Test Report

Random Rockfill Material

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I. Introduction
This report contains the results of test fill VR-24-4-1 which includes large volume in-place density test and grain size distribution tests performed before and after the test fill was completed. Also field permeability tests were performed on the test fill in-place, and several constant head permeability tests were performed on the random rockfill material. All these tests were conducted by Power Plant Construction Department personnel in the field and in the site laboratory.

II. Objective
There were three objectives in performing this test program:

A. To satisfy CP&L's commitment to NRC for defining the properties of rockfill material to be used in Class I dams and the west auxiliary dike.

B. To assure CP&L that the engineering properties assumed for the random rockfill material in the design were consistent with the actual compacted in-place material properties.

C. To determine if the test results are consistent with previous test fill properties which have already been deemed acceptable by the design engineer.

III. Procedure
Due to the fact that random rockfill material for Class I dams and dikes may be in short supply, it was determined that the blasted rock from the Cooling Tower Makeup Water Channel should be used if possible. In order to determine that the blasted rock material was suitable, an in-place test fill section was constructed on site to simulate the actual hauling, dumping, spreading and compaction process of the dam random rockfill construction. From this test fill in-place properties such as gradation, density, permeability, and settlement due to rolling were determined.

A. Description of test fill - Test fill section designated VR-24-4-1 was constructed between 12/11 and 12/16, 1978, just south of the Emergency/Service Water Intake Channel. The area selected was free of excessive surface water and was reasonably level. The area was staked out and graded and then proof rolled with a vibratory roller until no appreciable settlement was detected. The test fill was conducted in accordance with PPCD - SHNPP Technical Procedure TP-1. The test section was approximately 40 feet by 55 feet with 24 settlement points. Also a ramp was
constructed with a 5 H to 1 V slope. The sides of the test section were maintained at approximately 1.5 H to 1 V. The material was end dumped, spread in approximately 24 inch thickness and was compacted with 10 passes of a Rascal 600-A roller. The roller produces a dynamic force of 45,000 pounds operating force with a vibration frequency between 1100 and 1500 VPM at a maximum speed of 3 mph. The test fill section consisted of four lifts. The number and thickness of the lifts placed, number and speed of roller passes, type and operation requirements of the compaction equipment, and the methods of spreading and compaction were determined from previous test fills.

B. Material - The material used was blasted random rockfill removed from the Cooling Tower Makeup Water Channel. All the material came from approximately El. 220 and station 8 + 00. The material consisted of medium to fine grained sandstone with siltstone. Maximum particle size allowed for the test fill section was 22 inches or 90 percent of the lift thickness.

C. Settlement Measurement - Prior to placement of the first lift, initial readings were recorded for each of the 24 settlement points. A system of offset control was used to assure the settlement points were relocated in the same plane after each lift placement. The rockfill material was then end dumped by Euclid R 50 trucks and spread in approximately 24 inch lifts by a Caterpillar D 8 dozer. The method and operating time utilized by both types of equipment simulated anticipated field conditions. The surface of the lift after spreading was marked with paint sprayed directly on the lift surface for each settlement point. Level readings were recorded for each of the points and averaged to determine the initial lift thickness. The vibratory roller then made one pass over the entire surface of the lift and level readings were taken to determine the degree of settlement. The procedure was then repeated for a total of 10 passes for the first 3 lifts. The settlement points were repainted as necessary. After completion of the first lift, settlement data
was collected in the same manner for the second and third lifts. The final level readings recorded from a previous lift were used as the initial readings in determination of the thickness of the next lift. A plot of percent decrease in lift thickness versus number of passes was constructed from the data collected for each lift. An examination of the settlement plots for the first three lifts revealed that approximately 6 passes of the roller produced an optimum amount of settlement per compaction effort. The fourth lift was rolled with only 6 passes.

D. **In-place Density Determination** – After the final layer was compacted and all settlement data was recorded, an in-place density test was performed on December 16, 1978. The following procedure was used to conduct the test:

1. A wood frame measuring 8 feet x 8 feet x 7 inches high was placed over the test area and held in-place by stakes.
2. Level readings of all four corners at the frame were recorded from a nearby established bench mark.
3. One sheet of polyethylene was laid loosely over the frame so that they were in as close contact as possible with the inside of the frame rock surface.
4. The depression in the slack membrane was filled with water via a calibrated barrel to within 3 or 4 inches of the top of the frame.
5. The volume of water added and the distance from the top of the frame to the water surface was measured and recorded.
6. The water was removed without disturbing the ring or damaging the membrane.
7. The polyethylene sheet was removed and checked for leaks.
8. The material within the frame was then carefully excavated and placed into a truck.
9. The hole was then hand-cleaned to remove all loose or sharp material in the sides and bottom.
10. The weight of the total sampled excavated was determined by weighing the truck full and empty.
11. The polyethylene sheet was again placed loosely over the excavated hole and frame.
12. The hole was filled with water to the same level as in step 4.

