTION

The main purpose of the test pads was to determine the required procedures (watering, disking, lift thickness and number of compactor coverages) for "soil-like" and "intermediate" quality siltstone to obtain the desired level of compaction. Three test pads were constructed, utilizing different types of compaction. The test pad specification is provided in Appendix B.

The test pads were a part of the regular embankment construction. The test pads were located within the bridge approach embankments, extending 150 feet beyond the abutments. The width of each test pad was about 50 feet. The fill material was placed in 12-inch loose lifts and spread using a tracked dozer or compactor with a dozer blade. Oversized material was pushed out towards the embankment slopes. Water was added by spray bar to bring the fill material close to optimum water content (but not wetter than optimum). The addition of water also helped to initiate degradation of the nondurable rocks. Photo 1 shows nondurable rock boulders that degraded during fill placement.

Compaction was achieved using several types of compaction equipment. Density tests and/or visual deflection evaluations were conducted between each coverage to determine the optimum compaction method and coverage for the materials being used.

Compaction Method Types

Three types of equipment were evaluated, one at each test pad. The types of equipment consisted of 1) Caterpillar 627-B rubber-tired scrapers, 2) a Caterpillar 815 22-ton tamping-foot roller, and 3) a Caterpillar D-8 dozer. The compacting equipment was required to make 3 to 4 passes per 12-inch lift in order to breakdown rock fragments and to achieve suitable density. The most success was achieved by using the Caterpillar 815 roller, followed by the D-8 dozer which had moderate success. The scrapers were not effective in breaking down the material. Photo 2 shows the tamping-foot roller compacting the nondurable fill materials.

Compaction Control

Control of the test pad construction was achieved by visual deflection inspection and/or density/moisture testing. Visual inspection consisted of watching for excessive deflection under the weight of the compaction equipment. Density and moisture control, wherever possible, was monitored using a nuclear gauge, with sandcone density and speedy moisture tests as periodic back-up checks.

LONG TERM PERFORMANCE

Evaluation of the project embankment performance has been done on a long-term qualitative basis. This was done through periodic roadway evaluation by engineering and maintenance staff. The last inspection of the project was conducted by two of the authors and by the Region Geologist to determine the condition of the pavement overlying the embankments and the condition of the riprap protection on the slopes of the embankments. This investigation included a drive-through at normal travel speeds to evaluate rideability, followed by detailed inspections of the embankments at each structure, including the test pad locations. This last inspection took place during June, 1988, approximately five years after the completion of construction.

No significant settlement or distortion problems have occurred in the embankments with the exception of the embankment at the east end of Bridge 16414, located east of Signal Tree. The test pad at this location was compacted using the Cat 627-B scrapers which were rubber-tired vehicles. The settlement was small, less than 2 inches, and rideability was determined to be satisfactory.

Some minor transverse pavement cracking had recently occurred near the approach slabs of the bridge structures and at other locations along the alignment. These cracks occur regardless of whether they are located at cut or fill sections. Therefore, these cracks do not appear to be related to embankment construction or settlement and are most likely a result of thermal pavement contraction.

During construction, the criteria described herein was also used for the selection and segregation of hard, durable rock was for use as riprap on the slopes of embankments. Visual examination of the riprap revealed that this operation had, for the most part, been successful. About 75 percent of the slope protection material has not degraded. The remaining rock still provides a suitable slope revetment. Photos 3, 4 5A and 5B show the condition of the revetment and specifically the degradability of nondurable rock boulders.

NEW SPECIFICATIONS

The satisfactory embankment construction and performance on this project helped to shape the current earthwork specification used by the Oregon Department of Transportation. In addition, portions of the Indiana Department of Highways, specifications [Section 203.20(b), 1988] were used to improve the Oregon specification. The new Oregon Specification is presented in Appendix C.

CONCLUSIONS

1. Slake-durability tests on core specimens would be useful in the project design phase to determine which rock units are degradable. The quantities of "soil-like", "intermediate", and "rock-like" materials could be estimated for project applications. This information is also valuable for planning construction staging.

