STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
SUPPLEMENTAL SPECIFICATION 862
ROCKFALL PROTECTION
January 20, 2012

862.01 Description
This work consists of providing rockfall protection on an existing rock slope. The rockfall protection may consist of scaling, trim blasting, furnishing and installing a slope drape, or a combination of these.

Select the scaling methods, the trim blasting methods; and the slope drape and anchor installation methods to obtain the required results.

862.02 Materials. Furnish materials conforming to:

Steel components, including anchors and clamps ......ASTM A36
Bolts, nuts, and washers..............................................................711.09

Furnish wire rope, cable net if required, and support ropes that are galvanized in conformance with Federal Specification RR-W-410F. For all other steel components that are not manufactured from zinc-coated wire, galvanize according to 711.02.

Furnish materials that are labeled by the manufacturer so that they can be identified on the manufacturer’s working drawings.

A. Wire Mesh. Furnish a double-twist, 8 × 10 hexagonal type wire mesh that is manufactured from either zinc-coated steel wire conforming to ASTM A641, Class 3 coating, soft temper, or from Zn-5Al-MM-coated steel wire conforming to ASTM A856, Class 3 coating, soft temper. Mesh openings for 8 × 10 type are nominally 3.25 in × 4.5 in (83 mm × 114 mm). Use a wire with a minimum nominal diameter of 0.120 inch (US Steel Wire Gage No. 11, 3.05 mm) and a minimum tensile strength of 60,000 pounds per square inch (414 MPa), as tested according to ASTM A370, to manufacture the mesh. Include the zinc when calculating the tensile area. Furnish locking clips, lacing wire, and fasteners (hog rings) conforming to the above
requirements except the minimum nominal diameter is 0.148 inch (US Steel Wire Gage No. 9, 3.80 mm).

B. Cable Net. Furnish cable net consisting of individual square cable net panels joined along their edges. Furnish cable net panels composed of woven wire ropes with a maximum opening size of 12 in × 12 in (305 mm × 305 mm). Securely fasten wire ropes where they cross using a clip strong enough to resist slipping or breaking when subject to the loads generated by the design conditions.

Use a galvanized wire rope with a minimum diameter of 5/16 inch (7.9 mm) and a minimum breaking strength of 9,000 pounds (40 kN) to manufacture the cable net. Use the same wire rope to lace the cable net panels together.

C. Tecco Rockfall Drape. In place of wire mesh with cable net, the Contractor may furnish and install Tecco Rockfall Drape from Geobrugg as an alternative (Geobrugg North America, LLC, 551 W. Cordova Road, PMB 730, Santa Fe, NM, 87505). Furnish Tecco Rockfall Drape manufactured with 0.157 inch (4 mm) diameter wire.

D. Top Horizontal Support Wire Rope. The top of the slope drape is secured to a top horizontal support wire rope. For the wire rope used to support wire mesh, furnish a galvanized wire rope with a minimum diameter of 0.5 inch (12.7 mm), and a minimum breaking strength of 25,000 pounds (111 kN). For the wire rope used to support cable net, furnish a galvanized wire rope with a minimum diameter of 0.75 inch (19 mm), and a minimum breaking strength of 50,000 pounds (222 kN). Furnish additional wire rope meeting these requirements to use as tag lines to connect the perimeter rope to the anchors.

E. Anchors. Furnish either steel bolt or wire rope anchor types. For steel bolt anchors, furnish a 1 inch (25 mm) diameter, galvanized, continuously threaded or deformed steel bar conforming to ASTM A615, Grade 75, with a minimum ultimate strength of 79,000 lbs (351.4 kN). For wire rope anchors, furnish a galvanized 0.75 inch (19 mm) wire rope with a minimum breaking strength of 50,000 pounds (222 kN). Furnish centralizers fabricated from Schedule 40 PVC plastic pipe or tube, steel or other material not detrimental to the anchor. Do not use wood.

For soil anchors, furnish concrete conforming to C&MS 499, Class F, or grout conforming to the requirements for rock anchors.

