



DENVER

THE MILE HIGH CITY

CITY AND COUNTY OF DENVER
DEPARTMENT OF PUBLIC WORKS | ENGINEERING DIVISION

Storm Drainage and Sanitary Sewer Construction Detail and Technical Specifications

12.0 Riprap, Boulders and Slope/Channel Protection

12.1 General

12.1.1 Description

This work consists of furnishing all labor, equipment and materials necessary to place riprap, soil riprap, grouted riprap, and erosion resistant materials where detailed on the Plans or as directed by the Project Construction Engineer. The work includes water control, excavation and backfill, grading, sub-grade preparation, materials and installation of bedding, rock, riprap, boulders and grout as indicated herein and in the Contract Documents.

12.1.2 Submittals and Testing

In accordance with the Special Conditions submit documentation indicating source of stone and certifying materials for all types of rock will meet the requirements of this section. Include test results for specific gravity, abrasion, gradation and freeze thaw on samples of rock to be supplied on this project. Submit design mix for grout. In advance of delivery of rock to the work site an inspection of the quarry shall be arranged by the Contractor and shall include the Contractor, Project Construction Engineer, and Quarry Representative. The quarry will identify the rock source and procedures that will be used to stockpile, mix and grade the types of riprap and boulders specified. The Project Construction Engineer, following receipt and review of current gradation test results, may waive the requirement for field gradation tests at his discretion. If gradation tests are determined to be necessary by the Project Construction Engineer, the following procedures shall be used.

For each type of riprap specified a random sample will be selected by the Project Construction Engineer. The objective is to obtain a sample as it would be handled for normal delivery to the work site. It will then be placed in an approved area at the quarry and sized and sorted to identify and weigh the individual pieces as directed by the Project Construction Engineer. The Contractor and Quarry Representative shall apply all labor and equipment to sort and weigh the riprap. Submit weight data of individual pieces and summary gradation curve. The approved sample shall then be hauled to the work site and stockpiled for comparison of future riprap deliveries. If the riprap being delivered appears to be outside of the specified gradation, or does not resemble the same stockpiles, the Contractor shall make appropriate adjustments at the quarry to ensure riprap meets the requirement of the Specification.

Boulders shall be visually checked by the Contractor at the quarry or work site as required for size, elongation, cracks, deterioration and other defects visible on the entire surface of the stone. If cracks are observed, the Contractor shall notify the Project Construction Engineer to re-inspect and retest the rock. Stone with cracks or defects that are detrimental to a long lasting product shall not be shipped to the work site.

12.1.3 Types of Riprap

The types, size, or classification of riprap to be placed will be noted on the Plans. Unless otherwise specified in the Plans or the Contract Documents riprap placed in accordance with the requirements for "dumped riprap" will be considered satisfactory. All riprap shall be placed on a prepared slope on a prepared filter media consisting of either a heavy duty plastic filter cloth or a free draining granular bedding media as described in the materials section of this specification. If the existing soils conditions meet the requirements for filter media the filter media will not be required.

Dumped Riprap: This type of riprap shall consist of angular or fractured rock dumped in place on a prepared slope and filter media to form a well graded mass with a minimum of voids. Asphalt, broken concrete and other materials not classified as rock will not be allowed for use as riprap.

Soil Riprap: This type of riprap shall consist of angular or fractured rock mixed with 35% soil by volume dumped in place on a prepared slope to form a uniform mixture of soil and riprap without voids per Section 12.2.1C.

Grouted Riprap: This type of riprap shall consist of rock with all parts of the interstices filled with Portland cement mortar. The finished product shall be aesthetically pleasing resembling hand placed stone or fireplace rockwork. Colored concrete grout may be specified as defined elsewhere within these Detail and Technical Specifications.

12.2 Materials

12.2.1 Rock

A. **General.** Use quarry rock that is sound and durable against disintegration under conditions to be met in handling and placing, and is hard and tenacious and otherwise of suitable quality to ensure permanency in the specified kind of work.