2. Visual rock classification procedures, performed by an experienced geotechnical inspector, proved to be generally reliable to identify degradable materials. This was confirmed by two-cycle slake-durability tests.

3. The two-cycle slake-durability tests proved to be the most positive means of identifying the quality of rock during excavation. Point-load tests are not recommended on irregular laminated rock fragments, based on this study's experience.

4. The test pad construction approach was found to be valuable in confirming the appropriate lift thickness and number of passes for the actual equipment used by the contractor. Based on visual inspection during test pad construction and long term embankment performance, the Cat 815 tamping-foot roller and the CAT D-8 tracked dozer performed better than the pneumatic-tired scraper. The tamping-foot roller and the dozer did a better job of breaking down the rock fill material than did the scraper. The ODOT specifications now require the use of a 30-ton tamping-foot roller.

5. The satisfactory embankment construction and performance on this project helped to shape the current earthwork specification used by the Oregon Department of Transportation. This specification is presented in Appendix C.

6. The practicality of using point-load tests during exploration (design phase) would need verification research testing on core samples. The aim of this further research would be to determine if the point-load tests provide distinctive data. Also, the additional research would confirm the use of the Shale Rating Chart (Reference 3, Figure 2) for design purposes.

REFERENCES

1. R. J. Lutton, "Design and Construction of Compacted Shale Embankments; Volume 3, Slaking Indexes for design," FHWA-RD-77-1, February 1977, Federal Highway Administration, Offices of Research and Development, Washington, D. C.

2. W. E. Strohm, Jr., G. H. Bragg, Jr., and T. W. Ziegler, "Design and Construction of Compacted Shale Embankments; Volume 5, Technical Guidelines," FHWA-RD-78-141, December 1978, Federal Highway Administration, Offices of Research and Development, Washington, D. C.

3. J. A. Franklin, "A Shale Rating System and Tentative Applications to Shale Performance", Transportation Research Record #790, 1981, National Academy of Sciences, Washington D. C., p. 2-12.

Photo 1: Rock Degradation During Embankment Construction.

Photo 2: Compaction of Degradable Rock at Test Pad, Wing Tamping-Foot Roller.

Photo 3: Condition of Slope Revetment 5 Years After Construction.

Photo 4: Degradable Rock Boulders Within Slope Revetment, 5 Years After Construction.

Photos 5A & 5B: Degradable Rock Boulder Shatters on Impact, 5 Years after Construction.

APPENDIX A

TEST RESULTS

TABLE 1: SLAKE DURABILITY TEST RESULTS

SAMPLE NO.	ROCK DESCRIPTION	SLAKE DURABILITY INDEX, I_D
1	Friable Sandstone	85.4%
2	Siltstone	13.0%
3	Sandstone (Coarse)	82.6%
4	Sandstone	90.8%
5	Friable Sandstone	70.8%
6	Siltstone	15.9%
7	Sandstone	95.0%
8	Siltstone (Not Rippable)	96.0%
9	Siltstone (Partly Rippable)	47.6%
10	Sandstone	90.8%
11	Friable Sandstone	62.7%
12	Sandstone	93.4%
13	Sandstone	98.8%
14	Siltstone	(49.6 First Cycle)
15	Sandstone ?	96.5%
16	Sandstone ?	90.5%
17	?	44.7%
18	?	53.1%
19	Sandstone	89.5%
20	Sandstone	97.2%
21	Sandstone/Siltstone	81.7%
22	Sandstone (Coarse)	74.1%
23	Sandstone	97.8%
24	?	0.0
25	Siltstone ?	47.8%

SUMMARY OF TEST RESULTS

a) All Sandstone Specimens : I_D = 62.7 to 98.8%; Average I_D = 83.3%

b) Visually good quality Sandstone (excluding samples 1, 3, 5, 11, 21, 22) : I_D = 89.5 to 98.8%; Average I_D = 93.3%

c) Siltstone (excluding sample 8) : I_D = 13.0 to 47.8%

SLAKE DURABILITY TEST PROCEDURE

1. Select 10 representative rock pieces, weighing 40-60 grams each.
2. The oven-dried weight is obtained.
3. The wire-mesh (#10 size) drum, with rock pieces inside, is rotated in a trough of water. The drum is rotated at 20 rpm for 10 minutes.
4. The retained rock pieces are oven dried and weighed.
5. A second 10-minute test cycle is then performed.
6. The retained rock pieces from the 2nd cycle are oven dried and weighed.
7. The I_D is calculated as the ratio, in percent, of the 2-cycle retained rock pieces weight divided by the original weight (oven dried weights).

