897. 13 DPWH
03-19-2013

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

MAR 19 2013

DEPARTMENT ORDER No. 33 Series of 2013 03.19.13	**SUBJECT :**	**DPWH Generic Specification for Rockfall Protection Systems, Item 522**

In line with the mandate of the Department of providing effective standard specifications in the implementation of various infrastructure projects and in view of the need for setting a standard specification for rockfall protection systems, the attached **DPWH Generic Specification for Rockfall Protection Systems, Item 522** is hereby prescribed, for the guidance and compliance of all concerned.

This specification shall form part of the revised edition of the DPWH Standard Specifications (Volume II – Highways, Bridges and Airports).

This Order shall take effect immediately.

ROGELIO L. SINGSON
Secretary

Department of Public Works and Highways
Office of the Secretary
WIN3U00739

DPWH GENERIC SPECIFICATION FOR

ITEM 522 – ROCKFALL PROTECTION SYSTEMS

522.1 Description

This Item shall consist of furnishing and installing rockfall protection systems in accordance with this Specification and to the details shown on the Plans, or as required by the Engineer.

522.2 General

522.2.1 Function

The rockfall protection systems shall be used to keep rocks in place and/or stop what comes loose from doing damage and provide safety to infrastructures and its users.

522.2.2 Design

Rockfall protection systems must consider rock and soil types, the angle of the slope and conditions on top, and the toe of the affected area. Installation problems, which can be complicated by existing vegetation, access, aesthetics, and environmental issues or regulations, shall fall to the constructor responsible for installing rockfall protection measures.

The contractor shall supply design computations, details, dimensions, quantities, and cross sections necessary to construct the system.

The design calculations shall include:

a. Statement of all assumptions made and copies of all references used in the calculations.

b. Analyses demonstrating compliance with all applicable earth and water surcharges, seismic, or other loads.

c. Analyses or studies demonstrating durability and corrosion resistance of the system for the proposed location and environment. The designer shall provide all corrosion protection devices necessary for the system to have a minimum service life of 10 years in the proposed location and environment.

522.2.3 Types of Rockfall Protection Systems

There are 2 types of rockfall protection systems, namely "active systems" and "passive systems". A key distinction shall be made between active and passive system so that the most suited type of protection is selected.

522.2.3.1 Active Systems

Active systems are those that act to prevent excessive movement of a rock detachment once it has occurred. It shall stabilize the rock mass surface layer containing potentially unstable rocks.

Types of active systems are shown in Table 522.1.

Table 522.1 - Types of Active System

	Type		Application
a.	Cable - Reinforced Wire Mesh	-	It prevents the possibility of rocks detaching from the slope and improve the slope surface stability.
b.	High Strength Cable Reinforced Mesh Panel	-	It is commonly used for high stiffness drapery.

522.2.3.2 Passive Systems

Passive systems are those which do not affect the process of the rock detachment, but rather focus on containing and intercepting falling and sliding debris. Types of passive systems are shown in Table 522.2.

Table 522.2 - Types of Passive System

	Type		Application
a.	Simple Drapery Systems	-	Simple mesh draperies are usually installed along rock slopes whose surface can break down into fragments not smaller than the opening of the mesh and generally not larger than 0.5 m in diameter.
b.	Rockfall Barriers	-	Rockfall barriers (catch fences) of variable geometry are made of a complex system of steel cable panels or ring net panels, steel cables connected to structural elements, posts, energy dissipater devices and anchors. It dissipates energy with system deformation, thus enabling the system to withstand energies ranging from 500 kJ to 8,000 kJ.
c.	Reinforced Erosion Control Mat		Simple mesh draperies with three dimensional polymer material that are usually installed along rock slopes with soil whose surface can break down into fragments not smaller than the opening of the mesh generally not larger than 0.5 m in diameter. It strongly promotes vegetation for permanent erosion protection.

Note: kJ – Kilojoules

522.3 Material Requirements

522.3.1 Rockfall Netting

Rockfall netting shall be made from flexible steel woven wire mesh coated with zinc and/or zinc alloy or a combination of zinc and plastic coating. The mesh can be used in combination with steel cables interwoven in the mesh during the production as a composite material.

The wire mesh shall be dimensionally stable and able to retain its geometry under manufacture, transport, and installation.

