

Use of Ring Nets for Slope Protection for Rockfall: End-of-Construction Report

WA-RD 729.1

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GEOTECHNICAL REPORT

Use of Ring Nets for Slope Protection for Rockfall: End-of-Construction Report

FHWA Experimental Feature Study

C-7540, SR 28, Rock Island – Rock Slope Nettings

June 2009



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16. ABSTRACT The Washington State Department of Transportation (WSDOT) has used double-twisted hexagonal wire mesh and wire rope cable nets for several decades as slope protection to control rockfall initiating from slopes along state highways. Double-twisted hexagonal wire mesh has generally been applied to slopes with rock blocks less than 2 ft in size, while wire rope cable nets have been employed where larger blocks, typically up to 4-5 ft, are expected. In recent years, ring nets have been increasingly used for slope protection (drapery), mostly outside North America, to control large-sized rockfall. Because of the reported high strength of ring nets and the need to examine cost-competitive alternatives to cable nets, WSDOT proposed to evaluate ring nets for slope protection on a Federally-funded rockfall mitigation project. As outlined in the work plan submitted to FHWA, the study includes an evaluation of the ring net installation and an annual assessment of the performance for a 5-year period. This end-of-construction report documents the installation of the ring nets.		13. TYPE OF REPORT AND PERIOD COVERED End-of-Construction Report	
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INTRODUCTION

The Washington State Department of Transportation (WSDOT) has used double-twisted hexagonal wire mesh and wire rope cable nets for several decades as slope protection to control rockfall initiating from slopes along state highways. Double-twisted hexagonal wire mesh has generally been applied to slopes with rock blocks less than 2 ft in size, while wire rope cable nets have been employed where larger blocks, typically up to 4-5 ft, are expected. In recent years, ring nets have been increasingly used for slope protection (drapery), mostly outside North America, to control large-sized rockfall.

Because of the reported high strength of ring nets and the need to examine cost-competitive alternatives to cable nets, WSDOT proposed to evaluate ring nets for slope protection on a Federally-funded rockfall mitigation project. A study of ring nets was proposed to FHWA as an Experimental Feature in August 2007, which was accepted and approved by FHWA in September 2007. At the time the study was proposed and approved, only one manufacturer was producing ring nets that could meet Buy-America steel requirements. To compare attributes and performance of various ring nets from known manufacturers producing ring nets outside the US, a Buy-America steel waiver was concurrently sought from and granted by FHWA to use these ring nets from foreign manufacturers.

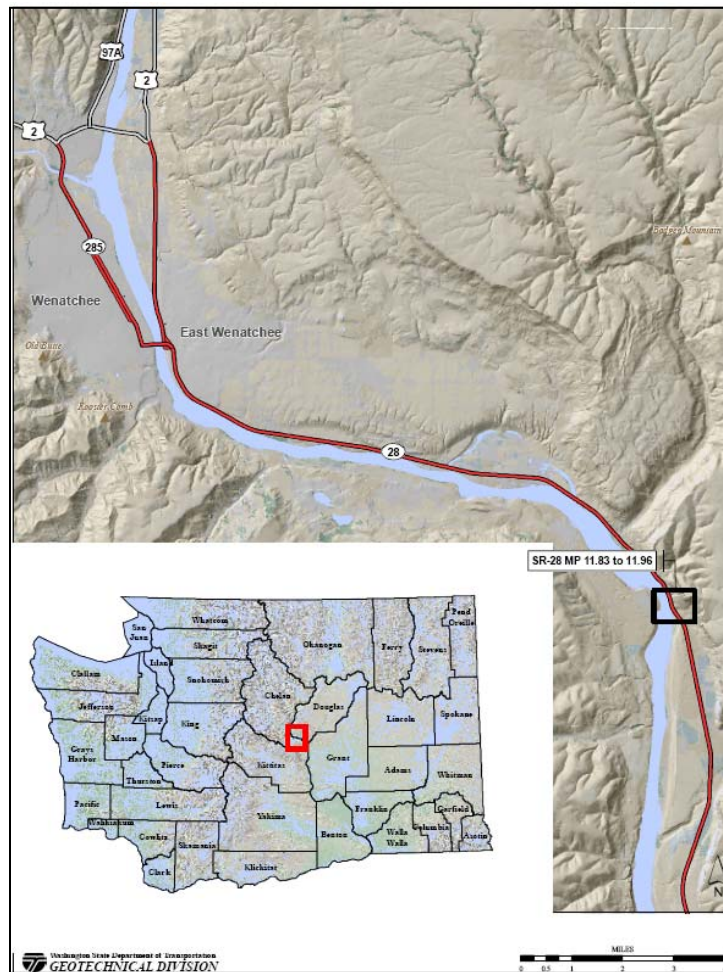


FIGURE 1. Project is located on steep valley wall of the Columbia River east of Wenatchee, Washington around mile post 12 on State Route 28.

The study was incorporated into a rockfall mitigation project (*Contract #7450 State Route 28 Rock Island – Rock Slope Nettings*) located in central Washington State about 12 miles east of Wenatchee on State Route 28 (Fig. 1). The project was to address rockfall hazards from a 300-foot-high natural/cut slope approximately 700 feet in length (Fig. 2). The north and south ends of the slope are near vertical. The middle portion includes an intermediate slope about 80 feet in width and inclined $\sim 45^\circ$ beneath a large overhang that extends back into the slope about 20 feet. Above the overhang the rock slope rises another 100 feet vertically to the crest of the slope. A soil nail wall was constructed beyond the rock slope crest as part of previously planned, but currently unfunded, highway widening project. The rock slope is composed of columnar to hackly basalt with typical block sizes ranging from 2 to 6 feet. The slope frequently produced rockfall, some of which would reach the shoulder and travel lanes. The project entailed some initial safety scaling to remove large strained blocks/masses, and then a drape of ring net slope protection.

