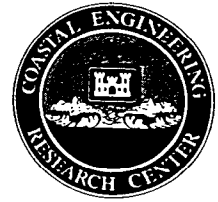




# Coastal Engineering Technical Note



## SPECIFICATION GUIDELINES FOR THE PLACEMENT OF QUARRYSTONE ARMOR UNITS - LESSONS LEARNED

**PURPOSE.** Good specifications are needed for projects using quarystone armor units because of the variables present which can affect the ultimate performance of the project structures. The purpose of this CETN is to provide suggested guidelines for specifications.

**BACKGROUND.** As a portion of the effort on a new R&D Work Unit, "Selective Placement of Quarystone Armor Units," a field office working group was formed to provide input to the Coastal Engineering Research Center on field practice and experience in the placement of quarystone armor units on Corps structures. Members of this working group are Messrs. Douglas Pirie, CESPD-CO-O, Bradd Schwichtenberg, CESPL-ED-DC, Thomas J. Bender, CENCB-PE-TC, Jeff Wiggin, CENAB-OP-N, and Jack McKellar, Consultant. One of the functions of the working group was to formulate guidelines for specifications for the placement of quarystone armor units. The guidelines provided in this CETN were formulated at a meeting of the working group held at the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center on 21-22 March 1995. Additional review comments were provided by Dorinda Y. H. Won and Alfred M. Cambra, CEPOH-HA-C, Yuri Yatsevitch, CENED-ED-G, and John Sanda, CECW-EG.

**GUIDELINES FOR SPECIFICATIONS AND INSPECTION FOR STONE QUALITY.** Some general guidelines apply to all procurement of quarystone, regardless of the method of placement. The following are suggested general guidelines for preparing project specifications and inspecting quarystone. Additional guidance may be found in EM-1110-2-2301, "Test Quarries and Test Fills."

- a. Contractor bids should be reviewed to ensure bid items are not unbalanced, i.e., that some bid items are not priced high in anticipation of potential claims for extra payments.
- b. Whenever possible, the start of project construction should be timed to allow significant completion before any required seasonal shutdown.
- c. The availability and accessibility of stone need to be ensured if the specification calls for contractor quarrying. Environmental, historic preservation, and biologic constraints may make quarrying unviable without prior Federal, state, and/or local clearances and permitting actions.

- d. The quarry pit should be visited to ensure adequate stone quality, quantity, and gradation.
- e. Over-blasting in the quarry pit can lead to fractured (cracked) stone, including in situ stone, which is unacceptable for armor stone.
- f. Inspectors need to be trained in blasting procedures, potential effects on stone quality, and techniques for inspecting stone.
- g. There may be variations of stone quality within a quarry, and production techniques may affect the acceptability of the stones. A record of stone quality from various known quarries or areas should be maintained. Although newly quarried stone may appear acceptable, actual performance over time may be unsatisfactory. Quarries from which unsatisfactory stones have been obtained should be disqualified up front.
- h. Specific areas of unacceptable stone within the quarry (stone from an untested face, stone from unacceptable strata, etc.) should be communicated to the inspector by qualified District personnel (District geologist or other knowledgeable personnel). This will aid the inspector in identification of potential stone quality problems during construction.
- i. Stones representing the approved rock type(s) and several different weights should be set aside at the quarry pit, with their weights clearly marked, for reference by the inspector and the contractor.
- j. Stones should be spread out in the quarry for inspection before being loaded for delivery. Stones should be rotated to inspect all sides.
- k. Stone gradation should be maintained in delivery and in the staging area at the construction site.
- l. Weights should be checked on samples of stones delivered to the construction site.

#### GUIDELINES FOR SPECIFICATIONS FOR SELECTIVE PLACEMENT.

The following guidelines relate to the handling and placement of quarystone. Additional guidance may be found in EM-1110-2-2302, "Construction with Large Stone."

- a. Stones should not be dropped in loading, transit, or placement on the structure. Stones should be placed on the structure by feeling with the handling equipment to achieve

- contact when vision is obscured, and then released. Line and grade should be maintained through approved quality control methods.
- b. Smaller stones may be stockpiled for chinking but should not be used for building the structure.
  - c. A sacrificial toe berm is recommended on structures. This is a general recommendation for all structures, including structures using random placement of quarystone.
  - d. The lowest line (tier) of armor stones should be keyed into the sea bottom or bedding layer.
  - e. A line (tier) of stones should be placed in the saddle points of the next lower line (tier).
  - f. Stone should be placed on the slope from the bottom up, diagonally toward the equipment operator.
  - g. Use of a spotter is highly recommended to direct the leverman to stay on line and on grade and to ensure proper placement of stones. It is recommended that batter boards be erected defining the crest elevation and side slopes at intervals along the breakwater/jetty. Use of this tool is especially helpful for maintaining the proper slope relationship around structure head sections.
  - h. When construction is proceeding seaward from the shore, such as in the case of an attached breakwater or jetty construction, the rate of construction must stay ahead of scour in front of the structure.
  - i. In general, the longitudinal axis of each stone should be normal to the axes of the structure, and slope downward toward the center of the structure. All cap stone should be placed together as closely as practical.
  - j. The center of gravity of the placed stone should be closer to the underlayer than to the face of the structure.
  - k. Stones should be keyed and fitted, maximizing contact on all sides. Three points of contact (minimum) are required between a stone and other stones in the same layer, or with other stones in the layer and a structure cap.
  - l. Placement of stone is critical near the waterline. Laboratory testing has shown that, with uniform placement, failure (displacement) of armor stones tends to occur at or slightly above the still-water line.

- m. The specified stone gradation should be consistently maintained throughout the structure.
- n. During O&M on a structure, removing existing stone may be necessary to make dissimilar stones fit.
- o. The project inspector should periodically check the quantity of stone used versus the original estimate to determine if more or less stone than the estimate is required.
- p. The top line of armor stones on the seaward face of a breakwater or jetty should extend slightly above the top of the structure cap to reduce wave action on the cap.
- q. The top of the top line of armor stones on the landward face of a breakwater or jetty should be slightly below the top of the structure cap to reduce wave action on the stones.
- r. Stones should not protrude excessively from the structure face (in relation to the stone size) to prevent excessive wave action on individual stones, and the neat lines for the structure should not be excessively tight. As a suggested guideline, a stone should not protrude more than one fifth of its dimension perpendicular to the structure face. This is considered to be especially important for single layer construction.

It is suggested that samples of the desired finish be included in the specifications or drawings. This could be accomplished by providing photographs of completed structures exhibiting the proper characteristics and/or listing previous projects in the area that can be used as a reference model. Without a physical model for reference, the final face is subject to the inspector's opinion.

- s. It is recommended that stone gradation should be uniform on the front face and back face of a structure such as a breakwater or jetty, i.e., stone on the landward face should not be smaller than the stone on the seaward face, as wave transmission can cause stones to blow out.
- t. Daily stone quantity and gradation reports should be obtained from the contractor.
- u. Contractor's quality assurance must be spot-checked by qualified Corps personnel.
- v. Well-qualified personnel from other Corps Divisions and Districts or well-qualified contractors should be utilized as specialized inspectors/mentors.

ADDITIONAL INFORMATION. For further information, contact members of the working group or Dr. Fred E. Camfield, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Wave Dynamics Division, at (601) 634-2012, FAX (601) 634-3433, or Internet camfield@coafs1.wes.army.mil.