

## **SECTION 225: SLOPE AND EROSION PROTECTION STRUCTURES**

### **225.1 DESCRIPTION**

This work consists of providing and placing riprap, gabions, revetment mattresses, sacked concrete revetment, concrete block revetment, wrapped rock faces, and other systems on embankment slopes, the sides and bottoms of channels, drainage outlets, ditches, and other such locations.

### **225.2 MATERIALS**

Unless otherwise specified in the Contract, the Contractor shall provide slope and erosion protection structures as follows:

1. Hexagonal double-twisted wire mesh riprap, gabions, and revetment mattresses; or,
2. Welded wire mesh gabions, revetment mattresses, and wrapped rock faces.

The Contractor shall provide galvanized slope protection items in accordance with ASTM A 641. If specified in the Contract, the Contractor shall coat galvanized items with PVC in accordance with Section 225.2.2.2.9, "PVC Coating."

The Contractor shall provide double-twisted riprap, gabions, and revetment mattresses in accordance with ASTM A 975. The Contractor shall provide welded wire mesh gabions, revetment mattresses, and wrapped rock faces in accordance with ASTM A 974.

#### **225.2.1 Classifications**

Riprap and gabions shall be classified in accordance with Table 225.2.1:1, "Riprap Classifications and Gabion Requirements."

The Contractor shall provide riprap with at least 80% of the stones meeting the specified size requirements. The Contractor shall use stones less than the minimum dimensions to fill voids. For riprap Class A, wrapped rock faces and gabions, the Contractor shall not use stones smaller than the mesh openings. The size of the stone shall be as stated in the plans.

Class D, Derrick Stone shall follow the gradation requirements in Table 225.2.1:2, "Gradation Requirements for Class D, Derrick Stone."

#### **225.2.2 Riprap, Gabions, Revetment Mattresses, and Rock Faces**

##### **225.2.2.1 Stone for Riprap, Gabions, Revetment Mattresses, and Rock Faces**

All stone provided and installed shall be angular rock with fractured faces, not rounded. All stone must be sound and durable, free of seams, fractures and coatings, and of such characteristics that it will not disintegrate when subject to the action of flowing water.

Except for Class G riprap, the Contractor shall provide rocks or rough quarry stone with no more than 60% wear, in accordance with AASHTO T 96. The Contractor shall provide stone with a soundness loss of no more than twenty-one (21), in accordance with AASHTO T 104, using a magnesium sulfate solution with a five-cycle test duration.

The Contractor shall provide stone for riprap, gabions, revetment mattresses, and rock faces in accordance with Section 225.2.1, "Classifications."

**Table 225.2.1:1  
Riprap Classifications and Gabion Requirements**

Class	Description	Stone Volume (ft <sup>3</sup> )		Minimum Dimension (in) <sup>a</sup>
		Minimum	Maximum	
A	Wire-Enclosed Riprap	1/6	2/3	4
B <sup>b</sup>	Non-Enclosed Riprap	1	2	6
C <sup>b</sup>	Non-Enclosed Riprap	2	4	9
E	Grouted Riprap	1/3	1	3
F	Grouted Riprap	1	2	6
G	Rock Plating	--	--	4-8 <sup>c</sup>
N/A	Wrapped Rockfacing	--	--	1
N/A	Gabions	--	--	4-8 <sup>c</sup>

<sup>a</sup> Minimum size in the least dimension.  
<sup>b</sup> Class B and C stone — at least two (2) fractured faces.  
<sup>c</sup> 70% to 80% of the stone — at least four (4) inches but not more than eight (8) inches in the smallest dimension.  
<sup>c</sup> 30% to 20% of the stone — no larger than four (4) inches in any dimension.

**Table 225.2.1:2  
Gradation Requirements for Class D, Derrick Stone**

Class, Description	Percent of Rock Equal or Smaller by Count, D <sub>x</sub>	Range of Intermediate Dimension <sup>1</sup> (inches)	Range of Rock Weight <sup>2</sup> (pounds)
D, Derrick Stone <sup>3</sup>	100	30	5000
	70	24 – 18	1780 – 2500
	40	11 – 14	360 – 500
	20	6 – 8	70 – 100

<sup>1</sup> Intermediate dimension measured as the shortest straight-line distance from one side of the rock or rock particle to the other on the maximum projection plane (i.e., plane of rock or rock particle with the largest projected surface area).  
<sup>2</sup> Weights based on a specific gravity of 2.65.  
<sup>3</sup> Include spalls and rock fragments to provide a stable dense mass.

