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Standard Guide for Placement of Riprap Revetments[1]

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ϵ^1 NOTE—Section X1.2 was corrected editorially in June 2004.
ϵ^2 NOTE—Section X1.2 was corrected editorially in September 2004.

1. Scope

1.1 This guide covers methods to place riprap with associated filters for erosion control purposes. This guide does not recommend a specific course of action because of the diverse methods and procedures that are capable of producing a functional product. This guide identifies favorable riprap qualities and recommends practices best suited to obtain those qualities. The production of rock, use of recycled materials, rock with cut dimensions, and engineering and design is beyond the scope of this guide. Special forms of riprap, including hand placed riprap, grouted riprap, or keyed (plated) riprap that is tamped into place to smooth the surface, are also beyond the scope of this guide.

1.2 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been developed and approved through the ASTM consensus process

1.3 *This standard may involve hazardous operations and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates
C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
D 75 Practice for Sampling Aggregates
D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 4992 Practice for Evaluation of Rock to be used for Erosion Control
D 5519 Practice for Particle Size Analysis of Natural and Man-Made Riprap Materials
D 6092 Practice for Specifying Standard Sizes of Stone for Erosion Control

2.2 *AASHTO Standard:*

M 288–2000 Geotextile Specification for Highway Applications[2]

3. Terminology

3.1 Terminology used in this guide, which is not included or not completely defined in Terminology D 653, is defined below.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bedding*—an aggregate mixture placed below the riprap. Bedding material is usually sand and gravel sized, but may include cobble sized material. If placed without a geotextile, the bedding material may be used as a filter. If placed in conjunction with a geotextile, the bedding may provide a cushion for protection of the geotextile during riprap placement and provide confinement of the geotextile. It is possible to have more than one bedding layer.

3.2.2 *chinking*—the practice of filling riprap surface voids with smaller sized rock or aggregate.

3.2.3 *clam shell*—a bucket tool that is operated from a dragline or crane. The bucket is hinged at the top and opens like a clam so that rock can be placed without dropping it.

3.2.4 D_x—the particle diameter at which x % by weight (dry) of the particles of a particular sample are finer.

3.2.5 *filter*—any substance, as geotextile or layer of sand/aggregate, placed to provide separation and retention of materials, while allowing water to pass.

3.2.6 *floater*—a individual rock within the riprap layer that is not interlocked with the surrounding rocks.

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[2] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

3.2.7 *maximum aspect ratio*—the ratio of the greatest to the least dimension, measured across mutually perpendicular axes, for any piece of rock; synonym, *slabbiness*.

3.2.8 *orange peel*—a bucket tool that is operated from a dragline or crane and resembles the shape of an orange peeling. The sides lift up and out so that rock can be placed without dropping it.

3.2.9 *pit run material*—rock that has been blasted but not processed to remove undersize pieces; synonym, *shot rock* or *quarry run*.

3.2.10 *revetment*—bank protection by armor, that is, by facing of a bank or embankment with erosion-resistant material.

3.2.11 *riprap*—material generally less than 2 tons (1.8 tonnes) in mass, specially selected and graded. When properly placed, riprap prevents erosion through minor wave action, or strong currents and thereby preserves the shape of a surface, slope, or underlying structure. Riprap may be specifically produced for the intended purpose, or it may be a by-product from a mining operation, structure demolition, or industrial process.

3.2.12 *rock*—any naturally formed aggregate of mineral matter occurring in large masses or fragments. Rock may be either insitu or excavated material.

4. Significance and Use

4.1 Riprap is a commonly used form of scour protection and general slope protection. Riprap provides a long term solution when properly sized and installed. Riprap has structural flexibility so it will conform to irregular surfaces and adapt to minor subgrade settlement. It is often appropriate for use in conjunction with soil bioengineering (vegetation establishment) alternatives. In some environments, riprap may provide habitat for benthic organisms and fish.