All rock shall be angular, each piece having its greatest dimensions greater than 3 times its least dimensions and shall conform to the following test requirements of the American Society for Testing Material Standards:

B. **Riprap.** Riprap used shall be the type designated on the DRAWINGS and shall conform to the following:

See Table on Next Page

Riprap Designation	% Smaller Than Given Size By Weight	Intermediate Rock Dimension (inches)	d ₅₀ * (inches)
Type VL	70 - 100	12	6
	50 - 70	9	
	35 - 50	6	
	2 - 10	2	
Type L	70 - 100	15	9
	50 - 70	12	
	35 - 50	9	
	2 - 10	3	
Type M	70 - 100	21	12
	50 - 70	18	
	35 - 50	12	
	2 - 10	4	
Type H	70 - 100	30	18
	50 - 70	24	
	35 - 50	18	
	2 - 10	6	
Type VH	70 - 100	41	24
	50 - 70	33	
	35 - 50	24	
	2 - 10	9	

* d₅₀ = Mean Particle Size

1. The riprap designation and total thickness of riprap shall be as shown on the DRAWINGS. The maximum stone size shall not be larger than the thickness of the riprap.
2. The specific gravity of the riprap shall be two and one-half (2.5) or greater.
3. Neither width nor thickness of a single stone of riprap shall be less than one-third ($\frac{1}{3}$) of its length.
4. Broken concrete or asphalt pavement shall not be acceptable for use in any portion of the Project. Rounded riprap (river rock) is not acceptable unless specifically designated in the Contract Documents.
5. The color of the riprap shall be gray with gray/blue hues or other acceptable colors approved by Project Construction Engineer prior to delivery to the Project site. Color shall be consistent on the entire Project and shall match the color of rock to be used for all other portions of the Project Scope.
6. Minimum density for acceptable riprap shall be one hundred sixty five (165) pounds per cubic foot. The specific gravity shall be according to the bulk-saturated, surface-dry basis, AASHTO T85.
7. The riprap shall have a percentage loss of not more than forty percent (40%) after five hundred (500) revolutions when tested in the Los Angeles machine in accordance with AASHTO Test T96.
8. The riprap shall have a percentage loss of not more than ten percent (10%) after five (5) cycles when tested in accordance with AASHTO Test T104 for ledge rock using sodium sulfate.
9. The riprap shall have a percentage loss of not more than ten percent (10%) after twelve (12) cycles of freezing and thawing when tested in accordance with AASHTO Test T103 for ledge rock, procedure A.
10. Rock shall be free of calcite intrusions.
11. Each load of riprap shall be reasonably well graded from the smallest to the largest size specified. Stones smaller than the two-to-ten percent (2-10%) size will not be permitted in an amount exceeding ten percent (10%) by weight of each load.

Control of gradation shall be by visual inspection. However in the event Project Construction Engineer determines the riprap to be unacceptable, the Project Construction Engineer shall pick two (2) random truckloads to be dumped and checked for gradation. Mechanical equipment and labor needed to assist in checking gradation shall be provided by Contractor at no additional cost.

C. **Soil Riprap.** Rock requirements are to comply with riprap as specified in the above Paragraph A. The soil material shall be native or topsoil and mixed with sixty five percent (65%) riprap and thirty five percent (35%) soil by volume. Soil riprap shall consist of a uniform mixture of soil and riprap without voids. Bedding material is not required for soil riprap.

D. **Bedding.** Gradation for Granular Bedding:

U.S. Standard Sieve Size	Percent by Weight Passing Type I	Square Mesh Sieves Type II
3 inch		90 - 100
1-½ inch		
¾ inch		20 - 90
⅜ inch	100	
No. 4	95 – 100	0 - 20
No. 16	45 - 80	
No. 50	10 - 30	
No. 100	2 - 10	
No. 200	0 - 2	0 - 3

Granular bedding designation and total thickness of bedding shall be as shown in the Contract Documents. Granular bedding shall meet the same requirements for specific gravity, absorption, abrasion, sodium sulfate soundness, and freeze-thaw durability as required for riprap and specified above and as follows:

1. Broken concrete asphalt pavement or sledge, shall not be acceptable for use in any project. Rounded river rock is not acceptable unless specifically designated in the Contract Documents.
2. Shall conform to the quality requirements of AASHTO M197.
3. The requirements for the wear test in AASHTO T96 shall not apply.

