Chapter 7
Test Quarry Operations

7-1. Supervision

A major purpose of a test quarry is to determine how rock characteristics and excavation variables affect the rock material produced and how they affect the side slopes and bottom of the excavation. The technical aspects of the test quarry operation are normally best supervised by a geologist experienced in rock excavation methods and procedures. This person, the Technical Test Quarry Supervisor (TTQS) should have sufficient staff to allow complete oversight of the contractor's operations as the work progresses. This work differs from a normal construction contract operation because it is an exploration and testing program with the objective of developing data and procedures to be subsequently incorporated into project design and construction. Numerous variations of excavation procedures, such as ripping and blasting, with its many variables, must be tested to determine what works best in each different rock type. For this reason, considerable flexibility must be written into a test quarry contract to allow the Contracting Officer's Representative (COR) to exercise control of the contractor's excavation procedures, including blast hole sizes, pattern spacing, depth of hole, subdrilling, stemming, type of explosives, powder factor, and loading configuration. Loading and hauling procedures also cause considerable variation in the rock gradation produced and are variables which should be within the control of the COR. A test quarry contract should not be an end-product type but should be a method type and essentially call for the contractor to furnish supervision, labor, materials, equipment, and supplies to proceed with test excavation(s) as directed by the COR.

7-2. Safety Considerations

Safety considerations pertaining to test quarry programs are as follows:

a. Operations. Test quarries are frequently located in areas of very steep terrain where access is very difficult. Rock excavation procedures also require operations which can be very dangerous unless all safety precautions are strictly followed. A safety analysis should be performed before any work begins to establish any added precautions that may be needed beyond those set forth in EM 385-1-1.

b. Affects on test quarry location. Access to the test quarry site is frequently a major problem because of very steep topography and because of the high cost of haul-road construction into such areas. Safety considerations limit the maximum grade to which haul roads may be constructed. Because of access-road cost, the decision is often made to locate the test quarry, not in the area where future construction is to take place, but in one with similar rock types. This may lead to test-quarry and test-fill results which are not totally applicable to the project construction. This can also result in later contractor claims and cost over-runs which are many times greater than if safe access roads to the planned required excavation area were constructed in the first place. If at all possible, the test quarry should be sited within the limits of the excavation area which has been selected as the main source of rock required for project construction. If the costs of doing so exceed the limitations of Preconstruction Engineering and Design funding, consideration should be given to making the test quarry and test fill contract(s) and the access road contract the first construction contract in order to transition from PED to Construction General (CG) funding. This will allow adequate monies to safely construct the test quarry in the most appropriate location(s).

7-3. Modification of Design

As data are obtained during the progress of the test quarry development, it becomes necessary to modify the test quarry design to take into consideration new information about the rock's behavior that was not available at the time of the original design. The test quarry contract specifications should be written to permit these changes at the direction of the COR (as discussed in paragraph 7-1). The test quarry modifications must be developed in full coordination between the TTQS and the designers to assure that all future needs for design information are being met.

7-4. Blasting Plans

Blasting plans should be required by the contract specifications. These are necessary to permit the TTQS to assure that the contractor's plan of operation is in accordance with the test-quarry design. Approval of the blasting plans by the COR should be required by the contract. In addition to the guidance contained in Chapter 5, detailed guidance on blasting techniques is contained in TM 5-332 and EM 1110-2-3800.

a. Master plan. The contract specifications should require the contractor to prepare and submit for review, modification (if necessary), and approval, a master plan of excavation prior to initiation of any excavation. This master plan should include a complete description of the contractor's proposed scheduling sequence, equipment, staffing, overburden removal and disposal/reclamation plans, drainage control, plans for ripping (if required), overall plan for each test blast, and loading and hauling procedures. The plan should also include a description of his provisions for modifications and/or changes to equipment and procedures as required by the COR as excavation progresses and information is developed on which to base such changes.

b. Individual plans. Prior to each blast, the contractor should be required to furnish a detailed blasting plan. This plan should show location of bench to be blasted (with respect to the overall excavation), presplit or smooth blasting plan for side slopes, depth of excavation, burden and free-face location, blast-hole pattern and powder factor, blast-hole diameters, subdrill, stemming, loading configuration, and delay sequence. This plan should be used by the TTQS as the basis to make any modifications deemed necessary to provide the desired breakage data. The contract should require approval of this plan by the COR prior to initiation of the work in the particular test area.

c. Blast reports. The contractor should be required to furnish a post-blast report which will detail any variation that occurred to the individual blasting plan as furnished prior to the blast. Such things as misfires, under or overloaded holes, water in the holes, variations in stemming, and any other observed variables should be reported. Video documentation is helpful in verifying and evaluating blast reports. Test quarry specifications can be written to include video documentation submittals to the TTQS. The TTQS and staff should prepare their own report of each blast. This should contain a description of the rock mass including rock type and condition, as-blasted gradations, condition of slopes, bottom configuration and depth of pull, location of the post-blast rock pile, slope mapping, photographic documentation of the slopes, bottom, and the rock pile before loading and hauling. Report conclusions should include an evaluation of the effectiveness of the blast in providing the design gradation, designed slopes, and bottom conditions. Recommended modifications to subsequent test blasts based on these results should be included in the report.