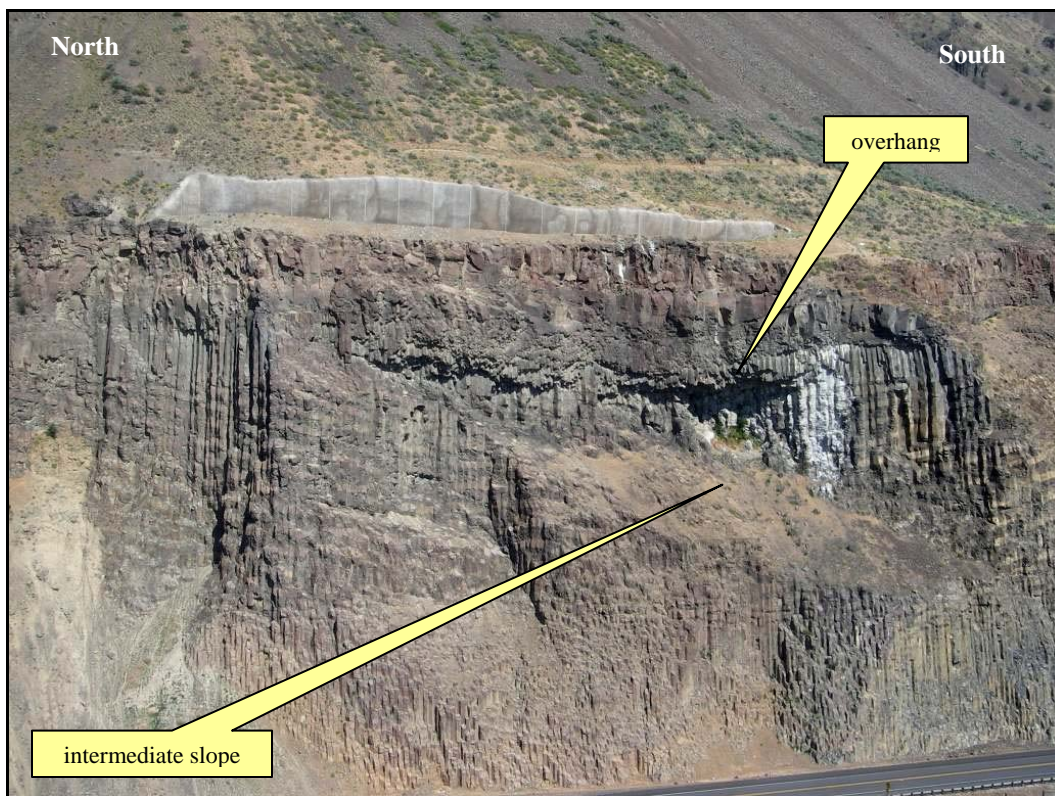


FIGURE 2. The 300-foot-high basalt slope consists of near vertical, northern and southern sections, a middle section with a prominent intermediate slope and overhang, and a soil nail wall beyond the slope crest.

As outlined in the work plan submitted to FHWA (Appendix A), the study includes an evaluation of the ring net installation and an annual assessment of the performance for a 5-year period. This end-of-construction report documents the installation of the ring nets.

DESIGN AND CONTRACT AWARD

During the project design phase, four ring net manufacturers, all that possessed a U.S. market presence, were identified and solicited to provide product information for potential inclusion in the contract. Based on product availability and the documentation

provided, four types of ring nets, one from each of the manufacturers, were specified to cover an equal portion of the slope (Fig. 3). These included two 4:1 and two 6:1 weaves, referring to how many rings are woven into each ring. The specified products included:

- Geobruigg: 300 mm diameter – 3 mm galvanized wire – 5 wires – 4:1 weave
- IGOR: 300 mm diameter – 2 mm galvanized wire – 7 wires – 6:1 weave
- Maccaferri: 300 mm diameter – 3.5 mm galvanized wire – 6 wires – 4:1 weave
- ROTEC International: 12 in diameter – 5/16 in wire rope – 6:1 weave

Because the study was intended to compare the performance of ring nets to cable nets, we attempted to select ring nets that were close in strength and weight to cable nets. The selected Geobruigg, IGOR, and ROTEC ring nets were thought to be close in this regard; however, Maccaferri only offered the heavier and stronger ring nets at the time of the contract preparation and award.

The slope protection was designed to include both a standard installation, which is secured along the slope crest to a top horizontal support rope that lies on the ground, and a modified (hybrid) installation, which lifts the top of the slope protection off the ground with steel posts to intercept rockfall originating upslope of the installation. The standard slope protection was specified for the entire southern and northern sections, and the upper portion of the middle section. A section of modified slope protection was specified for the intermediate bench. All ring nets and cable nets incorporated double-twisted wire mesh on the outside to prevent smaller rocks from passing through the larger openings.

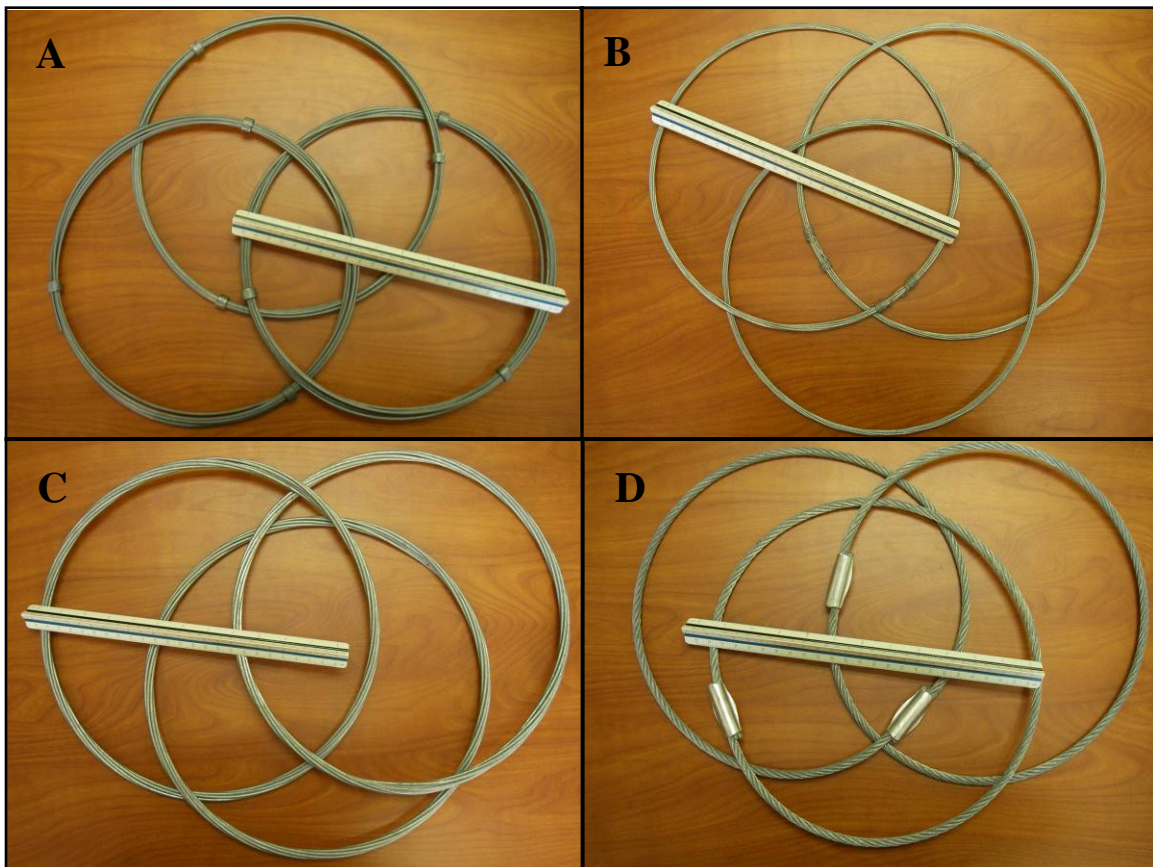


FIGURE 3. Photographs of (A) Geobruigg, (B) IGOR, (C) Maccaferri, and (D) ROTEC rings with 12 inch engineer scale for reference.