TABLE 2: POINT LOAD TEST RESULTS

SAMPLE NO.	ROCK DESCRIPTION	POINT LOAD INDEX (psi)
P1	Siltstone	73.7
P2	Soft Coarse Sandstone	18.8
P3	Siltstone	26.6
P3	Siltstone	13.4
P4	Siltstone	72.8
P4	Siltstone	72.9
P5	Siltstone	75.0
P5	Siltstone	62.0
P6	Sandstone	73.2
P7	?	90.0
P8	Coarse Sandstone	86.7

POINT LOAD TEST DESCRIPTION

The Point-Load Test is a hand operated test. It involves compressing a rock specimen between two points. The Point Load Index is calculated as the ratio of the maximum applied load (causing specimen failure) to the square of the distance between the loading points.

TABLE 3: STANDARD TESTS DURING EMBANKMENT CONSTRUCTION

SAMPLE NO.	SOIL DESCRIPTION	ATTERBERG LIMITS		COMPACTION TESTS, ASTM D698	
		LIQUID LIMIT	PLASTIC LIMIT	MAX. DRY DENSITY, pcf	OPTIMUM MOISTURE CONTENT
SP-1	Silty Clay, CL	33%	13%	104.3	19.3%
SP-2	Sandy Clay, CL-ML	41%	15%	103.5	20.5%
SP-3	Sandy Clay, CL	31%	13%	109.5	20.2%
SP-4	Sandy Silt, ML	35%	8%	106.0	19.0%
SP-5	Gravelly, Sandy Silt, CL-ML	27%	6%	112.5	?

APPENDIX B

PROJECT SPECIFICATIONS:

EMBANKMENT CONSTRUCTION
AND
TEST PADS

203.38 Use of Selected Materials - Materials excavated from required excavations will be subject to selection for use as selected topsoil, rock embankments, rock slopes, and rock ditch linings as shown on the plans and in accordance with the following general requirements:

Selected Topsoil Material - Topsoil material shall be fine, dirt like material capable of sustaining plant life.

Selected Rock Embankment - Material shall consist of a mixture of rock fragments weighing up to 1,000 pounds with 40% to 60% of fragments weighing over 400 pounds. The fragments shall be durable rock, not subject to degradation by the construction processes or by weathering. The mixture shall be well graded from coarse to fine fragments uniformly mixed together in the embankment and free from soil fines so that most interstices are visible voids.

Control of gradation of selected rock embankment will be by visual inspection of the engineer.

Selected Rock in Ditches - Material for the selected rock in the ditches shall be 10"-4" rock fragments reasonably well-graded from maximum size to minimum size.

Salvage Asphalt Concrete Pavement - The asphalt concrete pavement removed from the existing roadway not used for recycling in new asphalt concrete pavement or treated base shall remain the property of the State and shall be stockpiled by the contractor right of Station 1550 ± in a neat stockpile as directed by the engineer. The greatest dimension of the material shall not be greater than 2 feet.

203.39 Embankment Construction - Delete the third paragraph and substitute the following paragraphs:

"Where roadway embankments except for bridge ends are constructed predominantly of rock fragments, the thickness of the layers shall be as the engineer may direct but not greater than 2 feet. However, the placing of the individual rock fragments having dimensions greater than 2 feet will be permitted provided (a) that they have no dimensions greater than 4 feet, (b) that clearances between adjacent fragments provide adequate space for the placing and compacting of material in horizontal layers as specified, and (c) that no part of them comes within 4 feet of subgrade.