**225.2.2.2 Wire Mesh**

The Contractor shall provide non-raveling, double-twisted wire mesh forming hexagons for riprap, gabions, and revetment mattresses in accordance with Section 225.2.2.3, "Pull-Apart Test." The Contractor shall provide non-raveling welded wire mesh for gabions, wrapped rock faces, and revetment mattresses forming squares or rectangles in accordance with ASTM A 974, Section 7, *Material Properties*, except that the strength requirement for mattress joints are 900 pounds per foot instead of 600 pounds per foot.

**225.2.2.2.1 Wire**

The Contractor shall provide soft temper wire with a Class 3 zinc coating for constructing wire mesh in accordance with ASTM A 641. The Contractor shall provide 0.120-inch diameter wire for gabions and riprap and 0.087-inch diameter wire for revetment mattresses and wrapped rock faces.

**225.2.2.2.2 Mesh Openings**

The Contractor shall ensure that mesh openings are uniform and hexagonal. The Contractor shall make mesh openings for riprap and double-twisted gabions approximately 3 1/4 inch × 4 3/4 inch, and for double-twisted revetment mattresses approximately 2 1/2 inch × 3 1/4 inch. The Contractor shall make mesh openings for welded wire mesh gabions approximately 3 inch × 3 inch, and for welded wire mesh revetment mattresses approximately 1 1/2 inch × 3 inch.

**225.2.2.2.3 Selvedges**

The Contractor shall mechanically selvedge the edges of double-twisted gabions, revetment mattresses, and wrapped rock faces, including end panels and diaphragms. The Contractor shall use a selvedge wire with a diameter of at least 0.150 inch.

**225.2.2.2.4 Lacing and Tie Wire**

The Contractor shall provide lacing wire for double-twisted gabions, revetment mattresses, and wrapped rock faces with a diameter of at least 0.087 inch. The Contractor shall provide tie wire for double-twisted gabions and revetment mattresses with a diameter of at least 0.087 inch. The Contractor shall provide tie wire for riprap with a diameter of at least 0.120 inch. The Contractor shall provide lacing and tie wire with the same tensile strength and coating as the mesh wire.

**225.2.2.2.5 Spiral Binders**

The Contractor shall provide spiral binders for welded wire mesh gabions, revetment mattresses, and wrapped rock faces of the same wire quality as the mesh wire with a diameter of at least 0.106 inch. Unless otherwise approved, the Contractor shall provide spiral binders with a maximum inside diameter of 2 1/2 inches and with a maximum pitch of 3 inches.

**225.2.2.2.6 Alternate Fasteners**

The Contractor may use alternative fasteners, such as ring fasteners, with double-twisted wire mesh, and welded wire mesh riprap, gabions, revetment mattresses, and wrapped rock faces, if approved by the City Engineer or designee. The Contractor shall provide wire for alternative fasteners in accordance with Section 225.2.2.2.5, "Spiral Binders."

**225.2.2.2.7 Minimum Strength of Fasteners**

The Contractor shall use fasteners that provide a minimum strength of 1,400 pounds per foot for gabion baskets, and 900 pounds per foot for revetment mattresses and wrapped rock faces.

**225.2.2.2.8 Approval of Alternative Fasteners**

The Contractor shall use a certified laboratory to test alternative fasteners in accordance with Section 225.2.2.3, "Pull-Apart Test." At least 60 days before using alternative fasteners, the Contractor shall submit Certified Test Reports (CTRs) to the City Engineer or designee verifying that the fasteners meet the pull-apart test requirements.

The Contractor shall provide a description of the fastener, with drawings and photographs showing the number of fasteners required, details of the fasteners, and load capacities. In addition, the Contractor shall:

1. Lock and close each interlocking fastener. For gabions, use fasteners in every other opening. For revetment mattresses and wrapped rock faces, use fasteners in every opening; and,
2. Close each overlapping ring fastener and overlap ends a minimum of one (1) inch. Provide one (1) ring for each opening.