For rock anchors furnish grout consisting of a neat cement or sand/cement mixture. Furnish Type I, Type II, Type III, or Type IV cement conforming to ASTM C150 for the grout. Expansive admixtures may be used. Admixtures which control bleed or retard set may be used if approved by the Engineer. Furnish grout with a minimum 3-day compressive strength of 1500 psi (10.5 MPa) and a minimum 28-day compressive strength of 3000 psi (21 MPa) per AASHTO T106/ASTM C109.

If using a steel bolt anchor, furnish a 0.375 inch (9.5 mm) thick, galvanized, 6-inch square or round mild steel bearing plate. The plate must have a rounded edge on the side in contact with mesh wire and/or anchor cable. Furnish a galvanized flat washer and hex nut torqued to 100 ft-lbs.
Furnish wire rope clips compatible with the cable sizes shown in the plans, with drop forged carbon steel bases and heavy-duty hexagonal type nuts. Use thimbles and wire rope clips in accordance with the manufacturer’s recommendations for size, number, spacing and torque.

862.03 Qualifications. Before beginning work, submit a list of proposed personnel and documentation verifying that they meet the qualification requirements listed below. Include a list of employer's names and telephone numbers, location and dates of previous slope drape projects, and the extent of work performed. This information must be verifiable. Slope drape work is defined as all activities related to the slope drape installation, including furnishing, fabricating, drilling, installing, and testing. Allow 14 days for the review of the documentation. Obtain approval of all personnel before beginning construction.

A. Slope Drape Site Supervisor. The Slope Drape Site Supervisor must be present at the job site at all times during the performance of slope drape work. Employ a Slope Drape Site Supervisor with at least two years of construction experience in the installation of slope drapes and who has supervised the successful installation of at least ten slope drapes.

B. Drill Operators. Employ Drill Operators who have successfully installed at least 50 anchors.

C. Scaling Foreman and Scaling Crew. Provide a scaling crew with one Scaling Foreman present at all times when scaling is performed. A Scaling Crew consists of three qualified scalers, one of which may also be the Scaling Foreman. Employ a Scaling Foreman and Scaling Crew who have at least two years of demonstrated experience in rock scaling in similar capacities.

D. Mechanical Scaling Operator. Provide one or more persons to operate the mechanical scaling equipment selected. Employ operators who have successfully operated the selected equipment for at least one year.

862.04 Design Requirements. Design the slope drape system to control falling rocks of the sizes specified in the plans. Also design the slope drape system to prevent rocks with a minimum dimension specified in the plans from passing through. Design the slope drape to resist the applied loads without causing distress or damage to the connecting elements. Include calculations that demonstrate these requirements in the Slope Drape Installation Plan.

Use a slope drape design that has demonstrated satisfactory performance under similar conditions. Provide evidence of the satisfactory performance to the Engineer upon request.

Use standard components to the greatest extent practical and minimize custom components in the slope drape design. Design the slope drape to require minimal maintenance when subjected to the design conditions. Design a slope drape that is resistant to corrosion, UV degradation, and thermal deterioration. Design a slope drape that can be pulled outward at the bottom for rock removal.
862.05 Submittals.

A. Scaling Work Plan. Submit a written work plan for the rock slope scaling to the Engineer for acceptance at least ten days before beginning work. Submit five copies. Include the following information:

1. Proposed construction sequence and schedule.
2. Type and quantity of equipment.
3. Number of scaling crews required for the project.
4. Methods of mechanical scaling (if any).
5. Removal and disposal plan for materials generated from the scaling and slope crest preparation.
6. Contractor’s protection plan to protect personnel, facilities, and other structures from injury or damage caused by scaling activities.