13. Level readings were again taken at all four corners of the frame to assure the frame had not moved.

14. The volume of water added was recorded.

15. Steps 6 and 7 were repeated.

E. Grain Size Distribution Test - A before and after gradation analysis was performed on the random rockfill used in the test fill. One gradation sample was loaded on a flat bed truck directly from the point of blast production. This sample appeared to be representative of the type and size of material that was being excavated from the Cooling Tower Makeup Water Channel. The sample was taken directly to an enclosed area, spread out on a concrete floor, and heated with space heaters to remove the moisture. The material was graded by hand to remove all large rocks in the 12" to 24" range, then the 8" to 12" range, then the 4" to 8" range. The sample was then reduced by quartering and graded down to the #8 sieve using a Gilson Sieve Shaker. A Ro-Tap Sieve Shaker was used to determine particle size down to the #100 sieve. The weights retained on each sieve were carefully measured and the Percent Passing Total was determined for each sieve ranging from 24" down to #100.

The after compaction gradation sample was obtained from the in-place density test to determine how much breakup particles. The sample was dried and graded in the same manner as the before compaction test sample. The Percent Passing Total was computed for each sieve size and recorded.

Utilizing the above data the two gradation curves were plotted to obtain a visual aid in determining which sizes broke down the most. Most of the breakdown occurred in the 4" to #16 gradation range. There was not an appreciable increase in the amount passing the #100 sieve. However, the after compaction sample was, on the whole, finer than the before compaction sample due to rock breakdown.
F. **Permeability Test** - A total of five permeability tests were performed on the test fill and the random rockfill obtained from the test fill. A constant head method was used to determine the coefficient of permeability of the random rockfill material. A brief discussion of each permeability test will follow and the procedure used:

1. Two in-place permeability tests were performed on the test fill in accordance with the Bureau of Reclamation Department of the Interior, Field Permeability Test (Well Permeameter Method) Designation E-19. The procedure used is as follows:
   a. An air track drilling rig drilled two holes in the top of the test fill. These holes were 2.83' deep.
   b. The sides of the well were scarified and all loose material was removed from the bottom of the holes.
   c. The well was filled to the top with Ottawa sand of known density.
   d. The volume of the well is then determined as is the radius of the well.
   e. Water is added through a float valve which assures a constant head in the well.
   f. Water was allowed to flow into the well for approximately 2 hours to saturate the area adjacent to the well.
   g. Measurements were then begun in 30 minute intervals to measure the quantity of water that flowed into the well. This was continued for 4 hours. An average flow rate was then calculated.
   h. All the data was compiled and entered into a formula to yield the permeability of the test fill.
   i. These two well permeability tests were designated as VR-24-4-1-PF-1 and VR-24-4-1-PF-2 respectively.

2. One laboratory permeability test was performed on a regraded sample of the random rockfill material to gain more insight on the material's permeability. The following steps were performed in the laboratory trial:
a. No gradation sizes larger than 3" were used in the test.

b. The after-compaction gradation curve was used and redrawn to eliminate any sizes larger than 3". In essence, the curve was redrawn to indicate that 100% passed the 3" size and the new curve then blended back into the after compaction gradation curve between the 3/8" and the #4 sizes. This is the same method that was used by the Corps of Engineers, South Atlantic Division Laboratory dated October 24, 1974. The procedure is explained in detail in CP&L correspondence letter CE-03589. The purpose of redrawing the curve was to eliminate any sizes larger than 3" (which could not be adequately handled by our test equipment). The curve was redrawn in such a manner as to closely match the actual after-compaction gradation of the test fill section for sizes smaller than the #4 sieve.

c. Quantities of test fill blasted rock were warm-air dried overnight and then sieved in a Gilson machine into the following gradation limits:
   1. 1" to 3" range
   2. 1/2" to 1" range
   3. #4 to 1/2" range
   4. Passing #4

d. The percentages in each gradation range needed were calculated from the gradation curve drawn in step 6.

e. The weights needed in each gradation range were calculated and then water was added to the weighed out sample to reproduce the water content of the blasted random rock material.

f. The sample was then thoroughly mixed to combine all 4 gradation ranges into a homogeneous mass representative of the rockfill test fill material.