- E. **Feature Boulders.** Feature Boulders shall consist of the same material as riprap, differing only by size. Feature Boulders shall have a minimum dimension of four (4) feet, or as shown on the Plans.

- F. **Boulders.** Boulders shall consist of the same material as riprap, differing only by size. Boulders shall have a minimum dimension of two (2) feet, or as shown on the Plans.

12.3 Execution

12.3.1 Unclassified Excavation – Complete in Place

Unclassified excavation shall consist of the excavation of all materials of whatever character required for the work, obtained within the project limits, including surface boulders, masonry, organics, muck, and slag that are not removed under some other item. The work will also include hauling of unsuitable unclassified excavation materials off the site.

The excavations shall be finished to smooth and uniform surfaces conforming to the line and grade specified. Variation from the finished grade elevations specified shall not be more than 1.0 inch. Materials shall not be wasted without written permission of the Project Construction Engineer. Excavation operations shall be conducted so material outside of the slope limits will not be disturbed. Prior to beginning grading operations, all necessary clearing and grubbing in that area shall have been performed. The top six (6) inches of material from all areas to be excavated shall be designated as topsoil and shall be removed and stockpiled in the designated location on the plans. Following removal of topsoil, in the designated excavation areas, the remaining material shall be removed and stockpiled separately for use as sub-grade material in the designated location on the plans. All excavation from six (6) inches below existing grade to the top of sub-grade shall be designated as Unclassified Excavation.

Unless otherwise stipulated in the Proposal and in the Measurement and Payment, no separate payment will be made for unclassified excavation, except for overexcavation as directed by the Project Construction Engineer, and all costs incurred will be considered to be included in the unit price bid for the associated structure. The cost of overexcavation will be paid for as specified in Section 12.3.2 below.

12.3.2 Overexcavation

In locations where soil with unsuitable bearing characteristics are encountered, the Project Construction Engineer may order that the unsuitable material be removed and be replaced with granular and/or rock backfill material to provide suitable bearing for the structure. At least eight (8) inches of acceptable material must be present below the proposed riprap, soil riprap, or boulders within two (2) feet of existing grade.

The overexcavation will be paid for based on the classification of the soil encountered. No measurement for payment will be made of any material required to fill overexcavated areas outside of the pay limits specified in CDOT Section 206.03, if the Contractor for his own convenience, excavates beyond the limits required for structure excavation, the excess excavation and backfill thereof shall be at the Contractor's expense; or where excavations for footings, slabs, etc., are made below the required elevations without specific authorization from the Project Construction Engineer, the overexcavated area shall be filled in a manner satisfactory to the Project Construction Engineer by the Contractor at the Contractor's expense.

12.3.3 Removal of Water

During construction, the Contractor shall provide and maintain adequate equipment to properly remove and dispose of all water entering the work area. In water bearing strata, well points, sub drains or any other method approved by the Project Construction Engineer may be required to provide a dry trench.

The discharge from any dewatering operations shall be conducted to natural drainage channels or other structures as approved by the Project Construction Engineer and in accordance with applicable permits. Ground water shall not be discharged into sanitary sewers.

Excavation work areas shall be kept free from water during excavation, fine grading, pipe laying and grouting. Dewatering, sufficient to provide a completely dry work area, shall be maintained during all excavation, construction and grouting operations. The Contractor shall be responsible for damage of any nature resulting from the dewatering operations.

Unless provided for in the Contract Documents, dewatering shall be considered as incidental to construction and all costs incurred will be considered to be included in the unit price bid for the construction of each section of sewer line, associated structures, laterals and appurtenances.

12.3.4 Backfill

Backfill around structures shall be as per requirements of CDOT Section 206.03 and shall be placed only after walls or other constructed items have been inspected and the approval of the Project Construction Engineer to commence backfilling has been obtained. Backfilling against structures is allowed only after the concrete has properly cured for not less than seven days, or until other testing procedures (concrete test cylinders) indicate that the concrete has attained sufficient strength so as not to be damaged by the backfilling operation.