4.2 Revetments provide a facing or lining to armor a surface; and the layer thickness is typically minimized while providing the necessary resistance to scour. In this case, standardized practices to obtain consistent coverage having acceptable thickness tolerances and voids become important.

4.3 This guide may be used by owners, installation contractors, regulatory agencies, inspection organizations, and designers and specifiers who are involved in the construction of riprap revetments. Modifications may be required for specific job conditions.This guide is not intentded for construction specifications on large projects, but may be referenced where preparation of job specific construction specifications are not justified. If this practice is included by reference in contract documents, the specifier must provide a list of supplemental requirements.

5. Planning for Riprap Placement

5.1 Site conditions, level of protection required, construction methods, and equipment may affect the sizing, thickness, and lateral extent of a riprap revetment. For some small projects, riprap may be dumped with minimal analysis or quality control, and still fulfill the intended purpose. For larger projects and critical structures, engineering, careful placement, and quality control become increasingly justified to minimize material costs and reduce the chance of failure. The degree of control appropriate should be appropriate for each project. The methods for placement and quality control should be compatible with the level of site investigation and other considerations included in Table 1. Table 1 includes factors which should be considered, but are beyond the scope of this guide. Some recommended publications for further information on these factors and engineering criteria are given in the References section. Designing the revetment is beyond the scope of this guide.

TABLE 1 Predominant Factors for Placement and Maintenance of Riprap

No.	Factor	Site Condition	Design Control	Construction Control	Post Construction Control
1	Hydraulic bed shear stress flow velocity or wave amplitude flow turbulence flow depth or wave run-up water density (salinity)	X			
2	Debris impact and ice action	X			X
3	Bed slope, side slopes (hydraulic stability)	X	X		
4	Slope Stability (see Note 1)	X	X		
5	Site Conditions (under water placement, temporary access, encroaching structures, property limits, meandering rivers and scour adjacent to revetment)	X			X
6	Environmental considerations (water quality, recreation use, affects on vegetation and wildlife)	X			
7	Rock availability and cost	X			
8	Risk analysis (critical structure, return period for design storm or flood event)	X	X		
9	Filter requirements (subgrade drainage, filter clogging, installation damage, particle retention, degradation)	X	X	X	
10	Rock gradation, angularity and placement		X		
11	Revetment thickness		X	X	X
12	Revetment extent (toe protection, key-in, free board)		X		X
13	Construction Methods/Equipment		X	X	
14	Quality Control/Quality Assurance		X	X	
15	Disturbances (People moving stones, animals burrowing through filters)		X		X
16	Material Durability (rock degradation, exposure of geotextile)	X	X	X	X

NOTE 1—Slope stability should always be considered. If it is not investigated analytically by a qualified professional, then it should at least be considered subjectively in light of the site conditions and surrounding conditions (riverbanks, shorelines, or landforms). Many agencies have generalized maximum allowable slopes (usually in the range of 1.5H:1V to 3H:1V); however, these must be recognized as site specific. Limitations of the foundation, bank, material interfaces, seepage conditions, or toe scour may lead to instability.

6. Riprap Materials

6.1 *Stone Sources and Evaluation*—Rock must be durable material. In some cases, a source may be established based on rock classification, geologic evaluation, and observations of existing installations showing that the rock is durable. If a history of rock durability is not established, sampling and testing the rock may be required. Acceptable material properties for rock is dependent on the conditions (such as abrasion and saturation frequency due to wave run-up) and climate in the vicinity of where it will be used. Source selection must also consider the material properties available from local sources. Riprap is most commonly produced at a quarry, but it may also be screened from a gravel pit operation, processed from rock collected from some other source, or manufactured from crushed hydraulic-cement (recycled) concrete.

NOTE 2—Borrowing stone, cobbles or gravel from stream or lake beds that do not otherwise need to be disturbed may have environmental consequences and may not be allowed under state and federal permits.