This fastener will be allowed for forming individual baskets, but not for interconnecting baskets.

**225.2.2.2.9 PVC Coating**

The Contractor shall provide PVC coating with an average thickness of 0.0216 inch and a minimum thickness of 0.0150 inch per side. The Contractor shall apply PVC coating over the galvanizing.

The Contractor shall coat the galvanized wire with extruded or fusion-bonded PVC Material. Unless otherwise specified, the Contractor shall use a gray or green colored coating. The Contractor shall use a PVC coating that meets the following requirements:

1. Specific gravity of from 1.20 to 1.40, if tested in accordance with ASTM D 792;
2. Abrasion resistance of less than 12% weight loss, if tested in accordance with ASTM D 1242-95A, Method B at 200 cycles, CSI-A Abrader Recording, 80 grit;
3. Brittleness temperature no higher than 15-degrees Fahrenheit, if tested in accordance with ASTM D 746;
4. Tensile strength no less than 2,980 psi for extruded coating, if tested in accordance with ASTM D 412; and no less than 2,275 psi for fusion bonded coating, if tested in accordance with ASTM D 638;
5. Modulus of elasticity no less than 2,700 psi at 100% strain for extruded coating, if tested in accordance with ASTM D 412; and no less than 1,980 psi at 100% strain for fusion bonded coating, if tested in accordance with ASTM D 638;
6. Ultraviolet light exposure for a test period of no less than 3,000 hours, using apparatus Type E at 145-degrees Fahrenheit, if tested in accordance with ASTM G 152; and,
7. Salt spray test for a test period of no less than 3,000 hours, if tested in accordance with ASTM B 117.

**225.2.2.3 Pull-Apart Test****225.2.2.3.1 Sample Preparation**

The Contractor shall prepare two (2) identical rectangular panels along a selvedge wire, each about 10 1/2 mesh-openings wide. The Contractor shall attach the two (2) panels along the two (2) selvedge

wires using the proposed fastener system. If the Contractor uses alternative fasteners to join two (2) individual gabion baskets, the Contractor shall include two (2) additional selvedge wires (each mechanically wrapped with mesh wires) so that each fastener contains two (2) selvedges and two (2) mesh wires.

#### **225.2.2.3.2 Test Procedures**

The Contractor shall mount the joined test panels in a loading machine with grips or clamps that secure the panels uniformly along the full width. The Contractor shall use grips or clamps designed to transmit only tension forces. The Contractor shall apply the load at a uniform rate of 50.7 pounds per second until failure occurs. A failure is defined as a drop-in strength under continuous loading or, when an opening between two (2) joined selvedge wires exceeds two (2) inches. The minimum allowable strength at failure is 1,400 pounds per foot for joined gabions; and, 900 pounds per foot for joined revetment mattresses and wrapped rock face panels.

#### **225.2.2.4 Certification**

A certificate shall be submitted to the City Engineer or designee stating that the following proposed items meet the requirements of this Specification before their use:

1. Wire mesh;
2. Gabion baskets;
3. Lacing wire;
4. Tie wire; and,
5. Approved alternative fastener systems.

#### **225.2.2.5 Steel Stakes**

The Contractor shall use steel railroad rails, standard weight galvanized steel pipe, or steel angles for riprap stakes. The Contractor shall use railroad rails with a unit weight of at least 30 pounds per yard. The Contractor shall use standard weight galvanized steel pipe with a minimum outside diameter of four (4) inches. The Contractor shall use steel angles that are at least 4 inch × 4 inch × 3/8 inch.

#### **225.2.2.6 Grout**

The Contractor shall provide Portland cement, fine aggregate, and water for grout.

##### **225.2.2.6.1 Portland Cement**

Cement shall be Type II Portland cement complying with ASTM C 150. Type II Portland cement shall have an alkali content less than 0.60% by mass of alkalis as  $\text{Na}_2\text{O} + 0.658 \text{K}_2\text{O}$  when determined under AASHTO T 105.