12.3.5 Topsoil – Complete in Place

Top soil material shall be taken from the topsoil stockpile and placed to a minimum depth of six (6) inches to the limits shown on the plans. Additional topsoil material, if necessary, shall be obtained from the sub-grade stockpile as approved by the Project Construction Engineer. The topsoil shall be placed uniformly and compacted to a minimum of 85% Standard Proctor density ASHTO T-99. The intent is to provide a suitable medium for revegetation activities.

12.3.6 Muck Excavation

Materials encountered during construction that are deemed by the Project Construction Engineer to be unsatisfactory as structure sub-grade shall be removed to a maximum depth as approved by the Project Construction Engineer, and replaced with stabilization material including, rock, or other materials approved by the Project Construction Engineer. The source of stabilization material shall be approved by the Project Construction Engineer prior to placement. Excavated muck shall be removed and hauled off the site.

12.3.7 Construction Requirements

Channel slopes, bottoms, or other areas that are to be protected with riprap, soil riprap, or boulders shall be free of brush, trees, stumps, and other objectionable material and be graded to a smooth compacted surface. Contractor shall excavate areas to receive riprap or boulders to the sub-grade for granular bedding or for soil riprap to the specified depth (bedding material is not required for soil riprap). The sub-grade materials shall be stable. If unsuitable materials are encountered, they shall be removed and replaced as Muck Excavation in accordance with Section 12.3.6 of these Detail and Technical Specifications for sub-grade that has been excavated in undisturbed soil. Additional compaction shall not be required unless specified by Project Construction Engineer. When sub-grade is built up with embankment material it shall be compacted to ninety five percent (95%) optimum density (ASTM D698). After an acceptable sub-grade is established, the soil riprap or

bedding shall be immediately placed and leveled to the specified elevation. Immediately following the placement of the bedding material, the riprap shall be placed. If bedding material is disturbed for any reason, it shall be replaced and graded at Contractor's expense. In-place bedding materials shall not be contaminated with soils, debris or vegetation before the riprap is placed. If contaminated, the bedding material shall be removed and replaced at Contractor's expense.

12.4 Placement

Following acceptable placement of granular bedding, riprap placement shall commence as follows:

- A. **Machine Placed Riprap.** Riprap shall be placed on the prepared slope or channel bottom areas in a manner which will produce a reasonably well-graded mass of stone with the minimum practicable percentage of voids. Riprap shall be machine placed, unless otherwise stipulated in the Contract Documents.

When riprap is placed on slopes, placement shall commence at the bottom of the slopes working up the slope. Place the riprap in a stepped fashion with the bottom of the uphill riprap below the top of the downhill riprap by one half ($\frac{1}{2}$) of the height of the riprap minimum.

The entire mass of riprap shall be placed on either channel slopes or bottoms so as to be in conformance with the required gradation mixtures and to lines, grades, and thickness shown on the DRAWINGS. Riprap shall be placed to its full course thickness at one operation and in such a manner as to avoid displacing the underlying bedding material. Placing of riprap in layers, or by dumping into chutes, or by similar methods shall not be permitted.

All material going into riprap protection for channel slopes or bottoms shall be so placed and distributed that there shall be no large accumulations of either the larger or smaller sizes of stone. Some hand placement may be required to achieve this distribution.

It is the intent of these Details and Technical Specifications to produce a fairly compact riprap protection in which all sizes of material are placed in their proper proportions. Unless otherwise authorized by Project Construction Engineer, the riprap protection shall be placed in conjunction with the construction of embankments

or channel bottoms with only sufficient delay in construction of the riprap protection, as may be necessary, to allow for proper construction of the portion of the embankment and channel bottom which is to be protected. Contractor shall maintain the riprap protection until accepted. Any material displaced for any reason shall be replaced to the lines and grades shown in the Contract Documents at no additional cost to City and County of Denver. If the bedding materials are removed or disturbed, such material shall be replaced prior to replacing the displaced riprap.

The basic procedure shall result in larger materials flush to the top surface with faces and shapes arranged to minimize voids, and smaller material below and between larger materials. Surface grades shall be a plane or as indicated, but projections above or depressions under the finished design grade more than ten percent (10%) of the rock layer thickness shall not be allowed. Smaller rock shall be securely locked between the larger stone. It is essential that the material between the larger stones not be loose or easily displaced by flow or by vandalism. The stone shall be consolidated by the bucket of the backhoe or other means that will cause interlocking of the material. All rock is to be placed in a dewatered condition beginning at the toe of the slope or other lowest point.