Embankments at the ends of bridges and extending therefrom 150 feet shall be constructed as specified under the subsection heading "Test Pad Construction".

203.41 Compaction and Density Requirements - Delete paragraph (b-2) and substitute the following:

(b-2) Embankment - In embankments, fill and backfills other than at bridge ends (150-foot section), the compacted materials within 4 feet of established subgrade elevation, shall have a density in place of not less than 95 percent of relative maximum density and below said 4-foot limit shall have a density in place of not less than 90 percent of relative maximum density.

Test Pad Construction - As part of an experimental features project, being conducted by the Oregon State Highway Division, test pads will be constructed by the contractor. The test pad locations shall be set forth by the engineer. The purpose of the pads are to determine the required procedures (watering, disking, and number of compactor coverages) for soil like shales to obtain 95% of the maximum dry density. Soil like shales shall be considered as finely laminated material formed by the consolidation of clay, silt, and fine sand. The number of test pads to be constructed will be based upon the different types of compaction equipment employed by the contractor in the construction of the approach fills such as a heavy 30 ton tamping compactor or a 50 ton four-tired pneumatic roller. Samples of the excavated material to be used in the test pad shall be taken by the state for the purpose of classification and laboratory testing. A notice of one week and a list of the types of compaction equipment shall be given to the engineer prior to the construction of the test pad.

The following procedure shall be followed in the construction of the test pad:

1) A test pad shall have a width of 50 feet and a minimum length of 150 feet. Staking for sampling locations will be done by the State.

2) Excavated material shall be placed in 12-inch loose lifts and spread with a tracked dozer or compactor equipped with a dozer blade.

3) Addition of water by spray bar and disking of the material to bring near the optimum moisture content shall be set forth by the engineer.

4) Sampling and testing after each coverage by the compactor will be done by the State. One coverage shall be considered one pass of the compactor over the entire area being compacted. Compaction equipment shall not exceed three miles per hour.

5) The number of coverages will be set by the engineer to obtain 95% of the Maximum Dry Density, as determined by AASHTO T99. Both a nuclear moisture-density gauge and sand-cone-speedy moisture tests will be performed.

6) A minimum of three lifts are required to construct a test pad, or as set forth by the engineer.

APPENDIX C

GUIDELINE SPECIFICATIONS

SPECIAL SPECIFICATIONS FOR USING NONDURABLE ROCK IN EMBANKMENTS

OREGON DEPARTMENT OF TRANSPORTATION 1989

101.02 Definitions

Nondurable Rock - Nondurable rock is identified by the 2-cycle slake durability test or by visual examination. The rock is considered nondurable when the slake durability index is less than 60 percent or when the rock is observed to readily degrade by water and mechanical influence.

203.39 Embankment Construction - Embankment construction using nondurable rock, as identified in the plans or by the Engineer, shall be as follows:

- Pulverized to 12"-0 size.
- Placed in a maximum lift thickness of 12 inches.
- Watered to promote slaking and break-down of the nondurable material in conformance with 233.

    (233: The water shall be distributed by an approved method which provides uniform application of the required quantity of water.)

203.41 Compaction and Density Requirements: Add the following:

(a-4) Nondurable rock embankments -

- The moisture content of the material at the time of compaction shall be within plus or minus 2 percentage points of optimum moisture as determined by the methods set forth under 203.41 (a-1). The material shall be compacted with a heavy tamping-foot roller, weighing at least 30 tons. Each tamping-foot shall protrude from the drum a minimum of 4 inches.
- Compact the material to conform to 203.41(a) and (b) as directed by the Engineer.

    (203.41 (a) and (b): Standard moisture, density, and deflection requirements)

- Each embankment lift shall receive a minimum of 3 or more coverages with the tamping-foot roller to obtain the desired density. One coverage consists of one pass over the entire surface designated. One pass consists of the passing of an acceptable tamping-foot roller over a given spot. The roller shall be operated at a uniform speed not exceeding three miles per hour. No additional compensation will be made for additional roller coverages to achieve specified density requirements.