The coverage area for the slope protection was estimated using a digital terrain model (DTM) created with traditional survey and ground-based LIDAR data. Using a geographical information system (GIS), we estimated the coverage area for the standard slope protection to be about 166,000 ft² and the modified section to be 59,000 ft², which included a 20% contingency to account for slope irregularities, necessary panel overlaps, and other uncertainties. The quantity estimates planned for the slope protection to extend to within 5 feet of the ditch line and 15 feet beyond the slope crest. A 20-foot-long tail was specified to cover the upper portion of the intermediate bench. The slope areas to be covered with standard and modified slope protection were divided into equal areas with approximately 52,000 ft² specified for each type of ring net (Fig. 4). In addition, two control sections of cable nets were included for approximately 16,000 ft² of coverage area. Total plan quantity for slope protection materials was 224,664 ft².

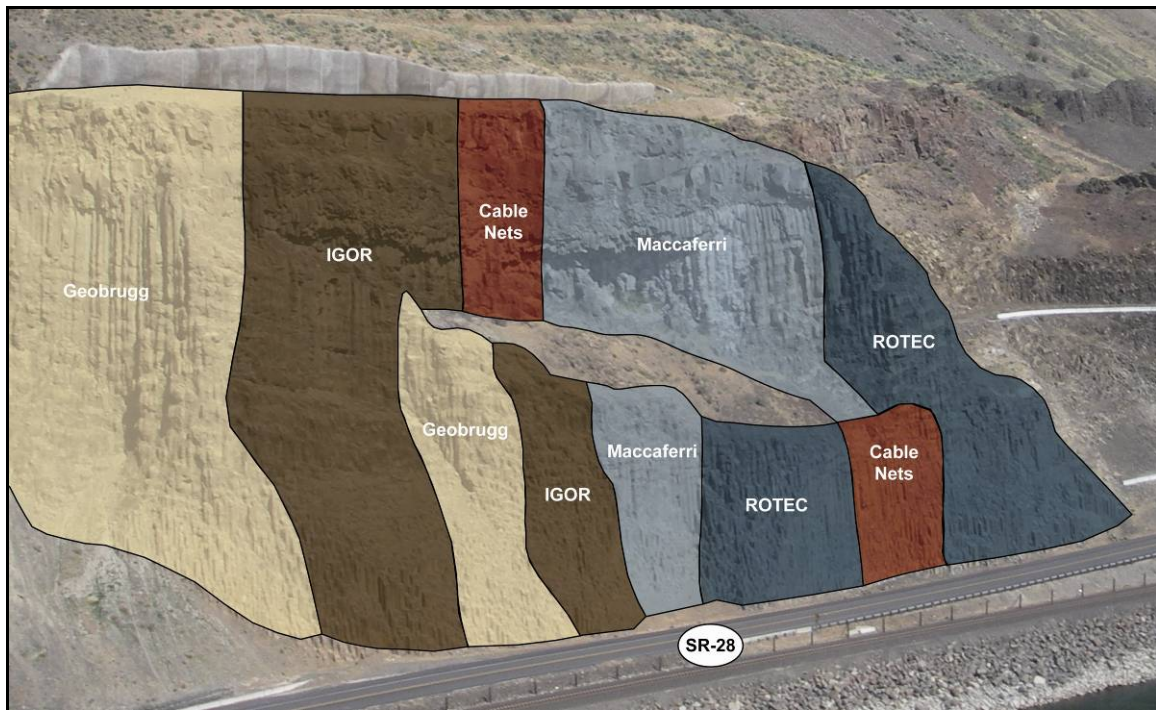


FIGURE 4. Design coverage for the specified ring nets for the sections of standard and modified (hybrid) slope protection, including two control sections of cable nets.

For the sections of standard slope protection, the top horizontal rope was specified to have a maximum segment length of 40 feet supported by cable anchors on 20-foot spacing. The modified section was designed with the top horizontal rope spanning a single 20-foot-wide section between two 10 ft posts and anchored on each end. All posts were inclined downslope at approximately 25 degrees from vertical.

The contract was advertised on November 13, 2007, and bids were opened December 13, 2007. Four pre-qualified contractors bid on the project with project bid costs that ranged from \$2.39 to \$4.10 million. The contract was awarded to Janod Incorporated of Champlain, New York for \$2.39 million, which was about \$848,000 less than WSDOT's engineers estimate.

The unit bid prices for installing the four ring nets and cable nets are summarized in Table 1. The unit bid prices for the fabrics are inclusive of all anchors, appurtenances,

and installation costs; 19 steel posts for supporting the modified slope protection are not included in the unit bid prices. Scaling was completed during a long weekend highway closure in late March 2008. As specified in the contract, installation of the slope protection was delayed due to environmental restrictions until mid July 2008. The on-slope work was completed and the contractor demobilized in late November 2008.

Table 1. Summary of ring net and cable net unit bid prices

Fabric	Plan Quantity (ft²)	Contractor Bids (\$/ft²)
Geobruigg	52,248	5.55 – 10.25
IGOR Paramassi	52,596	6.74 – 12.00
Maccaferri	52,056	6.26 – 11.50
ROTEC International	51,972	8.22 – 13.75
Cable Nets	15,792	5.97 – 11.00

CONSTRUCTION SUMMARY

Prior to placing the nets, the contractor utilized climbing gear, ropes, pneumatic pillows, and pry bars to hand scale large detached blocks from the upper portion of the slope that could potentially damage the ring/cable nets if they were to fall. The contractor utilized a wagon drill to drill the anchor holes for the top horizontal support ropes and for the posts along the intermediate bench. Three-inch-diameter anchor holes were drilled for the top horizontal rope anchors. Double, ¾-inch cable anchors were used to support the ¾-inch top horizontal support ropes. The contractor elected to install anchors to a depth of 20 ft, which were then fully grouted with cement grout. For the modified installation, four 1-inch-diameter anchor bars and three, double ¾-inch cable tieback/lateral anchors were installed for each post to a depth of 10 ft and were fully grouted with cement grout.