g. The material was placed in three lifts into a cylindrical steel drum and compacted until a dry density of 137.8 #/ft³ was obtained. This was the density of the material in the compacted test fill.

h. The surface between layers was scarified to eliminate
the highly compacted layer of fines directly on the surface of each layer.

i. The top of the cylindrical drum was sealed and a maximum of 5 psi vacuum pressure was applied to the top of the soil sample to pull water up through the soil sample thereby insuring complete saturation.

j. Once the sample was saturated, a constant head of water was maintained for a period of about 8 hours on the sample. Readings were taken every 30 minutes to determine the flow rate through the compacted sample.

k. This permeability test was marked VR-24-4-1 PL-1.

l. Once all the data was obtained, a coefficient of permeability, K, was computed from a constant head formula.

3. In addition, 2 more laboratory permeability tests were performed on the random rockfill material obtained directly from the compacted test fill area. The following steps were used in performing these permeability tests:

a. A representative sample was excavated from the test fill and placed in buckets. Approximately 150§ was retrieved.

b. The sample was taken to the lab where all sizes larger than 3" were removed from the sample and discarded.

c. The moisture content of the sample was determined.

d. The material was weighed out and compacted in three lifts until a dry density of 137.8 $$/ft^3 was attained. This was the density of the compacted material in the test fill.

e. A layer of burlap was placed in the bottom of the cylindrical drum before the 3 rockfill lifts were compacted in the drum. The purpose of the burlap was to prevent fine particles from clogging the drain holes in the bottom of the drum.

f. The surface between lifts was scarified to eliminate the highly compacted layer of fines directly on the surface of each layer.
g. The permeability test was then run utilizing the constant head test method. The top of the cylindrical drum was sealed and a maximum of 5 psi vacuum pressure was applied to the top of the soil sample thereby insuring complete saturation.

h. Once the sample was saturated, a constant head of water was maintained for a period of time and the quantity of water flowing through the sample was measured. The flow rate was then computed.

i. After all the data was collected, a coefficient of permeability value, K, was computed for the random rockfill sample.

j. These 2 tests were marked VR-24-4-1-PL-2 and VR-24-4-1-PL-3 respectively.

IV. Tabulated Results

A. Gradation analysis -
   1. Before - passing 1/4 inch = 17.5 %
   2. After - passing 1/4 inch = 35.0 %

B. In-Place Density -
   1. Wet Density - 147#/ft³
   2. Dry Density - 137.8#/ft³
   3. Moisture Content - 6.67%

C. Settlement Test - optimum number of 6 passes produced 1.2% settlement.

D. Permeability Tests - constant head:
   1. In-place test fill permeability test 1 & 2
      a. K = 2.8 x 10⁻⁴ cm/sec
      b. K = 2.8 x 10⁻⁴ cm/sec
   2. Laboratory constant head test using a reconstructed gradation produced by combining various sieve size particles.
      a. K = 7.28 x 10⁻⁴ cm/sec
   3. Laboratory constant head test using a random rockfill sample obtained from the test fill.
      a. K = 3.03 x 10⁻³ cm/sec
      b. K = 2.6 x 10⁻³ cm/sec

NOTES: The coefficient permeability listed above in 3a and 3b were determined for initial recorded data. See Discussion of Results for changes in
V. Discussion of Results

A. Settlement of Test Fill — Test results indicate that an adequate amount of compaction is produced by 6 passes of a Rascal 600-A vibratory roller. The settlement curves which were drawn for each of the 4 lifts in the test fill began to flatten out at approximately 6 passes of the roller. Further rolling did result in additional compaction, but the greatest amount of compaction came in the first 6 passes of the roller. The approximate percentage settlement in 6 passes of the roller was 1.2%.

B. Particle Gradation — A particle gradation was performed before roller compaction and again after roller compaction. The results are shown in the Data section of this report. There was an evident breakdown in particles due to the roller passes. The breakdown occurred over the entire spectrum of particle sizes but most notably in the 4" to 1/16 sieve sizes. The after compaction gradation for this test fill compared favorably with previous test fill samples that were sent to the Corps of Engineers for gradation analysis. In other words, the after compaction gradation for test fill VR-24-4-1 was similar to other test fill gradations that have been done at this site in the past.

C. In-Place Density Test — The in-place density test performed on the roller compacted test fill revealed that a dry density of 137.8#/ft³ was obtained. The moisture content of the material was 6.7%. These values are consistent with test values of previous test fills performed on site.