##### **225.2.2.6.2 Fine Aggregate**

Fine aggregate shall consist of clean and well-graded natural sand, manufactured sand, or combination of both, and free of trash, debris, organics, and other Deleterious Materials.

Fine aggregate shall meet the gradation requirements listed in Table 225.2.2.6.2:1, "Fine Aggregate Gradation Requirements." The gradation requirements represent the limits that the City will use to determine source acceptability.

**Table 225.2.2.6.2:1  
Fine Aggregate Gradation Requirements**

<b>Sieve Size</b>	<b>% Passing</b>
3/8 inch	100
No. 4	90 – 100
No. 8	70 – 95
No. 16	45 – 80
No. 30	25 – 60
No. 50	5 – 30
No. 100	0 – 8
No. 200	0.0 – 3.0

### **225.2.2.6.3 Water**

Water shall conform to ASTM C 1602. Water shall have a pH between 6.0 and 8.5; sulfate or chloride contents shall not exceed 1,000 ppm; and, shall be free of oil, silt, clay, organic matter, or other Deleterious Material.

### **225.2.2.7 Geotextile Material**

The Contractor shall provide Class one (1) non-woven geotextile (filter fabric) as per the New Mexico Department of Transportation's Specifications for Highway and Bridge Construction, Current Edition, Section 604 "Soil and Drainage Geotextiles."

### **225.2.3 Sacked Concrete Revetment**

The Contractor shall provide sacked concrete revetment from a vendor on the NMDOT's *Approved Products List*. The Contractor shall provide bags of concrete that weigh from 60 to 80 pounds each, dry weight, and contain from 0.018 to 0.025 cubic yards of concrete. The Contractor shall ensure each bag contains one (1) of the following mixes:

1. One (1) part cement to three (3) parts sand;
2. A mix design in accordance with the Contract; or,
3. A mix design approved by the NMDOT State Materials Bureau.

The Contractor shall provide a concrete mix capable of attaining a minimum compressive strength of 3,500 psi after 28 days, unless otherwise specified in the Contract. The Contractor shall keep the sacked concrete in dry storage until application.

#### **225.2.3.1 Packaging**

The Contractor shall use permeable, biodegradable sacks made of jute, cotton, or scrim-reinforced paper that can hold the sand-cement mix without significant leakage while allowing sufficient water to hydrate the concrete mix.

The Contractor shall provide non-asphaltic, three (3)-layer laminated, polyester-fiber-scrim-reinforced paper sacks. The Contractor shall perforate each of the three (3) layers and offset the perforations to prevent cement leakage.

The Contractor shall use only one (1) type and size of sack throughout the Project, unless otherwise specified in the Contract.

**225.2.3.2 Portland Cement**

The Contractor shall provide Portland cement as per the New Mexico Department of Transportation's Specifications for Highway and Bridge Construction, Current Edition, Section 509, "Portland Cement Concrete Mix Designs."

**225.2.3.3 Aggregate**

The Contractor shall provide fine aggregate per Section 225.2.2.6.2, "Fine Aggregate."

**225.2.3.4 Steel Anchorage**

The Contractor shall provide steel staples as per the New Mexico Department of Transportation's Specifications for Highway and Bridge Construction, Current Edition, Section 540, "Steel Reinforcement."

The Contractor shall use steel staples either epoxy coated in accordance with AASHTO M 284, or galvanized in accordance with ASTM A 153.

**225.2.4 Concrete Block Revetment**

The Contractor shall provide concrete block revetment products from the NMDOT's *Approved Products List*. The Contractor shall provide concrete block units compatible with the geotextiles being used and with a minimum compressive strength of 3,000 psi, unless otherwise specified in the Contract.

**225.3 CONSTRUCTION REQUIREMENTS****225.3.1 General Placement Requirements**

The Contractor shall place riprap stones forming a continuous blanket in accordance with the Contract. Unless otherwise specified, the Contractor shall construct rock plating using riprap Class G to minimum thickness of twelve (12) inches. The Contractor shall place stones with the long axis parallel to the toe of the slope, with a stable bearing upon the underlying soil or stones.

The Contractor shall place large stones as close together as possible. The Contractor shall use smaller stones to fill the areas between the larger stones, except when the Contract requires Class E or F (grouted) riprap.