The contract required submittals from the ring net manufacturers documenting unit weight of the fabric, 3-ring unrestrained tensile strength of not less than 7,000 lbf, mill certificates for the wire/wire rope, and galvanization information. Product information and test certificates are included in Appendix B, and a summary is provided in Table 2. The 3-ring tensile test results in Table 2 are either the average value of the test reports provided by the manufacturer (Geobruigg, IGOR, Maccaferri) or the value of a single test (ROTEC). The contract was not specific about the number or basis of passing tests.

Table 2. Ring net and cable net technical data

Fabric	Ring Diameter <i>in (mm)</i>	Ring Weight <i>lbs (g)</i>	Approx. Unit Weight <i>lbs/ft² (kg/m²)</i>	Wire Diameter <i>in (mm)</i>	3-Ring Tensile Test <i>lbf (kN)</i>
Geobruigg 4:1	11.8 (300)	0.70 (319)	0.55 (2.7)	0.12 (3.0)	8,990 (40.0)
IGOR 6:1	11.8 (300)	0.37 (168)	0.49 (2.35)	0.08 (2.0)	6,920 (30.8)
Maccaferri 4:1	13.4 (340)	1.22 (553)	0.84 (4.1)	0.13 (3.4)	22,900 (102)
ROTEC 6:1	12.4 (315)	0.59 (268)	0.60 (2.9)	0.31 (8.0)	13,000 (57.8)
Cable Nets	NA	NA	0.5 (2.4)	0.31 (8.0)	NA

Installation of Slope Protection

The contract specified for the double-twisted hexagonal mesh to be attached on the outside of the ring nets with high tensile steel hog rings (Spenax or King Hughes) at 1 ft intervals prior to placing the panels on the slope. Panels were fabricated offsite, and then transported to the top/base of the slope.

The contract specified both ring and cable net panels to be seamed with 5/16" wire rope. The wire rope seaming of the net panels was used initially, but the contractor proposed to substitute shackles for wire rope as a superior seam for the ring net panels being much less prone to seam failure. WSDOT agreed to the proposal, and a 1/2-inch screw pin shackle with a minimum ultimate breaking strength of 24,000 lbf was selected and paid for by change order.

The contractor seamed the narrow panel side of either 2 or 3 panels, depending on the unit weight of the fabric and the size and weight of each type of ring net panel. The panels were then connected to a spreader bar and lifted into place on the slope. The panels were installed as they would hang, seaming the top of the lifted panels to the bottom of those already on the slope. A 50-ton-crane mobilized to the top of the slope was used to place the upper portion of the ring and cable nets; the nets on the lower portion of the slope were installed with the crane set along the highway shoulder.

The contractor started on the south end of the project area with the ROTEC and Maccaferri ring nets and worked primarily northward to the cable net, IGOR and Geobugg ring net sections. During the initial placement of the ROTEC and Maccaferri, the contractor noted large deformations in the ring net panels. The contractor experienced increasing difficulty pulling the nets together as more were added, often requiring a come-along to move the nets and shackle the vertical seams together. The contractor noted an extreme contrast in deformability between the stiff wire mesh and the deformable ring nets, with the wire mesh inhibiting conformance of the ring nets with the slope. The situation resulted in extreme tensioning in the wire mesh with stresses concentrating in the connections of the high tensile steel fasteners. With the addition of ring net panels, many fasteners began to fail. In attempt to reduce the rigidity of the panels, a modification was made at WSDOT's direction to increase the fastener spacing from 1 to 2 feet. Shortly after implementing this change, a mesh panel separated from one of the ring net sections and fell onto two workers below; fortunately, no serious injuries occurred. The contractor temporarily suspended the placement of additional ring nets and secured all of the wire mesh to the top horizontal rope.

The contractor had previously advocated for not connecting the wire mesh to the ring nets. Following this incident, WSDOT consented and allowed the remaining ring nets and wire mesh to be placed separately and not require subsequent connection. The remainder of the placement of the ring nets, cable nets, and wire mesh proceeded without significant problems.

The final coverage area of the different fabrics is approximately depicted in Figure 5. The areas changed somewhat from the coverage area shown in the plans for a number of reasons. Some additional coverage area was required on the south end of the project, which was covered with ROTEC ring nets and additional cable nets. Detailed survey locations of the different fabrics were not included in the plans. Placement of fabrics was made primarily by estimating their location from photographs. With the large slope heights, slope irregularities exacerbated modifications to the design layout. Additional nets were also added along the entire top, due to a modification in the anchoring and top horizontal support rope. These areas requiring additional fabric totaled about 22, 246 ft². The final installed quantity was estimated to be 261,573 ft², representing a 36,723 ft² or

about a 16% shortage on plan quantities. This shortage was accommodated by the installation of additional cable nets.



FIGURE 5. As-built coverage for the ring nets and cable nets.

The following sections summarize the construction experiences of installing the four different ring nets and observations of their as-built condition.

Geobrugg Ring Nets

As specified, the Geobrugg rings were made of 5 loops of 3-mm-diameter wire with a 4:1 weave of interlocking rings. The wire loops are bound together with 3 pressed steel bands, with the wire ends commonly protruding 3 to 6 inches beyond the bands (Fig. 3A). These ring net panels are intermediate in weight as compared to the other specified ring nets.

The contractor's crane was able to lift three Geobrugg ring net panels in a single pick, with each three-panel section measuring 12 feet wide by 75 feet long for a total area of 900 ft². Initial placement of the upper sections of Geobrugg rings occurred with the wire mesh pre-attached until this requirement was dropped. When the panel sections were lifted, both with and without the wire mesh backing, some contraction (necking) and elongation of the fabric occurred (Fig. 6). On the vertical portions of the slope where the nets had little to no slope contact and the dead load was carried entirely by the fabric, rings slightly deformed from a circular to an ellipsoid form. This ring deformation caused many of the wire ends to protrude (Fig. 7). The contractor reported that the protruding wires caused the climbing ropes, wire mesh, and workers' clothing to "hang up", and felt this increased the difficulty of this fabric installation. The contractor also reported several occurrences of minor puncture wounds caused by the protruding wires. Despite the "necking" during lifting and initial placement, vertical seaming of the panel sections reportedly did not require excessive effort to place properly, as compared to some of the other fabrics.



FIGURE 6. Three panel section of Geobrug ring nets with wire mesh; note contraction (necking) of panels.