The contractor shall submit a manufacturer's certification that the wire mesh supplied met the criteria set when the wire mesh was approved, measured in full accordance with all test methods and as required in this specification. In case of dispute over validity of values, the

Engineer shall require the contractor to supply data from an approved laboratory to support the values submitted, at the contractor's cost.

522.3.1.1 Steel Wire

Type 1:

Steel wires used in the fabrication of the rockfall netting and in the wiring operations during construction shall conform to ASTM A 641. Wire diameters' tolerances shall be in accordance with the values in Table 522.3.

Table 522.3 Wire Diameters and Tolerances

Wire Diameter (mm)	Wire Use	Tolerance (mm)
2.20	Lacing wire/ Wire mesh (Body wire)	±0.10
2.70	Wire mesh (Body wire)/Selvedge wire (Simple Drapery Systems)	±0.10
3.05	Wire mesh (Body wire) (Cable Reinforced Wire Mesh)	±0.10
3.40	Selvedge wire	±0.10

Type 2:

Standard low carbon steel wires and high tensile steel wires used in the fabrication of the meshes and nettings shall conform to ASTM 370-97.

522.3.1.2 Zinc Coating/Zinc Alloy

Type 1:

Steel wires used in the fabrication of the rockfall netting and in the wiring operations during construction shall be galvanized and shall meet or exceed ASTM A 641 for zinc coating and ASTM 856/A for zinc alloy (95% zinc + 5% Al) coating. The minimum amount of the zinc or zinc alloy coating shall conform as shown in Table 522.4a.

Table 522.4a Zinc Coating Criteria

Wire Diameter (mm)	Zinc Coating (g/m^2) (min.) Class A	Zinc Alloy (g/m^2) (min.) Class A
2.20	214	214
2.70	244	244
3.05	259	259
3.40	259	259

The adhesion of zinc coating to the wire is such that when the wire is wrapped six times a four wire diameter size mandrel, it shall not flake nor crack to such an extent that any zinc can be removed by rubbing with bare fingers.

Type 2:

Steel wires used in the fabrication of the rockfall netting and in the wiring operations during construction shall be galvanized and shall meet or exceed ASTM A 641 for zinc coating and ASTM B 750 for zinc alloy (95% zinc + 5% Al) coating. The minimum amount of the zinc or zinc alloy coating shall conform as shown in Table 522.4b.

Table 522.4b Zinc Coating Criteria

Wire Diameter (mm)	Zinc Coating (g/m^2) (min.) Class A	Zinc Alloy (g/m^2) (min.) Class B
1.85 – 2.15	215	115
2.15 – 2.50	230	125
2.50 – 2.80	245	125
2.80 – 3.20	255	135
3.20 – 3.80	265	135
3.80 – 4.40	275	135

The adhesion of zinc coating to the wire is such that when the wire is wrapped six times a four wire diameter size mandrel, it shall not flake nor crack to such an extent that any zinc can be removed by rubbing with bare fingers.

522.3.1.3 Polyvinyl Chloride (PVC) Coating

Steel wires used in the fabrication of PVC coated rockfall netting and in the wiring operations during construction shall have extruded onto it a coating of polyvinyl chloride (PVC) or other materials having superior characteristics than PVC as otherwise approved.

The coating shall be 0.50 mm average thickness with a tolerance of ±0.05 mm, and nowhere shall be less than 0.40 mm thick. The PVC shall be gray in color.

It shall be capable of resisting deleterious effects of natural weather exposure, immersion in salt water, and shall not show any material difference in its initial characteristics such as the following:

	Characteristics		Value	Governing Specifications
a.	Specific Gravity	-	1.30 to 1.35	ASTM D 792
b.	Durometer Hardness	-	50 to 60	ASTM D 2240
c.	Volatile Loss (max.)	-	5% at 105^0C for 24 hours	ASTM D 2287 E2
	c.1. Residual ashes	-	less than 2%	ASTM D 2124-62T

d.	Tensile Strength (min.)	-	210 kg/m^2	ASTM D 412
e.	Elongation	-	200% to 280%	ASTM D 412
f.	Modulus of Elasticity at 100% Elongation (min.)	-	190 kg/cm^2	ASTM D 412
g.	Resistance to Abrasion (Loss in volume)	-	less than 0.30 cm^3	ASTM D 1242
h.	Creeping Corrosion	-	Maximum penetration of corrosion of the wire core from a square cut end shall not be greater than 25 mm when the specimen has been immersed for 2000 hrs. in a 50% solution of hydrochloric acid (HCL 12BE)	

