SECTION 31 37 00

RIPRAP, BOULDERS, AND BEDDING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The WORK includes excavation, grading, and installation of riprap, boulders, soil riprap, void-filled riprap, and bedding placed at the locations shown on the DRAWINGS. The materials to be used and the construction of such structures shall be as specified herein.

1.02 RELATED SECTIONS

A. The following is a list of SPECIFICATIONS, which may be related to this section:

1. Section 01 57 19, Temporary Environmental Controls
2. Section 31 23 00, Excavation and Fill.
3. Section 31 23 19, Dewatering.
4. Section 31 23 33, Trenching and Backfilling.
5. Section 31 25 00, Erosion and Sedimentation Controls
6. Section 31 37 19, Grouted Boulders, Stacked Grouted Boulders, and Grouted Rock Retaining Walls

1.03 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Association of State Highway and Transportation Officials (AASHTO):
    a. T85, Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate.
    b. T96, Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
    c. T103, Standard Method of Test for Soundness of Aggregates by Freezing and Thawing.
    d. T104, Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.
    e. T248, Reducing Field Samples of Aggregate Test Size.

2. ASTM International (ASTM): D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3)).

1.04 SUBMITTALS

A. CONTRACTOR shall cooperate with ENGINEER in obtaining and providing samples of all specified materials.

B. CONTRACTOR shall submit certified laboratory test certificates for all items required in this section.

PART 2 PRODUCTS

2.01 MATERIALS

A. RIPRAP

1. Riprap used shall be the type designated on the DRAWINGS and shall conform to Table 1.

Table 1: Riprap Gradation

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

*d_{50} = Mean Particle Size

**Mix VL, L and M riprap with 35% topsoil (by volume) and bury it with 4 to 6 inches of topsoil, all vibration compacted, and revegetate.

2. 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.

3. Neither width nor thickness of a single stone of riprap shall be less than one-third (1/3) of its length.

4. The specific gravity of the riprap shall be two and one-half (2.5) or greater.

5. Riprap specific gravity shall be according to the bulk-saturated, surface-dry basis, in accordance with AASHTO T85.

6. The bulk density for the riprap shall be 1.3 ton/cy or greater.

7. The riprap shall have a percentage loss of not more than forty percent (40%) after five hundred (500) revolutions when tested in accordance with AASHTO 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 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 T103 for ledge rock, procedure A.

10. Rock shall be free of calcite intrusions.

11. Gradation:

    a. Each load of riprap shall be reasonably well graded from the smallest to the largest size specified.

    b. Stones smaller than the two to ten percent (2 to 10%) size will not be permitted in an amount exceeding ten percent (10%) by weight of each load.

    c. Control of gradation shall be by visual inspection. However in the event ENGINEER determines the riprap to be unacceptable, ENGINEER shall pick two (2) random truckloads to be dumped and checked for gradation.

        1) Mechanical equipment and labor needed to assist in checking gradation shall be provided by CONTRACTOR at no additional cost.

12. Color:

    a. The color of the riprap shall approved by ENGINEER prior to delivery to the PROJECT site.

    b. Color shall be consistent on the entire PROJECT and shall match the color of rock to be used for all other portions of the WORK.

13. Broken concrete or asphalt pavement shall not be acceptable for use in the WORK.

14. Rounded riprap (river rock) is not acceptable, unless specifically designated on the DRAWINGS.

B. BOULDERS

1. Boulders used shall be the type designated on the DRAWINGS and shall conform to Table 2.

Table 2: Boulder Properties

Boulder Classification	Nominal Size (inches)	Range in Smallest Dimension of Individual Rock Boulders (inches)	Maximum Ratio of Largest to Smallest Rock Dimension of Individual Boulders
B24	24	20 - 28	1.50
B30	30	26 - 34	1.50
B36	36	32 - 40	1.50
B42	42	38 - 46	1.50
B48	48	44 - 52	1.50

2. The specific gravity of the boulders shall be two and one-half (2.5) or greater.

3. Boulder specific gravity shall be according to the bulk-saturated, surface-dry basis, in accordance with AASHTO T85.

4. The bulk density for the boulder shall be 1.3 ton/cy or greater.

5. The boulders shall have a percentage loss of not more than forty percent (40%) after five hundred (500) revolutions when tested in accordance with AASHTO T96.