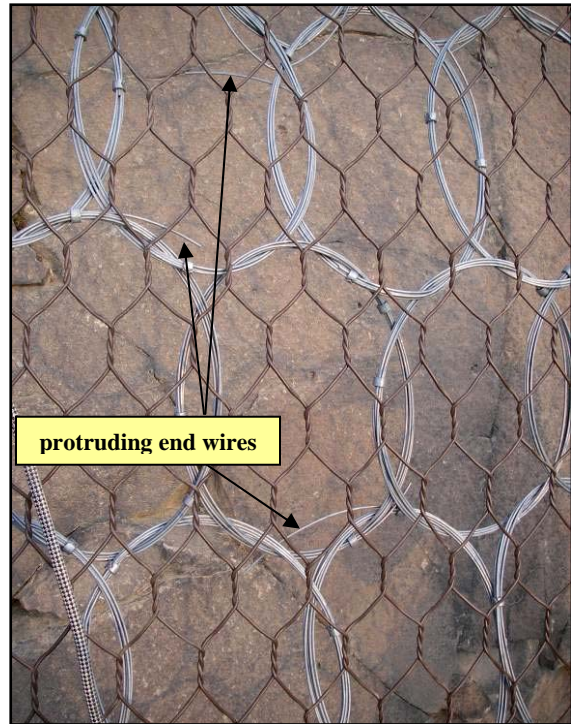


FIGURE 7. Elongation of individual rings caused wire ends to protrude on Geobrug ring nets.

IGOR Paramassi Ring Nets

As specified, the IGOR rings were made of seven 2-mm-diameter wires with a right-hand spiral lay and a 6:1 weave of interlocking rings (Fig. 3B). The wire ends are finished by curling several loops over the ring. IGOR ring net panels are the lightest of the four specified ring nets.

The contractor's crane was able to lift three IGOR ring net panels in a single pick, with each three-panel section measuring 14.5 feet wide by 111 feet long for a total area of 1614 ft². The panel sections were placed mostly without the wire mesh backing. When the panel sections were lifted, they maintained their rectangular shape and contracted very little (Figure 8). Similar to the other ring nets, the IGOR rings elongated somewhat where the nets had little to no slope contact and the dead load was carried entirely by the fabric (Figure 9). The contractor reported that the ring net sections were relatively easy to move around on the slope and to seam.



FIGURE 8. IGOR ring net panels without wire mesh maintained their rectangular shape when lifted.



FIGURE 9. Slight elongation noted in IGOR rings where panels were heavily loaded.

Maccaferri Ring Nets

As specified, the Maccaferri rings were made of six 3.5-mm-diameter wires with a right-hand spiral lay and a 4:1 weave of interlocking rings (Fig. 3C). The wire ends are turned into the ring. Maccaferri ring net panels are the heaviest of the specified ring nets.

The contractor's crane was able to lift only two Maccaferri ring net panels in a single pick, with each two-panel section measuring 13.5 feet wide by 67 feet long for a total area of 905 ft². Initially, the Maccaferri ring nets were placed with the wire mesh backing. During this phase of their installation, the ring net panels severely contracted in width as they were lifted by the crane and placed onto the slope (Fig. 10). The contraction of the ring net panels contributed to the wire mesh fasteners "popping-off" the mesh. Severe contraction persisted after the pre-attachment of wire mesh was discontinued (Fig. 11). Due to the heavy weight of these sections, the contractor found that once placed on the slope it was extremely difficult to pull the rings apart and to shackle the adjacent panels together (Fig. 12).



FIGURE 10. Maccaferri ring net with wire mesh backing exhibited severe contraction within the panels.



FIGURE 11. View of contracted panels without wire mesh backing.



FIGURE 12. Seaming the contracted panels was extremely difficult, often requiring the use of a come-along to pull the seam together and secure the shackle.

ROTEC Ring Nets

As specified, the ROTEC rings were made of a single 5/16-inch diameter wire rope joined with a pressed aluminum ferrule and a 6:1 weave of interlocking rings (Fig. 3D). Being fabricated of a wire rope rather than a bundle of stiff wire loops, ROTEC rings are highly deformable as compared to the other wire rings. ROTEC ring net panels are intermediate in weight as compared to the other specified ring nets.

The contractor's crane was able to lift three ROTEC ring net panels in a single pick, with each three-panel section measuring 12 feet wide by 75 feet long for a total area of 900 ft². Initially, the ROTEC ring nets were placed with the wire mesh backing. When these panel sections were lifted, they generally maintained their rectangular form (Fig. 13A); without the backing mesh, the panels contracted severely (Fig. 13B). With subsequent placement and seaming of panels, significant ring deformation and tension developed in the upper portion of the installation, around slope protrusions, and along seams (Fig. 14). However, because the ROTEC ring is fabricated from wire rope, ring deformation is not permanent as it would be with a ring of bundled wire loops.

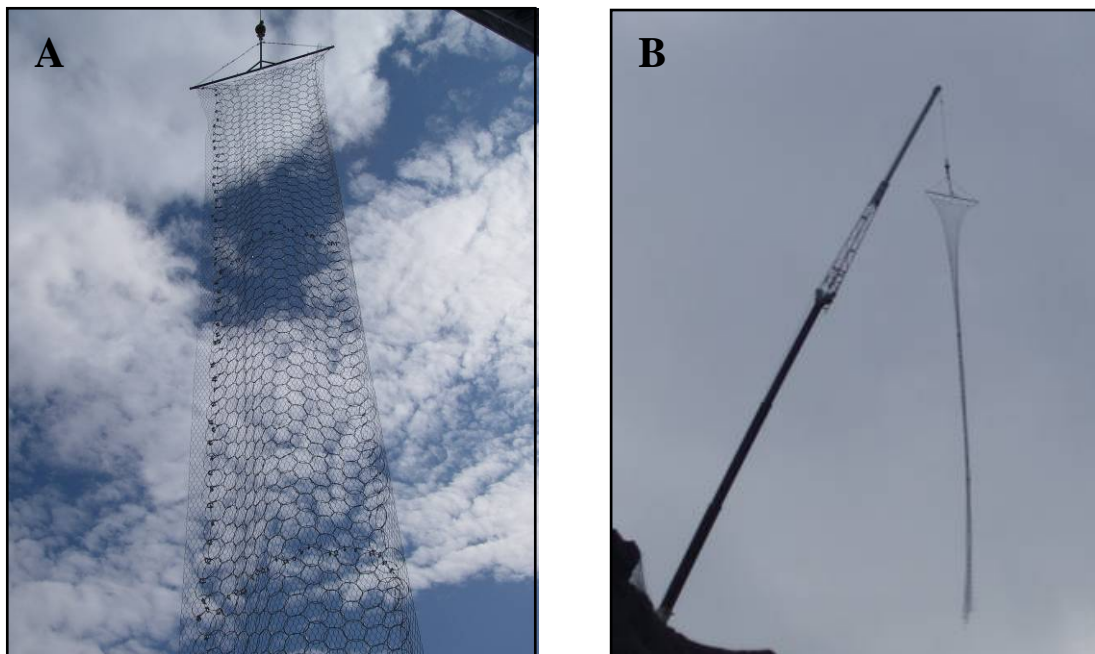


FIGURE 13. (A) ROTEC ring net panels with wire mesh backing and (B) without wire mesh.