PVC coating shall also be subjected to deterioration tests as described below:

	Deterioration Tests		**Period of Tests**	**Governing Specifications**
a.	Salt Spray Test	-	1500 hrs.	ASTM B 117
b.	Exposure to Ultraviolet Light	-	2000 hrs. at 63°C	ASTM D 1499 and ASTM G 23(93) apparatus type E
c.	Exposure at High Temperature	-	240 hrs. at 105°C	ASTM D 1203 and ASTM D 2287 (E2)
d.	Brittleness Temperature	-	Max. 9°C or lower temperature	ASTM D 746

Variation of the initial characteristics may be allowed, as specified hereunder, when the specimen is submitted to deterioration tests described above. After such tests, the PVC coating shall exhibit the following properties:

Properties			
a.	Appearance	-	The vinyl coating shall not crack, blister or split and shall not show any marked change in color
b.	Specific Gravity	-	Shall not show change higher than 6% of its initial value
c.	Durometer Hardness	-	Shall not show change higher than 10% of its initial value
d.	Tensile Strength	-	Shall not show change higher than 25% of its initial value
e.	Elongation	-	Shall not show change higher than 25% of its initial value
f.	Resistance to Abrasion	-	Shall not show change higher than 10% of its initial value

522.3.1.4 Wire Mesh Requirements

Type 1:

Wire mesh shall be mechanically prefabricated to become a uniform hexagonal woven mesh wherein the joints are formed by twisting each pair of wires through three half-turns (commonly referred to as "double twisted"), in such a manner that unraveling is prevented.

For the double twist mesh, the tensile strength of the mesh shall be as shown in the Table 522.5a.

Table 522.5aTensile Strength Double Twisted Mesh

Mesh Type	Wire Diameter (mm)	Minimum Nominal Mesh Tensile Strength (kN/m)
8 x 10	2.70	51
8 x 10	3.05	61

For the high strength cable reinforced mesh panel, the tensile strength of the mesh shall be as shown in the table 522.5b.

Table 522.5bTensile Strength of High Strength Cable Reinforced Mesh

High Strength Steel Cable – Reinforced Wire Mesh Composite Coating Type	Composite Type with Longitudinal Cable Spacing (cm)	Minimum Nominal Mesh Tensile Strength (kN/m)
With plastic coating	30	120
	50	90
	100	70
With zinc alloy coating	30	177
	50	120
	100	80

Type 2:

Wire mesh shall be mechanically fabricated into a rhomboid shaped mesh. The ends of the spirals shall be made into knots which can transfer the full strength from one panel to the other. The tensile strength of the wire is minimum 1770 N/mm^2.

Wire diameters shall be 2.00mm to 4.00mm. Certain other wire diameters may be utilized if the contract drawings allow alternative sizes and are approved by the Engineer.

522.3.1.5 Wire Mesh Dimensions

Type 1:

The dimensions and their corresponding tolerances are listed in Table 522.5a in accordance with ASTM A 975.

Table 522.5a Wire Mesh Dimensions and Tolerances

M (mm)	D (mm)	Tolerance (%)
83	114	±10

Note: M – Nominal mesh size which is measured at right angles between two nominally parallel twisted wires
D – Distance measured at right angles between two nominally parallel untwisted wires

Type 2:

The dimensions and their corresponding tolerances are listed in the following tables.

Table 522.5bHigh Tensile Wire Mesh Dimensions and Tolerances

D (mm)	d/ X x Y (mm)	Tolerances (%)	Tensile Strength (kN/m)	Shear strength at one anchor with anchor plate (kN)	Deformation at break load (%)
65	3/ 83 x 143	±3	150	30	7.0
80	2/ 102 x 177	±3	150	30	7.5
80	4/102 x 177	±3	190	45	6.5

Note: D – mesh width incircle diameter
d/ X x Y:d wire diameter X/Y – rhomboid shape diagonal masses

Table 522.5cHigh Tensile Spiral Rope Net Technical Property

Types (mm)	D/ X x Y (mm)	Tensile Strength of Mesh (kN/m)	Shear strength at one anchor (kN)	Deformation at break load (%)
6.5 (standard)	275/ 390 x 400	80	45	18
8.6 (heavy duty)	230/ 292 x 500	220	60	7

Note: D – mesh width incircle diameter
d/ X x Y:d wire diameter X/Y – rhomboid shape diagonal masses

522.3.1.6 Selvedge/Edge Wire

The cut edges of wire mesh used in the construction of rockfall netting except the bottom edges of end netting shall be tightly selvedged with a wire having a diameter as shown in Table 522.6.