6. The boulders shall have a percentage loss of not more than ten percent (10%) after five (5) cycles when tested in accordance with AASHTO T104 for ledge rock using sodium sulfate.

7. The boulders 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 T103 for ledge rock, procedure A.

8. Rock shall be free of calcite intrusions.

9. Color:

    a. The color of the boulders shall approved by ENGINEER prior to delivery to the PROJECT site.

b. Color shall be consistent on the entire PROJECT and shall match the color of rock to be used for all other portions of the WORK.

C. SOIL RIPRAP

1. Rock requirements are to comply with riprap as specified in Article Materials.

2. The soil material shall be native or topsoil and mixed with sixty-five percent (65%) riprap and thirty five percent (35%) soil by volume.

3. Soil riprap shall consist of a uniform mixture of soil and riprap without voids.

D. VOID-FILLED RIPRAP

1. Rock requirements are to comply with riprap material specifications in Paragraph A.

2. Samples of riprap and void-fill materials shall be submitted for the review and approval of the ENGINEER prior to construction.

3. Where “Void-Filled Riprap” is designated on the DRAWINGS, riprap shall be mixed with the materials and associated proportions listed in Table 3 and Table 4 to fill the voids of the riprap.

4. If specified, an alternate void-filled riprap mix that includes river cobble shall be used; this mix appears in Table 5 and Table 6.

5. Mix proportions and material gradations in Tables 3 through 6 are approximate and are subject to adjustment by the ENGINEER. No adjustment in unit price for void-filled riprap will be allowed based on modifications to the mix proportions.

Table 3: Mix Requirements for Type VL and L Void-Filled Riprap without River Cobble

Approximate Proportions (loader buckets)	Material Type	Material Description
6	Riprap	Type VL or L
1	Void-fill material	VTC (Vehicle Tracking Control) rock (crushed rock with 100% passing 4-inch sieve, 50-70% passing 3-inch sieve, 0-10% passing 2-inch sieve)
1	Void-fill material	4-inch minus pit run surge (round river rock and sand, well graded, 90-100% passing 4-inch sieve, 70-80% passing 1.5-inch sieve, 40-60% passing 3/8-inch sieve, 10-30% passing #16 sieve).
1	Void-fill material	Type II bedding
½ to 1	Void-fill material	Native topsoil

Note: Mix proportions and material gradations are approximate and are subject to adjustment by the ENGINEER.

Table 4: Mix Requirements for Type M and H Void-Filled Riprap without River Cobble

Approximate Proportions (loader buckets)	Material Type	Material Description
6	Riprap	Type M or H
2	Void-fill material	7-inch minus crushed rock surge (100% passing 7-inch sieve, 80-100% passing 6-inch sieve, 35-50% passing 3-inch sieve, 10-20% passing 1.5-inch sieve)
1	Void-fill material	VTC (Vehicle Tracking Control) rock (crushed rock with 100% passing 4-inch sieve, 50-70% passing 3-inch sieve, 0-10% passing 2-inch sieve)
1	Void-fill material	4-inch minus pit run surge (round river rock and sand, well graded, 90-100% passing 4-inch sieve, 70-80% passing 1.5-inch sieve, 40-60% passing 3/8-inch sieve, 10-30% passing #16 sieve).
1	Void-fill material	Type II bedding
½ to 1	Void-fill material	Native topsoil

Note: Mix proportions and material gradations are approximate and are subject to adjustment by the ENGINEER.

Table 5: Mix Requirements for Type VL and L Void-Filled Riprap with River Cobble

Approximate Proportions (loader buckets)	Material Type	Material Description
6	Riprap	Type VL or L
1	Void-fill material	2 to 4-inch cobble (round washed river rock that is well-graded, 100% passing 6-inch sieve, 35-50% passing 3-inch sieve, 5-20% passing 2-inch sieve)
1	Void-fill material	4-inch minus pit run surge (round river rock and sand, well graded, 90-100% passing 4-inch sieve, 70-80% passing 1.5-inch sieve, 40-60% passing 3/8-inch sieve, 10-30% passing #16 sieve).
1	Void-fill material	Type II bedding
½ to 1	Void-fill material	Native topsoil
Top layer	Top dressing	Additional 4 to 12-inch cobbles (round washed river rock that is well graded, 80-100% passing 12-inch sieve, 35-50% passing 6-inch sieve, 5-20% passing 4-inch sieve) shall be mixed in on the surface of exposed sections of void-filled riprap (covering approximately 15% of the surface) prior to compaction of the void-filled riprap. Cobbles shall be fully embedded into the mass of the void-filled riprap.