B. Slope Drape Installation Plan. Submit a written installation plan for the slope drape to the Engineer for acceptance at least ten days before beginning work. Submit five copies and a CD-ROM with the design in electronic format. Include the following information:

1. Complete working drawings and engineering calculations, prepared, signed, sealed and dated by a Registered Engineer.
2. Proposed construction sequence and schedule.
3. One sample of the proposed type of slope drape fabric (mesh types), ground anchor, and hardware (bearing nuts and plates) from the normal stock of the supplier. With the samples, include certified mill reports indicating tensile yield point and elongation results of the ground anchors, and the tensile and punching tests of the cable net and wire mesh.
4. Proposed anchor type and spacing.
5. Proposed anchor drilling methods and equipment, including drill hole diameter and length proposed to achieve the required pullout resistance.
6. Proposed grout design, including the following:
   a. Manufacturer’s certified test results of set time, shelf life, and compressive strength.
   b. Type of Portland cement.
   c. Aggregate source and gradation.
   d. Proportions of mix by weight and water-cement ratio.
   e. Manufacturer, brand name and technical literature for proposed admixtures.
   f. Results of compressive strength tests performed according to AASHTO T106/ASTM C109 and completed no more than one year before the start of grouting. Use an AASHTO accredited independent testing lab to verify the specified minimum 3 and 28-day grout compressive strengths.
7. Proposed anchor grout placement procedures and equipment.
8. Proposed anchor testing methods and equipment setup.
9. Identification number and certified calibration records for each test jack, pressure gauge and load cell to be used.
10. The manufacturer’s recommended maintenance program for the slope drape.
Allow at least ten days for review. Do not begin work until the submittals have been accepted by the Engineer. Any changes or deviations from the accepted submittals must be resubmitted. The Engineer will not grant an extension of time because of incomplete submittals.

862.06 Preconstruction Meeting. Meet with the Engineer before beginning rockfall protection work to clarify construction requirements, coordinate schedules and activities, and identify the division of responsibilities between the Contractor and the subcontractors. Have the slope drape subcontractor and scaling subcontractor attend the meeting.

862.07 Construction. Safety of the work is the responsibility of the Contractor. Perform the work in a manner that minimizes the exposure of the public, construction personnel, and equipment to hazardous and potentially hazardous conditions.

Preserve vegetation on the slopes wherever possible. Remove or prune vegetation only where anchors are required, where the vegetation reduces the effectiveness of the slope drape, or when directed by the Engineer. Where necessary, cut stumps flush with the ground surface, but leave root systems in place. Do not disturb vegetation more than 50 feet (15 m) upslope of the proposed limits of the slope drape. Dispose of removed vegetation according to 201.02 and 105.17.

A. Scaling. Perform scaling of the slope face by removing potentially unstable boulders, rocks, and trees to reduce the rockfall hazard and minimize required maintenance after construction. Perform scaling at the direction of the Engineer. Scaling may consist of hand or mechanical methods; including, but not limited to, pry bars, air bladders, air wands, pneumatic or hydraulic jacks, air bags, pneumatic drills or jack hammers, slusher, excavator, or hoe ram. Begin scaling at the top of the slope and proceed downward. Either stabilize or scale all loose rock and other unstable materials larger than one cubic foot (0.03 m$^3$) in volume to the satisfaction of the Engineer. Obtain approval from the Engineer before using power equipment to perform scaling. Remove and dispose of all waste material from between the bottom of the slope and the edge of the roadway. Remove overburden material above the rock face to round the top of the slope before scaling work is complete.

Protect personnel, the public, adjacent properties, structures, utilities, and roadway from injury or damage caused by scaling activities. The Contractor’s scaling work plan must be in place before beginning the scaling work. Any injuries or damages caused by scaling are the responsibility of the Contractor.

B. Trim Blasting. The Contractor may use trim blasting to remove large blocks or overhangs which are difficult to dislodge by hand or mechanical methods. Perform trim blasting according to all applicable Federal, State, and local laws and regulations; the provisions of 107.09; and the following requirements.

1. Drill blast holes 3.0 inches (75 mm) in diameter or less, and spaced 36 inches (900 mm) apart or less.

2. Use detonating cord as the primary explosive charge in all blast holes. The Contractor may also use small-diameter explosive cartridges only if they occupy 10 percent of the blast hole length or less.
3. Do not use a delay between blast holes.

4. Do not use more than 3 pounds (1.3 kg) of explosives per blast hole and not more than 200 pounds (90 kg) of explosives per blast.

5. Before firing any blast in areas where flying rock may result in personal injury or unacceptable damage to property, place blasting mats or wire mesh to prevent flyrock.