Table 522.6 Selvedge/Edge Wire Diameter

WireMesh Diameter (mm)	Selvedge/Edge Wire Diameter (mm)
2.70	3.40
3.05	3.40

522.3.1.7 Lacing Wire

Lacing wire shall be made of wire having the same coating material as the wire mesh. Lacing wire shall be supplied in the quantity of 3% of the total rockfall netting weight for adequate wire consumption.

522.3.2 Rockfall Barrier

System components of rockfall barrier shall be approved by the Engineer in conformance to the requirements of the supplier based on the desired resistance. Minimum rockfall barrier resistance shall be 500 KJ.

The performance of barrier shall be proved by full-scale crash test, carried out in accordance with ETAG 027 "Guideline for European Technical Approval of Falling Rock Protection Kits." The tests have to ensure the functionality of the structure for both levels of energy provided by ETAG 027 which are SEL (Service Energy Level) and MEL (Maximum Energy Level).

Referring to the terms and definitions adopted by ETAG 027, the barrier shall ensure minimum levels of performance with regard to residual height and maximum elongation as specified here below. The rockfall barrier shall satisfy the following technical and performance characteristics:

- pass n. 1 impact test with an energy greater or equal to 100% (MEL) of the nominal resistance class, stopping the block without any substantial damage to the main components of the kit, with a resulting residual height not lower than the values shown in the following table;

- pass n. 2 impact tests carried out in sequence, without any maintenance between the two launches, with an energy greater or equal to 1/3 (SEL) of the nominal resistance class, stopping the block without any substantial damage to the main components of the kit, with a resulting height not lower than 70% of the nominal height;

- the maximum elongation (in dynamic range) during the MEL and SEL tests shall not be higher than the values indicated in the following Table.

Barrier Energy Classification	500 kJ	1000 kJ	2000 kJ	3000 kJ	5000 kJ	8000 kJ
Minimum MEL residual height (%)	70% with tolerance of -2%	70% with tolerance of -2%	70% with tolerance of -2%	70% with tolerance of -2%	70% with tolerance of -2%	70% with tolerance of -2%
Maximum Elongation (m)	3.70m	4.45m	5.25m	6.05m	6.5m	8.5m

The barrier shall be accompanied by a certificate of full-scale crash test issued by the manufacturer in which shall contain the following information:

- Description of the components in the rockfall barrier system
- Test data of the full scale test for both SEL and MEL tests which shall contain but not limited to the following information;
  i) Speed of impact
  ii) Kinetic energy of impact
  iii) Maximum barrier elongation
  iv) Residual height of barrier after impact
  v) Record of any anomalies or defect of the barriers during impact

Further, the following documents shall be provided:
- installation manual comprising illustrative drawings;
- maintenance manual.

522.3.3 Miscellaneous Materials

All miscellaneous material such as clips, ropes/cables, etc. shall be supplied by the manufacturer with the system.

All miscellaneous material associated with the rockfall protection system shall be hot-dipped galvanized per AASHTO M11 (ASTM A 123/A123M) or equivalent.

Screw bolts and nuts shall be galvanized and conform to the requirements of AASHTO M 164 (ASTM A 325) or its equivalent.

522.4 Construction Requirements

522.4.1 Rockfall Netting

522.4.1.1 Material Delivery

Double twisted mesh rolls shall be supplied in roll form from the production facility in lengths of 25 m and 50 m. The rolls shall be individually strapped at the factory for easy handling and transporting.

522.4.1.2 Slope Preparation and Placement

Prior to installation of rockfall netting, loose rock particles and vegetation shall be removed from face of the wall to be blanketed. The netting shall be placed over the surface to be protected by lifting the rolls to the top of the face and then unrolling them. The netting shall be properly fixed using spike plates and soil and/or rock nails/anchors and tied to the wall. Final fastening shall be at the top, foot and if necessary the face.