Note: Mix proportions and material gradations are approximate and are subject to adjustment by the ENGINEER.

Table 6: Mix Requirements for Type M and H Void-Filled Riprap with River Cobble

Approximate Proportions (loader buckets)	Material Type	Material Description
6	Riprap	Type M or H
2	Void-fill material	7-inch minus crushed rock surge (100% passing 7-inch sieve, 80-100% passing 6-inch sieve, 35-50% passing 3-inch sieve, 10-20% passing 1.5-inch sieve)
1	Void-fill material	2 to 4-inch cobble (round washed river rock that is well-graded, 100% passing 6-inch sieve, 35-50% passing 3-inch sieve, 5-20% passing 2-inch sieve)
1	Void-fill material	4-inch minus pit run surge (round river rock and sand, well graded, 90-100% passing 4-inch sieve, 70-80% passing 1.5-inch sieve, 40-60% passing 3/8-inch sieve, 10-30% passing #16 sieve).
1	Void-fill material	Type II bedding
½ to 1	Void-fill material	Native topsoil
Top layer	Top dressing	Additional 4 to 12-inch cobbles (round washed river rock that is well graded, 80-100% passing 12-inch sieve, 35-50% passing 6-inch sieve, 5-20% passing 4-inch sieve) shall be mixed in on the surface of exposed sections of void-filled riprap (covering approximately 15% of the surface) prior to compaction of the void-filled riprap. Cobbles shall be fully embedded into the mass of the void-filled riprap.

Note: Mix proportions and material gradations are approximate and are subject to adjustment by the ENGINEER.

E. BEDDING:

1. Gradation for granular bedding shall conform to Table 7.

2. Granular bedding designation and total thickness of bedding shall be as shown on the DRAWINGS.

3. Granular bedding shall meet the same requirements for specific gravity, absorption, abrasion, sodium sulfate soundness, calcite intrusion, and freeze-thaw durability as required for riprap.

    a. Broken concrete asphalt pavement or sledge, shall not be acceptable for use in the WORK. Rounded river rock is not acceptable unless specifically designated on the DRAWINGS.

b. The requirements for the wear test in AASHTO T96 shall not apply.

Table 7: Granular Bedding Gradation

	Percent by Weight Passing Square-Mesh Sieves	
U.S. Standard Sieve Size	**Type I (CDOT Sect. 703.01)**	**Type II (CDOT Sect. 703.09 Class A)**
3 inches	-	90 - 100
1½ inches	-	-
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

F. FEATURE BOULDERS:

1. Feature Boulders shall consist of the same material as boulders, differing only by size.

2. Feature Boulders shall meet the same requirements for specific gravity, absorption, abrasion, sodium sulfate soundness, calcite intrusion, and freeze-thaw durability as required for boulders

3. Feature Boulders shall have a minimum dimension of four (4) feet, or as shown on the DRAWINGS.

PART 3 EXECUTION

3.01 PREPARATION

A. Channel slope, bottom, or other areas that are to be protected with riprap, boulders, soil riprap, or void-filled riprap shall be free of brush, trees, stumps, and other objectionable material and be graded to a smooth compacted surface as shown on the DRAWINGS.

B. CONTRACTOR shall excavate areas to receive riprap to the subgrade as shown on the DRAWINGS accounting for granular bedding.

C. CONTRACTOR shall excavate areas to receive boulders, soil riprap, or void-filled riprap to the specified depth (bedding material is not required for boulders, soil riprap, or void-filled riprap).

D. Subgrade Materials:

1. The subgrade materials shall be stable.

2. If unsuitable materials are encountered, they shall be removed and replaced as Muck Excavation in accordance with Section 31 23 00, Excavation and Fill, for subgrade that has been excavated in undisturbed soil.

E. Additional Compaction:

1. Additional compaction shall not be required unless specified by ENGINEER.

2. When subgrade is built up with embankment material it shall be compacted to ninety five percent (95%) maximum density (ASTM D698).