FIGURE 14. Deformation in upper portion of ROTEC ring nets.

The effort in pulling the heavy Maccaferri ring net panels together for seaming caused the adjacent ROTEC ring nets, which had been previously seamed to the Maccaferri ring nets, to be pulled laterally toward the Maccaferri nets (Fig. 15). The contractor then had to try to pull the ROTEC rings back. This was only moderately successful, and additional material was required for the net loss in coverage area of the ROTEC ring nets.

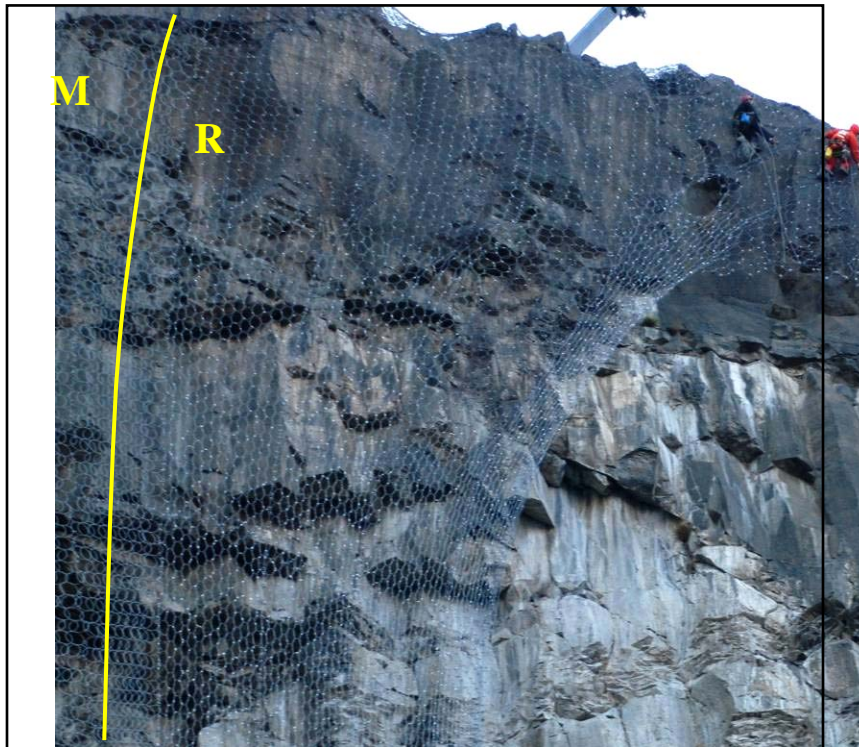


FIGURE 15. Yellow line denotes seam between Maccaferri nets (M) on the left and ROTEC rings (R) on the right. Note how the ROTEC rings have been pulled toward the Maccaferri nets.

Maccaferri Cable Nets

The wire rope cable nets were generically specified in the contract to be either square or diagonal grid with a 12-inch opening fabricated of 5/16-inch-diameter, galvanized wire rope with a 7x7 or 7x19 construction and minimum breaking strength of 9,200 lbf. The cable net panels were specified to include a perimeter rope with a minimum diameter of 5/16 inches. The contractor selected Maccaferri cable net panels, which use a wire wrap to secure the cable junctions rather

than a pressed steel clip. The cable nets provided also were diagonal weave rather than a square weave.

The panels were seamed with 5/16-inch-diameter wire rope, and later with shackles. The contractor's crane was able to lift two Maccaferri cable net panels in a single pick, with each two-panel section measuring 21 ft wide by 64 ft in height or 42 ft wide by 32 ft in height for a total area of 1344 ft². Initially, wire mesh was fastened to the cable nets prior to their hanging, but this requirement was eventually dropped and the wire mesh was added after placing and seaming the cable nets. As expected, the cable net panels kept their rectangular form with or without the wire mesh backing. The contractor reported that the cable nets maintained their shape well and were relatively easy to handle and seam. After the contractor ran short on ring net/cable net materials, additional cable nets were supplied by the contractor that used pressed clips instead of wire wraps for connecting the cable junctures. It was noted after these cable nets were placed that a number of the clips had either fallen off from not being properly secured or were not supplied (Fig. 16). The extent and overall effect on performance of missing clips or poorly fabricated cable nets has not been investigated to date. By not inspecting the extent of the problem and correcting deficiencies, future performance comparison of the ring nets to these additional cable nets may be inaccurate.

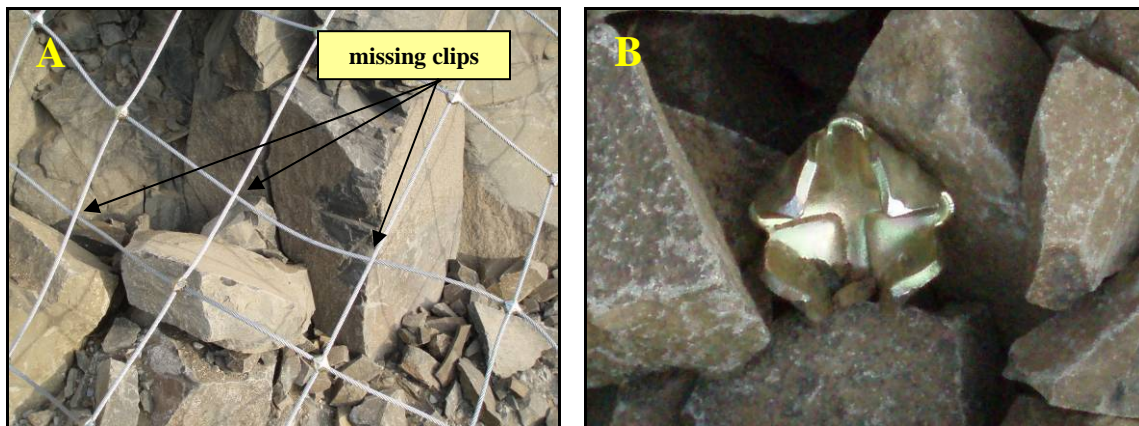


FIGURE 16. Cable nets supplied with pressed clips had numerous missing (A) or poorly fastened (B) clips that fell off during handling of the nets.

DISCUSSION AND CONCLUSIONS

This Experimental Features study provided an opportunity to compare the installation of different weaves, weights, and fabrication of ring nets for a large slope protection (drapery) installation.