522.4.1.3 Fixing Procedure

The distribution of the top anchorages shall be calculated on the basis of the maximum load that may occur at each anchorage, bearing in mind the breaking strain of the double twisted mesh. It shall be preferable to link the individual anchorage with a steel rope which must be tied to the mesh.

The following alternatives may be considered when small amount of debris are expected to be collected at the toe:

- Leaving approximately 0.3 m opening at the foot of the net to facilitate removal of debris
- Close the net at the foot to contain loose material.

The bottom fixing shall allow for periodic removal of accumulated debris after which the netting must be anchored again.

On the rock face, the sheets of netting shall be securely and continuously laced together using binding wire of diameter equal to or greater than the wire used for the manufacture of the mesh. The rolls of rockfall netting shall be rolled into position as per the contract drawings. New rolls shall be placed in the same direction directly overlapping the adjacent roll such that the selvedge of both rolls can be laced together by hand. Alternatively, metal stakes of various sizes can be used.

Lacing shall commence by twisting the end of the lacing wire tightly around the two selvedges. It shall then pass round the two edges being joined using alternate single and double loops at 100 mm intervals. The lacing wire shall be securely tied off at the bottom of the roll. The end of the lacing wire shall be turned in facing towards the mesh at the completion of the lacing operation. Each loop shall be pulled tight to prevent the joint opening under load.

When necessary, the sheets of netting shall be close together to prevent fragments of rock from rolling off. In addition, suitable anchorages shall be provided at the rate of one anchor every 15 to 30 m^2 of covered area, or a cross - slope cable system, or with tensioned steel bolts installed at the top and down the slope if the mesh is designed to adhere to the contour of the slope.

522.4.2 Rockfall Barrier

522.4.2.1 Barrier Layout

As much as possible, rockfall barrier shall follow a straight horizontal line. The maximum height difference between two adjacent posts shall be 0.50 m measured along the post. Posts shall be installed at 10 m intervals. Upslope anchors shall be installed between two posts. Downslope anchors shall only be required if called for on the approved plans.

The prepared concrete base/foundation on which the base plate sits shall be level with the surrounding ground and not raised above the soil profile. In case of foundation on very loose soil, the base plate shall be provided with tubular clutch for steel micropile.

522.4.2.2 Bracing/Longitudinal Cables and Energy Dissipater Devices

The upper longitudinal cable shall be thread thru the fairlead at the top of each post. The lateral junction cable/lower longitudinal cable shall pass through the fairlead of the lateral base plate and then connected to the lateral anchor using clamps. Free ends of the lower longitudinal cable shall be connected to the lateral energy dissipater on both sides using clips.

522.4.2.3 Square Mesh Panels Installation (Main Mesh Panel)

The steel cable mesh panels shall be laced to the upper and the lower longitudinal cables, interlacing the cables through the edge of the panels (along horizontal sides). Adjacent panels shall be joined together along vertical edges using panel cables. The panels shall be connected to the end posts using lateral junction cables/longitudinal cables, which shall be interlaced with the edges of the mesh panel.

522.4.2.4 Hexagonal Wire Mesh Net Installation (Secondary Mesh Panel)

The double twisted hexagonal wire mesh shall be installed on the upslope side of the panel, and shall be fastened to the panels and the longitudinal cables.

522.5 Method of Measurement

The quantities to be paid for under this Item shall be the number of square meters (m^2) of rockfall netting installed and accepted, and the number of linear meters (lm) of rockfall barriers of the required resistance, including the necessary posts, supports and energy dissipater devices, anchorages, steel bolts, clips, ropes/cables erected/installed and accepted.

522.6 Basis of Payment

The quantities measured as determined in Section 522.5, Method of Measurement, shall be paid for at the contract unit price shown in the Bid Schedule which price and payment shall be full compensation for the necessary designs and for furnishing and installing/erecting rockfall protection systems, for excavation, backfilling and construction of foundation blocks, and for furnishing all labor, equipment, tools and incidentals necessary to complete the item.

Payment will be made under:

Pay Item Number	Description	Unit of Measurement
522 (1) 522 (2)	Rockfall Netting Rockfall Barrier	Square meter Linear meter