F. Bedding:

1. After an acceptable subgrade is established, bedding shall be immediately placed and leveled to the specified elevation on the DRAWINGS.

2. Immediately following the placement of the bedding material, the riprap shall be placed.

3. If bedding material is disturbed for any reason, it shall be replaced and graded at CONTRACTOR's expense.

4. Contamination:

a. In-place bedding materials shall not be contaminated with soils, debris or vegetation before the riprap is placed.

b. If contaminated, the bedding material shall be removed and replaced at CONTRACTOR's expense.

3.02 PLACEMENT

A. RIPRAP

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

a. Machine Placed Riprap:

1) 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.

2) Riprap shall be machine placed, unless otherwise stipulated in the DRAWINGS or SPECIFICATIONS.

3) It is the intent of these SPECIFICATIONS to produce a fairly compact riprap protection in which all sizes of material are placed in their proper proportions. Unless otherwise authorized by ENGINEER, the riprap protection shall be

placed in conjunction with the construction of embankment or channel bottom 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.

b. Slope Placement:

1) When riprap is placed on slope, placement shall commence at the bottom of the slope working up the slope.

c. The entire mass of riprap shall be placed on either channel slope or bottom so as to be in conformance with the required gradation mixture and to line, grade, and thickness shown on the DRAWINGS.

d. Riprap shall be placed to 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.

e. All material used for riprap protection for channel slope or bottom shall be placed and distributed such 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.

f. 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.

g. Surface grade shall be a plane or as indicated, but projections above or depressions under the finished design grade by more than ten percent (10%) of the rock layer thickness shall not be allowed.

h. 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.

i. The stone shall be consolidated by the bucket of the backhoe or other means that will cause interlocking of the material.

j. All rock is to be placed in a dewatered condition beginning at the toe of the slope or other lowest point.

k. CONTRACTOR shall maintain the riprap protection until accepted. Any material displaced for any reason shall be replaced to the lines and grades shown on the DRAWINGS at no additional cost to OWNER. If the bedding materials are removed or disturbed, such material shall be replaced prior to replacing the displaced riprap.

2. Hand Placed Riprap:

a. Hand placed riprap shall be performed during machine placement of riprap and shall conform to all the requirements of PART 2, above.

b. 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 DRAWINGS or SPECIFICATIONS.

c. 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 on the DRAWINGS.

3. Soil Replacement Over Riprap:

a. 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.

b. Prevent excessive washing of material into stream.

c. When voids are filled and the surface accepted by ENGINEER, place a nominal six (6) inches of topsoil over the area, or as designated on the DRAWINGS.

d. Fine grade, seed, and mulch per the SPECIFICATIONS.

B. BOULDERS

1. Following excavation and acceptance of subgrade by ENGINEER Boulder placement shall commence as follows:

a. Boulders shall be placed on the prepared subgrade in a manner which will minimize voids.

b. Voids between boulders exceeding 4" shall be chinked.

2. If Boulders are to be grouted, boulders shall be installed according to Section 31 37 19, Grouted Boulders, Stacked Grouted Boulders and grouted Boulder Retaining Walls.

C. SOIL RIPRAP

1. 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.

2. Mix thirty-five percent (35%) soil by volume with stockpiled riprap, using additional moisture and control procedures that ensure a homogenous mixture; where the soil fills the inherent voids in the riprap without displacing riprap.

3. With prior approval of ENGINEER, layering the riprap and soil instead of premixing may be allowed if the native soil is granular.

4. 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.

5. The mixture shall be consolidated by large vibratory equipment or backhoe bucket to create a tight, dense interlocking mass.

6. The soil shall be further wetted to encourage void filling with soil.

7. Any large voids shall be filled with rock and small voids filled with soil.

8. Excessively thick zones of soil prone to washing away shall not be created (for example, no thicknesses greater than six (6) inches).

9. For buried soil riprap, the top surface shall be covered with four (4) inches of topsoil such that no rock points are protruding.

10. 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.

