APPENDIX B

STONE PRODUCTION

B-1. General. Interest and concern with practices at the source during production of project stone may be useful in more than one way. The producer's quality control program is bound to be sensitized by an awareness of close scrutiny and evaluation of methods and products of the source. Corps overviewing usually is passive and in that case must carefully avoid any direct influence that might later be perceived as having been a direction or recommendation or an acceptance or rejection of material. Observations at the source of materials by CE personnel may also constitute an extension of their quality assurance program.

B-2. Blasting. The size and gradation of quarry stone are generally recognized as being influenced by the blasting pattern. The influence may be conspicuous in massive rocks but subordinate to geological structure in bedded or highly fractured or foliated rocks. The effects and interactions are extremely complex and not practically amenable to explanation by theory or sophisticated model. Such tools should be avoided in favor of using first-hand experience and observation. Table B-1 illustrates the divergence among blasting methods for different purposes.

Table B-1. Blasting Methods for Various Purposes

Type	Diameter in.	Hole Depth ft	Pattern ft by ft	Rows	Charge* lb	Powder Factor lb/cu yd	Rock
Aggregate Production**	6	50	18 by 16	1	6,500	1.1	Limestone
Massive Excavation	3	18	7.5 by 7.5	6	8,500	1.5	Sandstone
Structural Excavation	3.5	15	10 by 8	5	3,400	0.5	Limestone
Armor-Stone Production	3	8	5 by 3	1	20	0.3	Limestone

* Mostly ammonium nitrate/fuel oil (ANFO) or similar agent.
** With armor stone as byproduct.

a. Aggregate.

(1) Most large commercial quarries produce aggregate as their primary product, and any large-stone material is a subordinate by-product. The same is true for quarries producing flux for iron ore reduction. This imbalance must be appreciated when considering an aggregate or flux-stone quarry as a source of large stone. The production and stockpiling of large stone usually is constrained rigidly by the production of the primary product. Occasionally, a separate operation for large stone is established within the quarry.

(2) An example blasting pattern for aggregate is given in Table B-1. Since crushing is a part of the processing of aggregate, most patterns are designed to fragment heavily. This universally suspected preference for heavy fragmentation leads to the widespread pessimism about the quality of large stone by-produced from aggregate or flux-stone quarries. Cracks from blasting may remain hidden in outwardly solid stone until aggravated by environmental processes after placement. This potential for delayed problems can sometimes be recognized by carefully scrutinizing large-stone material in the quarry, but the evidence is seldom clear-cut.

b. Construction Excavation. The emphasis in construction blasting is on maintaining a production rate toward meeting a construction schedule. There also should be an important concern with avoiding damage to adjacent structures and excavated rock surfaces, a concern that would ordinarily favor light shooting and the survival of undamaged large stone. However, incidental production of oversized pieces interferes with equipment operations and is normally avoided. Despite the apparent difference in the representative patterns in Table B-1, construction blasting achieves about the same results as quarrying for aggregate. The yield of large stones is low. See EM 1110-2-3800 for details of construction blasting.

c. Large-Stone Special. Small-scale quarrying specifically for high yield of large stone is sometimes feasible where geological structure such as bedding makes a massive ledge accessible and workable. Elsewhere, strong intact rock combined with very widely spaced irregular jointing may be suited to production of large stone, but even there, the yields seldom exceed 15 percent. The blasting pattern for large stone often positions light charges of low velocity (commonly ANFO) at intervals of a few feet parallel to the face. Black powder, with very low velocity and causing lesser impact on the rock, is sometimes recommended to minimize cracking in commercial quarries, but the use of black powder is prohibited at Corps projects according to EM-385-1-1.

d. Coyote. Coyote blasting is sometimes used to produce rock fill and larger stone because of its economy and speed. Charges measured in tons are detonated simultaneously at one or a few points in a tunnel to produce total stone needs. Application of this method should be considered with restraint. The poor control of effects may lead to damage of material and even the ruination of a source. Coyote blasting may yield an excessive amount of fines and dust, and these may have to be removed by extensive processing. Even oversize stone may result and have to be broken by secondary methods or otherwise removed.

B-3. Processing. Some processing is usually necessary to achieve the stone size distribution required in the specifications. Processing usually involves the removal of oversize and undersize material at the minimum but may also involve sophisticated means of separating stone pieces into classes by size.

a. Quarry-Run. Quarry-run stone is supplied directly from the source with little or no processing. Stone size is controlled partially by modifying blast size and pattern. The terminology is not universally defined; consequently, it is important that quarry-run stone and similar material such as spalls should be carefully defined as far as hidden size requirements likely to involve processing. Quarry-run rock is used in large volumes for constructing some rockfill dams and as stone protection in lieu of graded riprap.

b. Picking. Large stone is often separated from blasted rock by mechanically picking and setting aside or accumulating into a stockpile. This method of producing large stone is favored by some aggregate operations, since it tends to reduce the need for secondary shooting of oversize rock. Stockpiles are slow to assemble and may be exhausted unexpectedly under heavy volume demand. On the other hand, such stockpiles are usually dependable for intermittent or relatively small-volume jobs.

c. Grizzlying. The simplicity and ruggedness of grizzlies make them the primary element of stone processing at most quarries. They also are used extensively in construction excavation. Grizzlies functioning alone or in sets accomplish basic processing as indicated below.