6. Follow all safety procedures described in 208.08.

The Contractor may use non-explosive materials, such as expanding foams, instead of explosives for trim blasting.

C. Anchors. Design the anchor type, dimensions, and spacing to support the loads determined from the slope drape design. Do not exceed an anchor spacing of 25 feet (7.6 m) for a cable net slope drape or 50 feet (15.2 m) for a wire mesh slope drape. Determine the anchor length to meet the requirements of the pullout test. Do not use an anchor length less than 10 feet (3.05 m). Ground conditions may require anchors that are longer than the minimum length. Where the lengths of the anchors vary, the Engineer will permit the use of threaded couplers to extend the anchor tendon, or other methods recommended by the manufacturer.

Do not use water during drilling. Provide a uniform hole diameter for the entire length of the hole unless otherwise approved by the Engineer. The minimum hole diameter is shown on the plans. Drill holes within five degrees of the orientations and inclinations shown on the plans. Clean the hole before installing the anchor.

Place at least two centralizers on each anchor to position the tendon within 1 inch (25 mm) of the center of the hole. Place the centralizers within 2 feet (0.6 m) of the top and bottom of the hole. Securely attach the centralizers to the anchor tendon.

Test at least 25 percent of the anchors and at least one anchor of each type of anchor, soil, and rock. The Engineer will select the location of each test anchor. Perform each test in the presence of the Engineer. Each pullout test consists of incrementally loading the anchor assembly to the maximum test load or to failure, whichever occurs first. Failure is defined as when the movement of the anchor continues without an increase in the load or when the anchor has displaced 2 inches (50 mm). If more than 20 percent of the tested anchors fail, increase the number of tested anchors to 50 percent of the total. Replace all failed anchors and retest them at no additional cost to the Department.

Apply the test load by jacking against a temporary yoke or load frame. No part of the yoke or load frame may bear within 3 feet (0.9 m) of the anchor. Measure the applied test load using either a calibrated pressure gage with graduations no greater than 100 psi (0.7 MPa) or a calibrated load cell. Calibrate the pressure gage and the hydraulic jack as a unit and provide the certified calibration chart. Calibrate against a test machine whose calibration is traceable to the National Institute of Standards and Technology (NIST). Ensure the calibration is done to an accuracy of 2 percent and at least one year before shipment to the project. Measure movement of the anchor using dial gages that have an accuracy of 0.001 inch (0.03 mm). Measure movement relative to a fixed reference point that is at least 3 feet (0.9 m) from the anchor and yoke or load frame. Record all measurements, including the failure load if failure occurs.
Load each anchor in the following sequence (ADL = allowable design load):

<table>
<thead>
<tr>
<th>Load</th>
<th>Hold Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL (0.05 ADL max.)</td>
<td>Until Stable</td>
</tr>
<tr>
<td>0.25 ADL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>0.50 ADL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.00 ADL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.50 ADL</td>
<td>Until Stable</td>
</tr>
</tbody>
</table>

The alignment load (AL) is the minimum load required to align the testing equipment and should not exceed 5 percent of the ADL. Dial gages should be set to “zero” after the alignment load has been applied.

Unload the anchor after completion of the test.

**D. Slope Drape.** Install the slope drape according to the manufacturer’s recommendations when they do not conflict with the plans or specifications.

Have a representative from the slope drape manufacturer on site for at least one day at the beginning of the slope drape installation work to train and provide guidance on the installation of the slope drape. Have the slope drape manufacturer inspect the installed drape and submit to the Department a statement declaring that the slope drape was installed according to the manufacturer's requirements and recommendations.

Connect the wire mesh and cable net together before placing the slope drape on the slope. Securely fasten the wire mesh to each cable net panel and to the lacing. Fasten the wire mesh and cable net so they are flush without any gaps that exceed 4 inches (100 mm). No discontinuities in the wire mesh are allowed. Attach the mesh every 12 inches (305 mm), horizontally and vertically, using galvanized steel fasteners, approximately 0.148 inch in diameter (US steel wire gauge 9, 0.377 mm), after coating. Use fasteners that have a connection strength equal to or greater than the strength of the mesh.