7-5. Slope Mapping and Presplitting Observations

One of the purposes of a test quarry is to develop blasting procedures which will result in safe, satisfactory permanent slopes. This will require the testing of different presplitting patterns. Different presplit hole spacings should be tested, usually varying from 46 cm (18 in.) to 91 cm (36 in.); different slope angles, usually varying from 1 vertical on 1 horizontal to 1 vertical on 0.25 horizontal; different loading configurations in the blast holes; and different widths of buffer zones between the presplit patterns and the production blast holes. The results of these variables are affected very much by the relationship of the orientation of rock mass structural details to the orientation of the excavation slopes. Slopes cut on one side of the excavation may be entirely satisfactory while those cut on the opposite side may be unsatisfactory and even unstable. Detailed guidance on presplitting techniques is contained in EM 1110-2-3800.

a. Mapping. The excavated slopes should be mapped. The conditions noted and mapped should include cut slope angle, slope height, presplit blast-hole spacing, condition of each slope segment, rock type and condition, and location and orientation of rock fractures intersecting the slope. In addition to mapping rock fractures in the slopes, fracture spacing/frequency should also be noted along judiciously located scan lines for comparison with similar information developed from the design investigations and with the measured rock-pile gradations. Visible groundwater and surficial infiltration seepage areas should also be depicted during mapping.

b. Presplitting observations. Each slope should be carefully described and reported as to its condition, taking into account the results of the presplitting and those factors such as intersecting rock fractures and rock quality which affect the stability of the slope. The maintenance of design blast-hole spacing and orientation is very important. Where these deviate from design, the results should be described. Successful presplitting normally leaves a half-round of the individual blast hole visible in the slope. Where these are not seen, it is likely that the presplit shot was too heavily loaded or that there was an insufficient buffer zone between the production blast and the presplit slope. If the presplit plane between blast holes is highly irregular, it is likely that the hole spacing was wider than optimum. Excessive rock fracturing behind the permanent slope line is another indication of excessive hole loading.

By contrast, incomplete shearing of the rock between presplit holes may be an indication that the holes were under loaded or that they were too widely spaced. Rock structure induced (wedge or planar) slope failures may occur. These features should be incorporated into the slope maps and should be described for inclusion in the final report. Complete photo coverage of the as-excavated slopes is of considerable value in illustrating the observation descriptions. These photographs should be obtained after the slope is freshly cut and used generously in the final report.

7-6. Rock Quality and Pre-Test Fill Gradations

a. Rock quality after blast. It is important to evaluate and describe the quality of the blasted rock existing in each blasted area. Rock quality is a major factor of the design of rockfill structures and it is important to compare the rock quality observed from the test quarry program with the design assumptions. In addition, variations in rock quality often become the basis for disputes between the contractor and the government. Because of the uniqueness of each site and each rock type, rock quality evaluation systems should be designed on the conditions encountered in each test quarry program. Such evaluation systems should include, as a minimum: rock type, degree of weathering (unweathered, slightly weathered, moderately weathered, highly weathered, decomposed, EM 1110-1-1804), potential for degradation, both in stock piles and during fill placement and compaction (e.g., estimates of abrasion resistance, desiccation deterioration, incipient fractures, brittleness, softness, and physical or chemical instability), and rock mass gradation.