(1) Removes fines.

(2) Removes oversize.

(3) Classifies into two or more classes of specified size range.

d. Screening. Screening is basic to producing aggregate and similarly sized products and often gives some by-product large-stone classes also. The plant normally combines several vibrating screens and grizzlies with belt conveyors, bins, and surge piles. The size ranges of classes are varied in order to meet specifications of a job or jobs. Riprap and larger sizes are ordinarily removed well ahead of screening, but coarse classes from screening plants have been used for core stone within retention dikes and for interior zones in rockfill embankments.

B-4. Scheduling. The limitations imposed by the scale, methods, and principal product from blasting and processing frequently impact on the availability of material on schedule.

a. Direct Ship. Those large-stone products that can be hauled directly from the blasting face to the project present the least problem in meeting a construction schedule. The rate is increased by upscaling the quarry operation or construction excavation.

b. Stockpiling. Stockpiling of large stone is advantageous and often necessary as a contingency against interruptions at the source. Stockpiles may be located at the source or at or near the project. Stone available in a stockpile may be considered in terms of days of placement operation. When stockpiled stone is down to a few days of placement, there will be an urgency to replenishment. Figure B-1 shows technical provisions prepared for a large jetty project to avoid confusion and problems incidental to handling and stockpiling.

c. Curing Stone.

(1) In some regions and for some rock types, it is considered necessary to stockpile large stone through a curing period. Curing allows large stone

3. STOCKPILES OF STONE.

3.1 General. Separate stockpiles for each type armor and underlayer stone, each gradation of blanket stone and leveling stone shall be maintained at each quarry, intermediate transfer points, and at the worksite. Every stone of the armor and underlayer stone larger than 1,000 pounds shall be marked at the quarry with a distinctive marking, unique for each type armor or underlayer size gradation. The marking shall be placed on at least three (3) different sides of a stone.

3.2 Stone Breakage. Stones which are broken during shipment to the work site or during placement shall be reweighed and may be reassigned to a new armor/underlayer type provided they meet the weight criteria for any one type stone. Stones broken in placement shall be removed from the structure and returned to the stockpile area to accomplish the reweighing.

Figure B-1. Example technical provisions for stockpiling armor stone. (Not intended for direct use; this example only illustrates how technical data are ultimately presented in contract language)

to stabilize before placement and occasionally circumvents deterioration problems dramatically. A period of 90 days is sufficient for drying and possible stress relief and case-hardening effects to occur. However, stone buried in large stockpiles may need longer periods. Past experience can usually establish whether curing is critical. Where the question has not been clearly resolved, provisions may be considered for inclusion in the specifications for curing, unless the contractor can provide evidence that curing is unnecessary.

(2) It has also been found that some large stone fractures detrimentally when quarried in cold weather. The mechanism is a freezing of pore water. Figure B-2 shows a technical provision addressing the problem.

B-5. Dimension Stone. Dimension stone quarries are ideal sources of large stone for construction since they normally produce joint-free blocks of durable rock as a raw material for processing into monuments and facing for buildings. Light blasting is used in some operations while others use wire sawing systems. Keep in mind, however, that the large stone available for construction is generally the waste or reject excluded from the principal production and accordingly may be of somewhat lesser quality.

B-6. Boulder Accumulations. Boulders and natural stone blocks are useful forms of large stone where they can be concentrated economically. Since these stones have already experienced aggressive geomorphic processes in the past, they are likely to be very durable in construction applications.

a. Field Stone. Field stones naturally distributed on the ground surface over the source deposit have been used extensively for slope protection in the northern Great Plains, Hawaii, and elsewhere. Such material is

All stone shall be delivered to the jobsite during the period 15 April to 15 September except as follows: stone delivered later than 15 September shall have been quarried prior to 15 September. Stone quarried after 15 September will not be considered for acceptance until after the following 15 April. These restrictions may be waived for igneous or metamorphic rock or other rock with a history showing conclusively that the stone is durable irrespective of the time of year that it was quarried.

NOTE: Date for quarrying and delivery of stone may be varied at the discretion of the District's Geotechnical Branch.

Figure B-2. Example technical provision against deterioration from insufficient curing of stone. (Not intended for direct use; this example only illustrates how technical data are ultimately presented in contract language)

particularly attractive to contractors where it has been collected by man, as in the clearing of fields for agriculture.

b. Oversize. Boulders are sometimes available where they have been removed in an early stage of processing for sand and gravel. Construction sites in alluvial or glacial strata may also have accumulations of large stone as oversize.

c. Talus. Deposits containing large stone result naturally from local erosion in mountainous areas and along rock canyon walls. Talus is perhaps most useful, but deposits from colluvial and rock glacier activity are other possibilities. The clean surface of a talus deposit may be deceptive in regard to gradation since soil typically fills some of the open space at depth and processing may be needed.