- B. **Hand Placed Riprap.** Hand placed riprap shall be performed during machine placement of riprap and shall conform to all the requirements of Section 12.3.2A, above. Hand placed riprap shall also be required when the depth of riprap is less than two (2) times the nominal stone size, or when required by the Contract Documents.

After the riprap has been placed, hand placing or rearranging of individual stones by mechanical equipment shall be required to the extent necessary to secure a flat uniform surface and the specified depth of riprap, to the lines and grades as shown in the Contract Documents.

- C. **Soil Replacement Over Riprap.** Where riprap is designated to be buried, place onsite excavated material that is free from trash and organic matter in riprap voids by washing and rodding. Prevent excessive washing of material into stream. When voids are filled and the surface accepted by the Project Construction Engineer, place a nominal six (6) inches of soil over the area, or as designated in the Contract Documents. Fine grade, seed, and mulch per the Contract Documents.
- D. **Soil Riprap.** Adjacent stockpiles of riprap and soil shall be created and mixing done at the stockpile location, not at the location where soil riprap is to be placed. Mix thirty five percent (35%) soil by volume with stockpiled riprap, using additional

moisture and control procedures that assure a homogenous mixture, where the soil fills the inherent voids in the riprap without displacing riprap.

Place a first layer of smaller soil riprap of approximate d_{50} thickness. Then place the top layer with surface rocks that are largely d_{50} or greater, filling voids as necessary with smaller planted riprap. Create a smooth plane as described in Paragraph A. The mixture shall be consolidated by large vibratory equipment or backhoe bucket to create a tight, dense interlocking mass. The soil shall be further wetted to encourage void filling with soil. Any large voids shall be filled with rock and small voids filled with soil. Excessively thick zones of soil prone to washing away shall not be created (e.g., no thicknesses greater than six (6) inches). For buried soil riprap, the top surface shall be covered with four (4) inches of topsoil such that no rock points are protruding. The final surface shall be thoroughly wetted for good compaction, smoothed and compacted by vibrating equipment; the surface shall then be hand raked to receive planting or seeding. With prior approval of Project Construction Engineer, layering the riprap and soil instead of premixing may be allowed if the native soil is granular.

- E. **Rejection of Work and Materials.** Project Construction Engineer shall reject placed riprap which does not conform to this section and Contractor shall immediately remove and relay the riprap to conform with said sections.

Riprap shall be rejected, which is either delivered to the job site or placed, that does not conform to this section. Rejected riprap shall be removed from the Project site by Contractor and at Contractor's expense.

- F. **Feature Boulders.** Feature Boulders serve an aesthetic function and as such shall be placed and rotated into final position as directed by the Project Construction Engineer in order to achieve the desired result.

- G. **Grouted Boulders.** Grouted riprap and the boulder lined channel edge shall be placed at the locations as shown in the Construction Documents and installed with the following requirements:

NOTE: For purposes of Paragraph G, the items "boulders" and "rock" are used interchangeably.

1. The sub-grade to receive each boulder shall be excavated and any unstable material shall be removed. Approved material shall be placed and compacted

in a maximum of four-inch (4") lifts to ninety five percent (95%) of Maximum Standard Proctor Density (ASTM D698) to re-establish the sub-grade of each boulder. Unstable material shall be removed from the Project site and disposed of by Contractor. Removal and replacement of unstable material shall only be completed at the direction of Project Construction Engineer and shall be paid for under Muck Excavation. Backfill behind boulders shall be compacted to ninety five percent (95%) Maximum Standard Proctor Density (ASTM D698). Care shall be taken during compaction to avoid disturbing and/or damaging the integrity of the boulder channel edge.

The top of all boulders shall be as indicated in the Construction Documents. Finished grades and sub-grades for boulders will be determined from the height of each boulder used.