The Contractor shall ensure that the finished riprap surface varies no more than three (3) inches from the specified slope, and Derrick Stone riprap varies no more than eight (8) inches from the specified slope.

Unless otherwise specified, the Contractor shall place the riprap foundation course in a trench excavated to 24 inches below the toe of the slope of the embankment or side of channel.

The Contractor shall place a layer of Class one (1) non-woven geotextile filter fabric between the slope and erosion protection structures, and the backfill material.

**225.3.1.1 Grouted Riprap Placement**

The Contractor shall fill riprap voids with grout to the full riprap thickness. After placing grout, the Contractor shall sweep the riprap surface with a stiff broom.

The Contractor shall protect grout from freezing for at least four (4) days after placement.

The Contractor shall cure grouted riprap placed in hot, dry weather as per the New Mexico Department of Transportation's Specifications for Highway and Bridge Construction, Current Edition, Section 511.3.10, "Curing."

#### **225.3.1.2 Proportioning and Mixing Grout**

The Contractor shall use grout that consists of one (1) part Type II Portland cement and three (3) parts fine aggregate (by volume). The Contractor shall mix with water to a workable consistency. The minimum allowable air content is 6.5%.

#### **225.3.1.3 Class A Riprap Placement**

The Contractor shall enclose Class A riprap with wire mesh drawn tightly on all sides. The Contractor may connect wire mesh using approved fasteners or lacing wire. The Contractor shall weave adjacent edges at least once with double loops of lacing wire that is as strong and flexible as the mesh.

The Contractor shall provide continuous lacing as far as possible that passes through each mesh opening. Where splicing is necessary, the Contractor shall overlap the lacing at least twelve (12) inches.

The Contractor shall space galvanized wire ties connecting top and bottom mesh layers approximately 24 inches on center. The Contractor shall anchor the ties to the bottom wire-fabric layer. The Contractor shall extend the ties through the rock layer and secure to the top wire-fabric layer. The Contractor shall anchor wire-enclosed riprap to slopes with steel stakes driven into the embankment. The Contractor shall space stakes in accordance with the Contract.

#### **225.3.1.4 Placement of Geotextile Fabric**

The Contractor shall place Class one (1) non-woven geotextile (filter fabric) between the riprap or revetment mattresses and the supporting soil with sewn seams overlapped as approved by the City Engineer or designee.

#### **225.3.2 Sacked Concrete Revetment Placement**

The Contractor shall place sacked concrete revetment within  $\pm 0.2$  feet of the specified grade and slope, or as directed by the City Engineer or designee.

The Contractor shall place the foundation course in a trench excavated to 24 inches below the toe of the slope of the embankment or side of channel. The Contractor shall stagger the sack ends and steel staple anchors of succeeding courses.

The Contractor shall tamp each row of sacks, round out the bags, eliminate wrinkles, minimize voids, and prepare an even surface for the next row.

The Contractor shall obtain the City Engineer's or designee's approval of the compaction method prior to backfill and compact soil behind each row of sacks before placing the next row. The Contractor shall not place large stones and jagged objects adjacent to the bags.

The Contractor shall anchor the sacks with steel staples without damaging the sacks.

After placing the sacks, the Contractor shall wet thoroughly and keep moist for at least three (3) days.



### **225.3.3 Concrete Block Revetment Placement**

The Contractor shall construct concrete block revetment systems in accordance with the manufacturer's recommendations and the Contract. The Contractor shall remove slope obstructions, and fill voids with approved material or grade slopes before placing concrete blocks.

### **225.3.4 Gabions**

The Contractor shall supply gabions within plus or minus five percent ( $\pm 5\%$ ) of the manufacturer's stated sizes.

#### **225.3.4.1 Assembly of Gabion Baskets**

The Contractor shall fabricate gabions for individual assembly at the construction site.