D. VOID-FILLED RIPRAP

1. The ENGINEER and/or CONSTRUCTION INSPECTOR shall observe mixing and placing of the material.

2. Approved individual component materials of void-filled riprap mix shall be delivered to site in separate marked stockpiles. Mixing shall be accomplished using a front end loader or other approved means to add the specified number of "loader buckets" of each material to a mixing stockpile. Ensure that each loader bucket comprises an approximately equal volume. If the loader operator is only able to fill the bucket partially full with large riprap (due to the force required to push the bucket into the pile), but uses full buckets of finer material, the mix proportions will not be correct. Avoid picking up excessive amounts of native soil from the subgrade under the stockpiled materials during the loader bucket mixing operations. The ENGINEER may reduce or eliminate the volume of topsoil added to the mixture based on the amount of native soil was incorporated during the bucket mixing operation.

3. Once all the materials have been added to the mixing stockpile in the specified proportions, thoroughly mix the pile using a loader, large track-hoe excavator, or other approved means to fill the voids of the riprap **without displacing the riprap** or creating pockets of finer material absent of riprap.

4. Segregation of materials shall be minimized when hauling from the stockpile to the installation location. Remixing shall occur as necessary to correct for any segregation as the material is placed.

5. The loose material shall be placed in a single lift of sufficient height such that final grade will be achieved upon compaction. Additional mixing with a track excavator shall be required after initial placement to ensure that the void-filled riprap is thoroughly mixed and no segregation or excessive amount of smaller void-fill material is present on the surface. The mixing and placement process shall result in larger riprap (D_{50} size or larger) flush to the top surface with faces and shapes arranged to minimize voids, and smaller material between and below larger materials.

6. If the top of the compacted material is below final grade, placement of only the smaller void-fill materials to achieve final grade will not be permitted. Additional void-filled riprap shall be added and the entire section mixed with a track excavator to eliminate the presence of smaller void-fill material on the surface.

7. Avoid segregation of materials and remix any section where the combined material consists primarily of the void-fill materials. The density and interlocking nature of riprap in the mixed material shall essentially be the same as if the riprap was placed without filling the voids. This requires care and persistence on the part of the CONTRACTOR to install the work and on the part of the ENGINEER to assure that the work is installed correctly.

8. At the direction of the ENGINEER, a 50:50 mixture of pit run and Type II bedding shall be sprinkled on the surface of the void-filled riprap and washed-in with water using a high pressure hose to fill-in small voids. This shall be done just prior to compaction of the void-filled riprap.

9. If specified as part of the cobble mix, the top dressing of cobbles shall also be mixed in on the surface of exposed sections of void-filled riprap material prior to compaction of the riprap material.

10. Compaction of the void-filled riprap shall be performed by running over the void-filled riprap with a large, heavy duty track excavator or dozer. The moisture content of the mixture shall be at optimum conditions prior to compaction and water shall be added, as necessary, at the direction of the ENGINEER. Compaction of void-filled riprap shall be reviewed and approved by the ENGINEER.

11. Where indicated on the DRAWINGS, a surface layer of 4 to 6 inches moist topsoil shall be placed over the void-filled riprap. The topsoil surface layer shall be compacted to approximately 85% of maximum density and within two percentage points of optimum moisture in accordance with ASTM D698. Topsoil shall be added to any areas that settle.

12. CONTRACTOR shall install a test section of at least 100 square feet of void-filled riprap for the review and approval of the ENGINEER prior to installation of the remaining void filled-riprap.

13. Elevation tolerance for the void-filled riprap shall be 0.10 feet. Thickness of void-filled riprap shall be no less than thickness shown and no more than 2-inches greater than the thickness shown.

E. FEATURE BOULDERS

1. Feature Boulders serve an aesthetic function and as such shall be placed and rotated into final position as directed by ENGINEER in order to achieve the desired result.

3.03 REJECTION OF WORK AND MATERIALS:

A. ENGINEER will reject placed riprap, boulders, soil riprap and bedding that do not conform to this section. CONTRACTOR shall immediately remove and re-lay the riprap, boulders, soil riprap, void-filled riprap, and bedding to conform to SPECIFICATIONS.

B. Riprap, boulders, soil riprap, void-filled riprap and bedding that do not conform to this section shall be rejected, whether delivered to the job site or placed.

C. Rejected riprap, boulders, soil riprap and bedding shall be removed from the PROJECT site by CONTRACTOR at CONTRACTOR's expense.

END OF SECTION