Two fabrics (Geobrug and Maccaferri) were specified to have a 4:1 weave, and two (IGOR and ROTEC) were to have a 6:1 weave. As would be expected, when unrestrained by wire mesh backing, a wire ring is much stiffer and less deformable than a wire rope ring. Because ROTEC was fabricated with wire rope, it is not easily compared to the other three wire rings when considering panel weaves and their associated deformation. The 6:1 IGOR ring, being the lightest of the wire rings, exhibited the least contraction or stretch. The 4:1 Geobrug panels were intermediate in their weight and deformation, and the 4:1 Maccaferri were the heaviest and contracted the most. The Maccaferri section, however, had the greatest percentage of free-

hanging length with no slope contact as compared to the other ring nets. While the reduced slope contact and considerable weight of the Maccaferri nets appeared to exacerbate their deformation, in general, the 6:1 weave experienced less ring and panel deformation than 4:1 weaves. Subsequent discussions with some of the manufacturers corroborated this observation. The weight of the ring nets also has a significant influence on their contraction. The lighter 4:1 Geobrug nets deformed much less than the heavier 4:1 Maccaferri nets (Figs. 6 and 10). The heavy weight nets also reportedly made seaming much more difficult and labor intensive as compared to the lighter weight ring nets.

In preparation of the contract, WSDOT solicited input from several contractors experienced with ring net draperies about the need and means to control ring net deformations as additional panels were added. One method suggested by several contractors was to install support cables anchored at the top of the slope with their ends secured at multiple locations on the field of the mesh; these special support cables are referred to as “octopuses”. A design basis for determining the number and spacing of octopuses could not be established prior to advertising the project, and they were not included in the contract. Examination of the different ring nets revealed that all four types experienced some ring elongation where large panel sections were free-hanging and/or had very limited slope contact. The area of ring elongation was not distributed throughout the panel but generally occurred near the middle of the free-hanging length. In our judgment, the extent of elongation was not severe enough to diminish performance with the possible exception of the ROTEC wire rope rings. As expected, the ROTEC rings were the most deformable, but also best conformed to slope irregularities. However, their conformance around numerous slope protrusions resulted in extreme localized tensioning in small numbers of rings with the addition of more panels or when seaming adjacent Maccaferri panels. The long-term performance of these highly tensioned ROTEC rings should be examined. In summary, the benefit that octopuses would have provided for this project is judged to be minimal. Slopes with higher free-hanging lengths might possibly benefit from their inclusion.

For those ring nets that have a tendency to deform under their own weight, the attachment of the wire mesh can greatly reduce their deformation. This is well evidenced in the comparative photos of the ROTEC mesh (Figs. 13 A and B). This constraint on panel deformation, however, is limited to the strength of and stresses on the fasteners that secure the wire mesh to the ring nets. Even using high tensile steel fasteners on close spacing, the considerable weight of the Maccaferri ring nets and deformability of both the Maccaferri and ROTEC ring nets, especially after attaching additional panels, caused many of the fasteners to fail.

The contract requirement for pre-attaching the wire mesh to the ring nets was based on several decades of its successful practice for cable net installations. Because cable nets have fixed cable junctions and a perimeter cable, the rectangular panel shape as a whole is restricted in its ability to deform. Ring nets panels, however, have no perimeter rope or internal junctions of fixity, and, depending on their characteristics (i.e., weave, weight, deformability of each ring, etc.), the panels generally have greater ability to stretch and deform. Double-twisted hexagonal mesh has fixed wire junctions and is quite stiff. These differences in fabric deformability and stiffness were not fully appreciated in the design for this project.

With the wire mesh specified to be on the outside of the ring nets, the contractor had advocated that the ring nets and wire mesh should act as two separate systems and not be connected. The contractor started by placing the 6:1 ROTEC and the 4:1 Maccaferri panels, which were the most prone to deformation. After the fasteners started to fail on these ring net sections and a wire mesh panel detached, WSDOT agreed to drop the connection requirement. WSDOT concurred that by not attaching the wire mesh, it would likely still be effective in containing smaller sized rockfall debris that might pass through the ring nets. This assumption will be assessed during future performance reviews. Alternative installation methods that might help control panel deformation include:

- using a wider spreader bar and hanging the panels in the short (horizontal) dimension would result in less panel load per unit width and thus might reduce panel contraction, and
- seaming the bottom of the lifted panels to the bottom of the panels on the slope.

If the latter method had been used, the vertical seaming could have been done after the horizontal seaming as the top of the lifted panel is lowered onto the slope. This method would lessen the dead load acting on the point of seaming, potentially making it easier to pull the seams together.

The contract quantity shortage in ring/cable nets was due to a number of factors. First, additional areas not specified in the contract (estimated to be about 22,246 ft²) were added on the south end and along the slope crest. Second, most of the Maccaferri panels, and Geobrug to a lesser extent, representing the 4:1 weaves, contracted when lifted and typically could not be fully stretched out once the ring nets were placed on the slope or after additional panels were added. This resulted in reduced coverage area from a number of the panels (Fig. 17). Third, the slope was large and irregular, which complicated estimating the contract plan quantities. Estimation of the coverage area using ground-based laser scanning and GIS was a newly employed method for WSDOT. To account for uncertainties with this estimating method and variable fabric conformance with the slope, a 20% contingency was provided for in the plan quantities. Subtracting the 22,246 ft² of additional coverage area and discounting the 20% contingency in planned quantities, the coverage area calculated with GIS underestimated the as-built quantities by about 28%. We assume that the percent loss of coverage area due to panel contraction would be less for shorter slope heights, for lower deformation ring nets (i.e., 6:1 rather than 4:1 weaves, lighter rather than heavier panels, etc.), and by tailoring installation methods to optimize coverage area. For future projects, consideration should be given to controlling panel deformation and loss of coverage area. This might include specifications on method of placement and using lower deformation ring net panels.

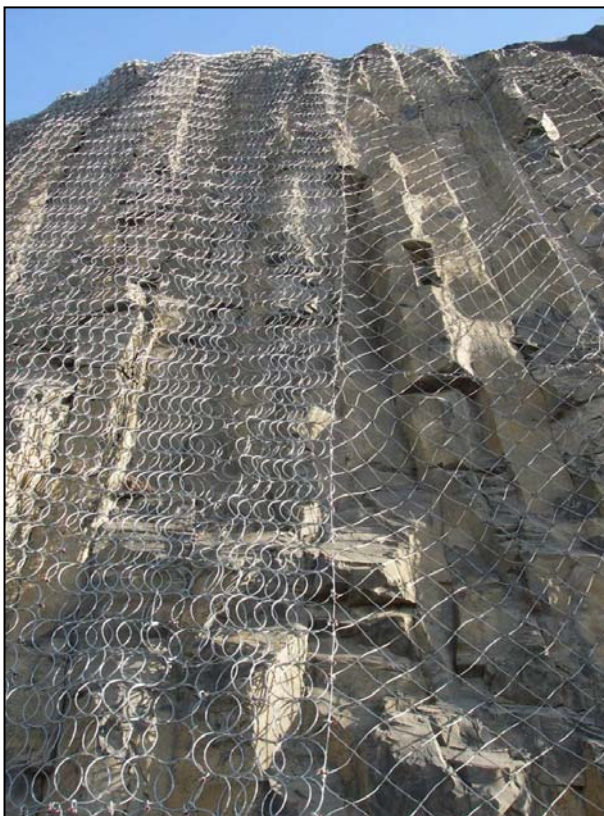


FIGURE 17. Photograph shows Maccaferri rings adjacent to Maccaferri cable nets. Note contraction in width of ring nets panels and less than optimal coverage area.