2. The boulders shall be carefully picked and arranged so that adjacent rock surfaces match within two (2) inches in top elevation and two (2) inches along the vertical exposed face or channel side of rock. Boulders shall be placed such that adjacent boulders "touch" each other and voids do not exceed four (4) inches. It is the intent of construction to minimize voids and grout placed between boulders.
3. Smaller rocks shall be "chinked in" to fill all voids behind the boulders. Placement shall be approved by Project Construction Engineer prior to grouting.
4. Prior to placing the grout, any type of debris, fines, smaller rock, or silt shall be removed from around or under the boulders.

Dewatering shall be implemented to guarantee that the grout will not be placed in water and for a period of twenty four (24) hours after the grout has been placed.

Keep boulders receiving grout wet at all times prior to receiving grout. The concrete grout shall be placed by injection methods by pumping under low pressure, through a two-inch (2") maximum diameter hose to ensure complete penetration of the grout into the void area as detailed in the Contract Documents. Grout will be placed up to eight (8) inches from the top of boulders, or as directed by the Project Construction Engineer. The Operator

shall be able to stop the flow and will place grout in the voids and not on the surface of the rocks.

Grout shall be troweled out and finished to minimize visibility. Clean and wash any spillage before the grout sets. The visual surfaces of boulders will be free of grout to provide a clean, natural appearance. If washing does not clean off grout residue, Contractor shall wash off any grout residue with muriatic acid and water, using a brush to scrub off the residue. A "pencil" vibrator shall be used to make sure all voids are filled between the boulders. The intent is to fill all voids from the sub-grade level around the boulders to a depth as shown in the Contract Documents. The "pencil" vibrator may be used to smooth the appearance of the surface, but Contractor shall use a wood float to smooth and grade the grout around the boulders. The grout mix shall be stiffened and other measures taken to retain the grout between the boulders.

5. Contractor shall, if deemed necessary, support the boulders from falling over before and during the placement of rock, grout, backfill, and compaction work on either side of the boulder.
6. Grout shall receive cold weather protection in accordance with Section 11.0.2.2 of these Details and Technical Specifications.

H Grouted Rock Retaining Walls

Grouted rock retaining walls shall be placed at locations as shown in the Contract Documents and installed with the following requirements:

1. The grouted rock walls shall be constructed to the dimensions in the locations shown in the Contract Documents. The walls shall be constructed with a one (1) horizontal to four (4) vertical batter on the front and back face, with a minimum width of one (1) foot at the top of the wall.
2. The stone of the wall shall be laid to form substantial masonry presenting a neat, finished appearance. Headers shall hold the heart of the wall to the face. Headers shall occupy at least twenty percent (20%) of the area and they shall be evenly distributed. The length of stretchers shall not exceed three (3) times their rise. Face stones shall be laid to break joint. Rock shall be hand graded so that only the larger stones are used in the face. Face stones shall be laid to

break joint so that each rock laid rests on two beneath it. Spalls and pinners will not be allowed in the face and shall be used in the backing only where necessary.

3. All face stones shall be pitched to a string line on straight walls or laid to batter stakes for curved walls. The batter shall be consistent with respect to all parts of the wall and shall meet the minimum requirements set forth in the detail. The degree of roughness on the exposed face shall be measured with a six-foot (6') straightedge supported between adjacent projections and stone face. Variations in excess of 3 inches, measured from the straight edge to the extreme depression in the stone, will not be permitted. Rear faces shall present approximately plane surfaces and shall in general conform to the detail.
4. Grout shall be placed to fill all voids between the rocks throughout the walls. Any "loose" rocks shall be regouted by machine or hand methods. Grout shall be recessed approximately two (2) inches from the face of the wall in order to give a "dry stacked" appearance.
5. Prior to placing the grout, any type of debris, fines, smaller rock, or silt shall be removed from around the rocks.

Dewatering shall be implemented to guarantee that the grout will not be placed in water and the area will remain dewatered for a period of ten (10) hours after the grout has been placed.

The surface of the rocks receiving grout shall be wet at all times prior to receiving grout.

6. Clean and wash any spillage before the grout sets on the outside face and top of walls. The visual surfaces of the rocks will be free of grout to provide a clean natural appearance. If washing does not clean off grout residue, then Contractor shall wash off any grout residue with muriatic acid and water, using a brush to scrub off the residue.
7. Grout shall receive cold or hot weather protection as required in accordance with these Detail and Technical Specifications.