Connect the cable net panels using 5/16 inch (7.9 mm) lacing cable (seam rope) through each square of the net. Loop the end of the seam rope back on itself and secure it with two 5/16 inch (7.9 mm) rope clips.

Place the wire mesh between the slope and the cable net. Place the slope drape so it follows the contours of the slope and minimizes gaps and large spaces between the drape and the ground surface. Secure the top of the slope drape to a top horizontal support wire rope. Position the top support rope at least 5 feet (1.5 m) above the top of the cut slope. Use top horizontal support ropes that are no longer than 100 feet (30.5 m) each. Interior horizontal support ropes are not required.

Connect wire ropes (tag lines) to the end of the anchors and secure the ends of the wire rope with wire rope clips. Install the wire rope clips according to the manufacturer’s recommendations.

**862.08 Method of Measurement.** The Department will measure Scaling by the number of crew hours accepted. The Department will not measure idle time or stand-by time. The
Department will measure the slope drape by the number of square yards of surface area of slope drape installed. The Department will not measure the area of drape used in any overlaps. Anchors and anchor tests are incidental to the slope drape and will not be measured separately.

The Department will measure trim blasting by the number of square feet (square meters) along the face of the rock where material was dislodged and removed by the blast. The Department will calculate the area for trim blasting by multiplying the maximum height, measured along the slope of the drill hole, by the maximum horizontal width.

\textbf{862.09 Basis of Payment.} The Department will pay for accepted quantities at the contract price as follows:

\begin{tabular}{|c|c|c|}
\hline
\textbf{Item} & \textbf{Unit} & \textbf{Description} \\
\hline
862 & Hour & Scaling \\
862 & Square Foot (Square Meter) & Trim Blasting \\
862 & Square Yard (Square Meter) & Slope Drape \\
\hline
\end{tabular}
**Designer Note:**
Consult with the Office of Geotechnical Engineering when considering the use of Rockfall Protection.

This work will produce rockfall, and will require a substantial laydown area during construction. Therefore, it is recommended that the road below this work be closed. At least two lanes of roadway should be available when performing this work. If a road closure is not possible, then a barrier or earthen berm should be placed to separate traffic from the accumulation of debris.

Construction limits are defined primarily on a visual and geometric basis. Wherever the slope visually appears to be susceptible to producing rockfall, or where the geometry of the slope is adverse, rockfall protection should be considered. The top of the slope drape should extend at least five feet beyond the crest of the slope (over more durable bedrock) and at least ten feet over weatherable bedrock or soil. The bottom of the slope drape should be about five feet above the bottom of the slope/ditch. Determine this minimum distance, and the minimum distance to the anchors, based on anticipated weathering advance of the underlying material. Anchors should be installed beyond anticipated areas of instability.

Scaling is recommended as part of all rockfall protection. Estimate the amount of time for scaling based on one hour of scaling for every 200 square feet of slope.

On slopes where rock overhangs and large boulders are present, trim blasting may be necessary in addition to hand and mechanical scaling. Estimate the area of trim blasting based on 100 square feet for every 2000 square feet of slope.

Determine the rockfall protection material, either wire mesh, high strength wire mesh, or cable net and wire mesh, based on the expected block sizes. Identify the design block size in the plans from which the Contractor will design the slope drape and anchor spacings and capacity. Determine the maximum anchor spacings and a minimum anchor capacity of 20 kips. For these and all parameters, consult the document, *Design Guidelines for Wire Mesh/Cable Net Slope Protection* (Muhunthan, B., S. Shu, N. Sasiharan, O. Hattamleh, 2005, Olympia, Wash: Washington State Dept. of Transportation).

Consider adding 10% to the estimated slope drape area to account for surface irregularities along the rock slope. Consider including erosion control mats and seeding at the brow of all slopes and on slopes 1:1 and flatter for erosion control.

Consider drainage above the drape for long overburden slopes. Consider drainage elsewhere on the slope where free water is evident.

Plan insert sheets are required and can be obtained from the Office of Geotechnical Engineering. Show a representative slope.