b. Pretest fill gradations. As part of the rock mass quality evaluation, it is important to develop information on the degree of degradation that occurs during the loading, hauling, processing, storage, and placement of rock fill in an embankment. In order to obtain this information, it is necessary to determine the gradations that exist after blasting but before loading, hauling, placement, and compaction. This should be done by the same procedures which will be used to control the gradation of fill placed in the test fills and subsequently in the embankment. Methods for obtaining mechanical gradations of rock fill were addressed in paragraph 6-5 and will be treated in more detail in Part 2: Test Fills. In addition to the mechanical grading methods, particle size scan-line measurements of the blasted rock pile should be performed and their accuracy evaluated. If particle shape and percentage of fines allow these types of measurements, they are a rapid, economical adjunct to time-consuming screen gradation measurements. A comparison of the initial rock mass gradation with gradations made at subsequent stages in the process of rock placement in test fills will provide data on which to base an appraisal of rock mass degradation that can be expected during loading, hauling, and embankment construction. If there is potential for the rock to deteriorate over time in a stock pile, this too should be evaluated. One approach is to establish test stock piles and perform initial and subsequent gradation tests and compare the results. A complication can develop in this test because the mechanical action of the test itself may tend to degrade the particles of the test specimen. This must be considered in evaluating the results. Hairline blast fractures develop in some brittle rock types. Because these fractures allow degradation of particle size during handling, processing, placement, compaction, and project operation, they need to be identified during this stage of test quarry development. Samples of varying particle size should be furnished to the appropriate Division Laboratory for testing to determine the presence of minute blast-induced fractures.

7-7. Rock Processing Results

Frequently, rockfill embankment designs require rock processing that goes beyond the quarry-run gradations that can be produced by the rock excavation procedures in the quarry. These can include simply processing the rock over a grizzly to separate it into two or three different sizes to the much more complex process of running the rock through a crusher and vibrating screens to produce a series of carefully controlled gradations. The more processing required, the more expensive the embankment construction will likely be. In addition, it is likely that there will be more opportunity for disputes between the contractor and government. If the design efforts indicate that processing will be required during construction, it is important to test it during the test-quarry and test-fill operations. Otherwise, the results from the test quarry and test fill may not be indicative of the results to be obtained during final construction. The gradations obtained from rock processing are the results of many variables. These include rock type, rock quality, excavation method, and rock crushing and screening plant design. It is frequently difficult for a smaller test quarry and portable processing equipment to reproduce the results that will be obtained from a full quarry and large production equipment. For these and other reasons, it is desirable to design the embankment to require as little processing as is possible and to construct the test fills with materials that are truly representative of those that will be obtained from the construction production excavations. Rock processing results should be carefully described in the Test Quarry and Test Fill Report.

7-8. Report

The data and information developed during the test quarry construction should be analyzed, evaluated, and reported in a Test Quarry and Test Fill Report. The test quarry portion of the report should contain sketches of each test blast, maps of all excavated slopes and bottoms, descriptions of the results of each test blast including presplit slopes, gradations of the quarry-run material produced by each blast in each separate rock type, and conclusions and recommendations. The report should be generously illustrated with geologic maps and cross sections, sketches, photographs, analyses of the rock fracture orientations and frequency/spacing revealed in the excavations and evaluations of the fracture orientation and spacing to slope stability to the blasted rock gradations produced. A typical outline of the test quarry section of the report is shown in Table 7-1. The report of the test quarry program is a very important document for use during final design and construction. Also, it can prove to be very valuable during the contract disputes which inevitably arise during the complicated construction of a large dam. The importance of a complete, accurate, well-conceived report cannot be overemphasized. The conclusions and recommendations section of the report should be specific with regard to the suitability of the rock materials for the uses to which it will be placed. Constraints upon the suitability of the materials must be clearly stated (e.g., shale partings in a rock mass will likely lead to an eventual breakdown in particle size). Recommendations for any special handling, processing, storage or placement methods that were developed during the test quarry operation should be clearly detailed in that section of the report.

Table 7-1
Typical Test Quarry Report Outline

1. Executive Summary

2. Introduction

3. Test Quarry Design and Objectives

   a. Discussion of objectives
   b. Overview of site selection criteria
   c. Thorough presentation of design including layout and slope stability

4. Geological Conditions in the Test Quarry

5. Description of Each Test Blast

   a. Rock type and condition
   b. Hole pattern
   c. Delay pattern
   d. Hole depths and loading design
   e. Explosives, detonators, and delays
   f. Blasted rock mass description
   g. Quarry-run gradation
   h. Laboratory test results
   i. Conclusions

6. Drilling, Loading, and Hauling Equipment and Procedures

7. Description of the Results of Each Presplit Slope Blast

   a. Rock type and condition
   b. Presplit hole and explosive charge configuration
   c. Presplit slope condition
   d. Rock joint analysis and slope stability
   e. Conclusions

8. Rock Processing Results

   a. Description of processing objectives
   b. Description of rock processing equipment
   c. Results of processing each rock type and condition
   d. Gradations and particle shapes
   e. Degradation during each stage of processing
   f. Laboratory test results

9. Conclusions and Recommendations

   a. Conclusions including lessons learned
   b. Recommendations

APPENDICES -- Laboratory Test Sheets, Boring Logs, Field Gradation Test Results, Description of Rock Processing Equipment, Photographic Documentation, Etc.