D. Permeability Tests — A total of 5 permeability tests were performed on the random rockfill material. Two tests were made in-place in the test fill itself. The first test resulted in a permeability of \( K = 2.82 \times 10^{-4} \) cm/sec. The second test value was a permeability of \( K = 2.86 \times 10^{-4} \) cm/sec. These two tests are identified as VR-24-4-1-PF-1 and VR-24-4-1-PF-2. The permeability of this material is less as compared to the permeability of previous test fill material performed by the Corps of Engineers.
One possible source of the reduced permeability in this test fill could be that an air track drilling rig was used to drill the two holes for the field permeability tests. As an air-track drill, it shatters the material below it and exerts great force upon the walls of the hole. This force could have helped to seal the hole with very fine shattered material that will impede the flow of water during a permeability test. However, the interior of the wells were scarified before the test was begun. Also, the test holes were drilled to a depth of about 33". This means that the hole penetrated into the second lift where the surface of the second lift was compacted by ten passes of the roller. The surface of the second lift and extending 2 or 3 inches deep is composed of highly compacted fines produced by the breakdown of rock particles caused by the 10 roller passes.

A third test was performed in the lab on material that was sieved and then recombined to artificially produce a gradation that had 100% passing the 3" sieve. A constant head permeability test was performed on a 9" thick sample inside a 12" diameter steel drum having perforations in its base to allow water to seep out. The results of this test give a permeability of \( K = 7.28 \times 10^{-4} \text{ cm/sec.} \) This test is designated as VR-24-4-1-PL-1. The permeability of this sample was a little lower than was anticipated. There were two factors which could have contributed to this low value:

1. The first 3" layer that was placed was compacted so much that many fines accumulated near the top creating an impervious glossy skim. This layer was not scarified to break up the glossy surface. This would have lowered the permeability.

2. The drain holes in the steel drum containing the sample became quite clogged with fine particles and prevented water from draining unrestrained from the sample. A porous layer of burlap was inadvertently omitted which was to have lain adjacent to the drain holes to prevent them from becoming clogged with fines.

Since it was suspected that the previous test may be erroneous, 2 more lab constant head tests were run. Material was taken directly from the test fill area and all particles larger than 3" were removed. The moisture content was determined. The material was then
compacted in three 3" lifts until a dry density of 137.8#/ft³ was obtained. Two layers of burlap were placed next to the drain holes before the first layer of soil was compacted. This was to prevent fines from clogging the holes. Care was also taken when compacting the sample so as not to over-compact any layer. The constant head permeability test was performed and a coefficient of permeability K value of 3.03 x 10⁻³ cm/sec and another of 2.6 x 10⁻³ cm/sec was obtained on tests designated as VR-24-4-1-PL-2 and VR-24-4-1-PL-3 respectively. A gradation was run on a representative sample of material not actually used in the test. The gradation matched up well with the artificially regraded and reconstructed test sample of VR-24-4-1-PL-1.

All three lab permeability tests had coefficients of permeability that reduced as time progressed. This lowering of the K value was attributed to migration of fines and clogging of the drain holes.

E. Examination of Test Fill After Compaction - After the test fill was completed, a D-8 dozer cut a path through the area so as to examine the cross-section of the test fill. The material was generally firmly compacted and there was good bond between horizontal layers. There were very few noticeable areas of loose compaction or voids. These voids were mostly limited to areas underneath larger rocks that were placed directly on top of the previous lift. These few areas had voids of about 1" width underneath the large rocks. Only 2 or 3 such areas were noted. A few other places did not have voids but contained loosely compacted material underneath larger rocks lying directly on top of the previous lift. On the whole, the test fill appeared to be well compacted. A good estimate would be that over 95% of the cross section did not contain noticeable voids and areas of loose compaction.

VI. Recommended Method of Placement and Compaction

Based on the data collected and observations made during the process of constructing the test fill, the following recommended methods of place-
ment of random rockfill in Class I dams and dikes:

A. A blast pattern of 8' x 10' should be used during production as this is the same blast pattern that was used on material in the test fill.

B. Material will be end dumped from Euclid R-50 trucks in the random rockfill zone of the dam or dike as close as possible to its final resting position.

C. D-8 dozers will spread the material in approximately horizontal lifts of 2 foot thickness.

D. All rocks larger than 90% of the lift thickness shall be removed from the random rockfill zone.

E. A minimum of 6 passes of a Rascal 600-A vibratory roller having a minimum dynamic force of 45,000 lbs. will be performed on each 2' thick lift. The roller shall not exceed 3 mph and passes shall overlap one foot.

For more in-depth information, see Ebasco Specification CAR-SH-CH-4, Rev. 6.