Coastal Engineering Technical Note

ARMOR UNIT PLACEMENT METHOD VERSUS STABILITY COEFFICIENTS

PURPOSE: This Technical Note provides clarification of the relationship of placement method to the selection of the stability coefficient K_D used in determining the weight of armor units.

BACKGROUND: A rubble structure is made up of several layers of randomly-shaped, randomly-placed stones, protected with a cover layer of selected armor units of either quarrystone or specially shaped concrete units. The stability coefficient K_D varies directly with several of the armor unit characteristics, including roughness of the armor unit surface, angular shape, and degree of interlocking between units. Of these, the degree of interlocking, which is of special interest in this note, is the variable most easily altered by the placement technique.

PLACEMENT METHOD CLARIFICATION: The Shore Protection Manual (SPM 1984) shows placement as either uniform, special, or random.

Uniform placement is applicable only to concrete armor units and cut or dressed quarrystones in that they are of a uniform size and shape, and, thus, lend themselves to a precise, orderly, placement pattern. Since quarrystone (as opposed to cut stone) is of random size and shape, uniform placement of quarrystone is impracticable.

Special placement is applicable only to parallel pipe-shaped stone, and it involves the longest axis being placed perpendicular to the slope of the structure face. This type of placement was originally used in the Buffalo District and was subsequently adopted for use in the Pacific Northwest. The stone produced by local quarries for the Portland District projects have a unique shape in that they are rectangular solids having a very distinctive

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long axis. Model studies conducted by the Waterways Experiment Station for the Portland District developed the appropriate stability coefficients (See Kibdy, Powell and Roberts 1964; Markle and Davidson 1979). Large scale tests of placed stone were conducted at Oregon State University (Debok, Sollitt 1974). For special placement, the longest axial dimension of the stone should be at least twice as long as either of the other two dimensions, as shown in Figure 1. The special placement method and the associated stability coefficient should not be used unless quarrystone meets these dimensional specifications and prospective contractors for the project can assure obtaining this type of quarrystone and placing it with the long axis normal to the face of the structure slope. Figure 2 illustrates the quarrystone used in applying the special placement stability coefficient. Additional factors are listed below.

1. The special placement method can be used only where it is possible to observe and place stones accurately. Even then special care must be taken to assure proper orientation and seating at the interface of the change-in-placement and at the slope-crown interface.

2. The special placement method will require close inspection and clear instruction to the contractor to assure proper placement procedures.

3. Special placement requires more time than random placement and would, therefore, increase the selection, handling, and placement costs of the quarrystone.

A similar method of placement was used many years ago on structures built in the Great Lakes and Delaware Bay where hewed-masonry blocks were fitted into the structure. Although these structures have been stable, it is not practical to publish a general stability coefficient for this particular placement method since each application depends upon the individual hewed shape and the special care used to place the blocks in a fitted structure.

<u>Random (formerly pell-mell) placement</u> is a term used in the SPM to describe a variety of placement techniques ranging from dumping the underwater armor stone from a scow to careful, individual placement of the angular quarrystone in the above water section. Quarrystone placement by a contractor can vary not only above and below the water level and along the axis of the rubble structure but also from one job to the next. Placement can also vary from one contractor to another. The variables and difficulties in placing

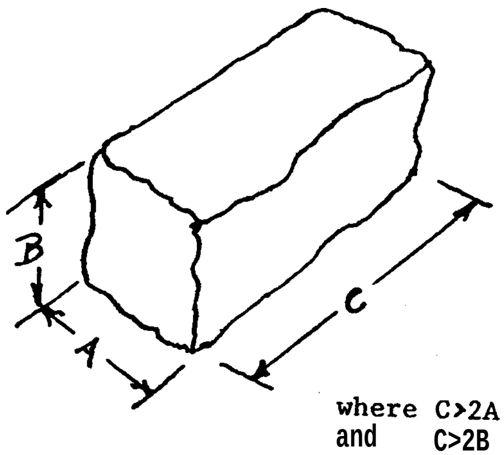

Figure 1 - Dimensions of quarry-stone required for use of special placement method

Figure 2 - Special placement method

armor units one at a time, or dumping by skiff, above and below water, present the engineer with a difficult design problem. The extent of interlocking achieved is unpredictable when using randomly sized (but still within specified limits) quarrystone. Generally, in specifying quarrystone armor units, the dimensions of the maximum axis are no greater than 3 times the minimum axis. This applies only to armor stone, as this ratio was devised to forestall the use of flat or plate-like stone which, if laid flat on the structure slope, would be less stable than a more cubic stone. It is rather obvious that the greater the care in placing and obtaining a higher degree of interlocking the higher the stability coefficient K_D (Jackson 1968). Because of these unpredictable variables, all methods of placement, except for uniform and special placements, have been lumped together in the SPM to encompass the range of placement methods. This provides a conservative structure design.

SELECTED PLACEMENT: Many Corps of Engineers field offices use selected placement to increase structure stability. Selected placement is the careful selection and placement of individual armor stones to achieve a higher degree of interlocking. Such attempts to increase interlocking should be encouraged both in the specification and by the Corps inspectors because of the increase in structure stability. Specific values of the stability coefficient KD have not been developed for the selected placement method because of the variation which may occur from project to project. Structures built above water, e.g., riprap bank protection, can generally be constructed with more careful placement than structures built below water. In general, additional laboratory testing will be required to determine possible increases in the values of K_D above the values shown for random placement.

ADDITIONAL INFORMATION: Contact Mr. D. D. Davidson, Chief, Wave Research Branch, (601) 634-2722 or Dr. F. E. Camfield, Chief, Coastal Design Branch, (601) 634-2012

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