If a gabion is greater than 1 1/2 times as long as it is wide, the Contractor shall divide the gabion into cells using diaphragms of the same wire mesh as the body of the gabion. The Contractor shall create cells that are no longer than the gabion is wide and anchor diaphragms to the base section of the gabion. The Contractor shall selvedge or bind perimeter edges so the joints are as strong as the gabion body. The Contractor shall assemble perimeter edges using approved fasteners or lacing wire. The Contractor shall place fasteners in each mesh opening. The Contractor shall secure lacing wire by double looping through every other mesh opening. The Contractor shall assemble gabions using one of the following:

1. Double-looped lacing twice; or,
2. Connect with approved fasteners and double-looped lacing once.

#### **225.3.4.2 Foundation Preparation**

The Contractor shall level and compact the top six (6) inches of the gabion foundation to at least 95% of maximum density in accordance with AASHTO T 180 (Modified Proctor), Method D (TTCP Modified), and to field densities in accordance with AASHTO T 310.

#### **225.3.4.3 Placement of Gabion Baskets**

The Contractor shall set assembled, empty baskets into the specified positions and wire each unit to adjacent units along the top and vertical edges before placing stone.

#### **225.3.4.4 Placement of Gabion Stone**

The Contractor shall place stone in equal layers from 9-inch to 12-inch spacing. The Contractor shall minimize local deformations by not filling a gabion more than 12 inches higher than an adjacent gabion. The Contractor shall hand place stone at exposed surfaces.

The Contractor shall provide cross-connecting wires on gabions with cells 18 inches or higher. The Contractor shall place cross connecting wires directly above each layer of stone. The Contractor shall equally space and tightly tie two (2) connecting wires in each direction for each layer through two (2) mesh openings at opposite faces of each gabion cell.

The Contractor shall maintain alignment while filling gabions (minimizing voids and bulges, and finishing to a neat square appearance).

After filling, the Contractor shall bend the lid over and tightly bind to the perimeters and diaphragms in accordance with Section 225.3.4.1, "Assembly of Gabion Baskets."

**225.3.4.5 Gabion Marking**

The Contractor shall mark each gabion in an identifiable manner that clearly indicates its size.

**225.3.4.6 Placement of Geotextile Fabric for Gabions**

The Contractor shall install Class one (1) non-woven geotextile (filter fabric) between gabion baskets and supporting soil, and between gabion baskets and backfill.

**225.3.5 Placement of Wrapped Rock Faces**

The Contractor shall place wrapped rock faces within ± 0.2 feet of the specified grade and slope.

The Contractor shall place the foundation course 18 inches below the toe of the slope of the embankment or side of channel.

The Contractor shall place each level of welded wire forms with biaxial geogrid embedded in the rock face in accordance with the Contract, and tensioned with anchor pins to remove slack. The Contractor shall lap the geogrid a minimum of 12 inches at the edges of adjacent panels. The Contractor shall tamp the welded wire form face to eliminate wrinkles, minimize voids, and finish to an even surface.

The Contractor shall backfill and compact behind each welded wire form level before placing the next row. The Contractor shall obtain the City Engineer’s or Designee’s approval of the compaction method.

**225.4 METHOD OF MEASUREMENT**

Measurement of payment of Riprap, Revetment, Wrapped Rockfacing and Gabions shall be:

- Riprap Class \_\_\_\_ shall be measured based on the specified thickness and accepted surface area or by the ton.
- Riprap Class G, Concrete Block Revetment, and Wrapped Rockfacing shall be measured based on the accepted surface area.
- Sacked Concrete Revetment shall be measured based on the specified thickness and accepted surface area.
- Gabions and Revetment Mattresses shall be measured based on the specified basket dimensions.

**225.5 BASIS OF PAYMENT**

<b>Pay Item</b>	<b>Pay Unit</b>
Riprap Class ____	Cubic Yard
Riprap Class ____	Ton
Riprap Class G	Square Yard
Concrete Block Revetment	Square Yard
Wrapped Rockfacing	Square Yard
Sacked Concrete Revetment	Cubic Yard
Gabions	Cubic Yard
Revetment Mattresses	Cubic Yard

### **225.5.1 Work Included in Payment**

The following work and items will be considered as included in the payment for the main item(s) and will not be measured or paid for separately:

- Excavation, backfilling, providing, placing and disposal of material required for the installation of slope and erosion protection structures;
- Any testing and/or certifications;
- Dewatering;
- Stakes and steel staples, including placement; and,
- Soil and drainage geotextile(s), including placement.