6.1.1 *Sampling and Testing Rock Sources*—Practice D 4992 provides guidance on sampling a source rock. Criteria for acceptance should consider criteria in EM 1110-2-2302, but may also consider characteristics of rock found in nearby quarries. Information provided with rock samples should include the location from which the sample was taken, and the stratigraphy for samples obtained at quarries. (See Note 3).

NOTE 3—Due to the relative cost of producing and transporting riprap in relation to placing it at the site, there is a potential for disputes where sampling and testing at the source have implied acceptance of the material and the Owner later rejects the material at the placement site. Contract specifications should clearly state where the riprap will be sampled for testing and what constitutes final acceptance of the material.

6.2 *Riprap Grading*—Recommended gradation requirements for processed riprap are given in Practice D 6092. The gradations are considered to be optimum size variations considering rock stability, riprap voids affecting filtration of the subgrade, and typical quarry processing capabilities. Research at the Corps of Engineers Waterways Experiment Station in the 1960s and 1970s confirmed that there is an optimum size variation for riprap stability. Riprap layers with uniform sized rocks have a rough surface which maximizes the tractive shear stress on the rocks, which detracts from the stability. Material that is too broad in grading is susceptible to segregation and loss of the small stones.

6.2.1 *Sampling and Testing Material Gradations*—The riprap grading should be verified. When gradation tolerances are critical, the grading should be determined in accordance with Practice D 5519. Riprap samples should be taken from stockpiles, loaded trucks or in place test plots. Bedding and filter materials should be sampled in accordance with Practice D 75 and tested in accordance with Test Method C 136.

NOTE 4—Due to the economical limitations of obtaining the number and size of samples to be statistically meaningful, the Owner and Contractor should have a partnering relationship. Both parties should make an effort to be present during rock source sampling and field testing.

6.2.2 Pit run material, rather than processed rock, is often used due to it's lower cost, greater availability, and broader grading. For similar rock stability and filtration characteristics, pit run material must be placed in greater thickness and stone size than processed riprap.

6.3 *Recycled Materials*—Recycled materials may be used for sustainable design and development. However, quality assurance of recycled material is generally more difficult and the material must be appropriate for the intended use. Crushed hydraulic-cement concrete may be obtained from various sources with inconsistent strength and durability. Slabs in the source material and the amount of reinforcing steel can complicate control of the grading requirements and the aspect ratio of individual stones.

7. Filter Materials

7.1 *Purpose of Filters*—For revetments placed as thin facings or linings, a filter is required to prevent loss of the subgrade by turbulent flow through the voids in the riprap. Filters for riprap consist of bedding or geotextiles. Filters are selected to provide soil retention and adequate permeability for subgrade drainage. This requires balancing two opposing criteria: the opening sizes (voids) must be small enough to retain the subgrade particles and large enough to provide adequate permeability for water passage. In some cases, multiple layers may be required.

7.2 *Bedding*—Bedding material should be composed of tough, durable particles, free from thin, flat and elongated pieces, and should contain minimal quantities of organic matter and soft friable particles. Aggregates should generally meet the quality requirements of Specification C 33. Some typical gradation requirements for bedding materials are given in Practice D 6092. It is sometimes more economical to specify a commonly produced gradation, such as a state transportation department gradation for concrete or bituminous aggregate. It may be necessary to adjust the gradation requirements to meet filter requirements for protection of the subgrade soils.

7.3 *Geotextiles*—The geotextiles must have adequate strength to withstand installation stresses during placement. AASHTO M 288–00 provides recommended geotextile properties for survival during construction. The geotextile properties listed in AASHTO M 288–00 are related to specific placement conditions and equipment operation.

8. Handling and Transportation

8.1 Riprap should be handled and selectively loaded onto trucks in a manner to avoid segregation and provide a distribution of rock sizes. Each truckload should be representative of the gradation requirements.

8.2 Rock breakage during handling and transportation will reduce the rock sizes and alter the gradation before final placement. The rock susceptibility to size degradation is very dependent on the rock strength, the rock formation, handling methods, and rock sizes. In areas where size degradation is significant, the riprap grading should be evaluated at the