While much of the slope was near vertical and the ring nets had little slope conformance, where the slope was more moderate in inclination, all of the rings nets and cable nets exhibited reasonably good conformance with the slope.

The final cost for completing this project was approximately \$3.2 million. The additional \$800,000 above the contract award price is attributed to acquiring about 7.5% more cable nets to cover the required area, the substitution of U.S. steel shackles for seam ropes, and some additional slope stabilization measures. These additional costs lead to the project being approximately 25% over the original contract award amount of \$2.39 million.

While no performance data is yet available, the installation phase provided useful information about the comparison of ring nets to cable nets for slope protection (drapery) systems.

- The unit bid prices for the installation of the ring nets from each of the contractors were competitive, but on the high end, with wire rope cable nets of comparable opening size (12 inches).
- The ring net panel with the least amount of deformation (lightweight IGOR 6:1 weave) was reportedly comparable to the cable net panels in terms of ease and time of installation. With the use of heavier ring nets and those utilizing a 4:1 weave (both being factors that result in increased panel deformation), installation effort increased substantially over what would be typical for cable net installations. The contractor provided data for the time required to install each of the fabrics, which is presented in Table 3. It is important to note that in addition to the specific properties of the ring nets, slope height and

construction methods/access influence installation time. The reported differences of the installation rates may be significantly less for shorter slope heights or less challenging slope conditions. A qualitative assessment for evaluating panel deformation and ease of installation might include lifting a single panel in the long direction and noting the amount of contraction/deformation.

Table 3. Fabric installation rates

Fabric	Square Feet Installed	Installation Time (hrs)	Installation Rate ft²/hr
Cable Nets	49,248	345	143
IGOR 6:1 Wire Ring Nets	54,896	439	125
Geobrugg 4:1 Wire Ring Nets	52,500	540	97
Maccaferri 4:1 Wire Ring Nets	52,461	688	76
ROTEC 6:1 Cable Ring Nets	52,200	902	58

- Attaching the wire mesh to the ring nets, as WSDOT currently requires for cable nets, is likely not problematic for the installation of low-deformation ring nets. The necessity or benefit of this practice in terms of performance, however, has not yet been assessed for this project. If the wire mesh is pre-attached, its stiffness has the potential of limiting the desirable attribute of ring net deformability (and potentially increase damage) during rockfall impacts (up to the yield strength of the fasteners and wire mesh). We assume that because cable nets do not have the capability to deform as much as ring nets, we have not observed any significant problems or damage on numerous WSDOT installations where the wire mesh has been attached to the cable nets. If this practice is found to be adverse or provides no discernable benefit, eliminating the requirement would result in substantial cost savings, both for ring nets and cable nets. Because of the differences in stiffness, the wire mesh placed on the outside of but not attached to the ring nets (or cable nets) would be expected not to conform as well to the slope and underlying ring (cable) nets without extra effort. This variance in slope conformance is likely to be more visible viewing from the side than from the front of the installation.
- Lacking performance data, the specification and installation of low-deformation ring nets had no significant negative or positive attributes when compared to cable nets. One concern that we will be looking for in their future performance is the permanent deformation of wire rings due to rockfall impacts. A positive attribute of wire rope that is used for cable nets (and the ROTEC ring net) is that it does not experience significant permanent deformation within its yield strength. Wire rings, on the other hand, permanently deform within their yield strength. The extent to which this permanent deformation affects performance after repeated impacts is not known.

The ring nets included in the contract were explicitly specified by WSDOT so as to compare different attributes that included weave (4:1 and 6:1), weight, and element type (wire or wire rope). These comparisons do not fully represent the quality or range of product availability provided by the manufacturers, or the suitability of the evaluated products for other applications.

APPENDIX A



WORK PLAN

Use of Ring Nets for Slope Protection for Rockfall

SR-28 / Rock Island – Rock Slope Netting Milepost 11.83 to Milepost 11.94

Prepared by

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Introduction

The Washington State Department of Transportation (WSDOT) has been using draped wire mesh slope protection for more than four decades to control rockfall originating from steep slopes adjacent to highways. Originally, lightweight chain link and double-twisted wire mesh were used, which have proven performance for block sizes up to 2 ft. In the late 1980s, WSDOT pioneered the use of cable nets to address larger block sizes that would otherwise damage lighter weight wire mesh. Until recently, drapery systems lacked quantitative design methodology and design primarily relied on past performance and engineering judgment. In 1999, WSDOT initiated a pooled-fund study to identify and quantify critical design parameters and limit states, and to develop design guidelines for drapery systems; two reports were completed in 2005 summarizing the research (Muhunthan et al., 2005a and 2005b).

More than a decade of experience with cable nets has demonstrated their effectiveness for block sizes approaching 4 to 5 ft, and during this time they have achieved widespread use in North America. Until recently, only one manufacturer (Chama Valley) produced cable nets using US steel, which is required by Buy-America legislation for federally funded projects. Chama Valley provides their nets to several different competing suppliers. Another manufacturer (Maccaferri) is now producing cable nets made with US steel, but this new product has not yet been offered for a WSDOT project. Within the last five years, another manufacturer (Geobruigg) has marketed a chain link fabric using high tensile steel wire (TECCO[®]), which is reported to be suitable for larger block sizes. For a variety of design and contractual reasons, WSDOT has not yet used TECCO[®] for a drapery system. To date, this situation has resulted in little to no competition for supplying more robust fabrics needed for rockfalls involving large block sizes.

Recent interest has arisen in the use of ring nets as an alternative to cable nets for use in drapery systems. Test data shows that ring nets are two to four times stronger than standard cable nets. This fact has resulted in a number of manufacturers providing ring nets rather than cable nets for moderate to high capacity rockfall protection fences. It also appears that ring nets may be less costly than cable nets. Lastly, corrosion protection for ring nets is likely superior to that of cable nets. Unfortunately, only one manufacturer (Geobruigg) produces ring nets using US steel; however, numerous companies are

producing ring nets using foreign-made steel. It is also our understanding that ring nets have not yet been used for a permanent drapery system for a North American highway project. We propose to use ring nets for a large drapery installation on a 300-ft-high, steep rock slope on SR 28 east of Wenatchee (Fig. 1).

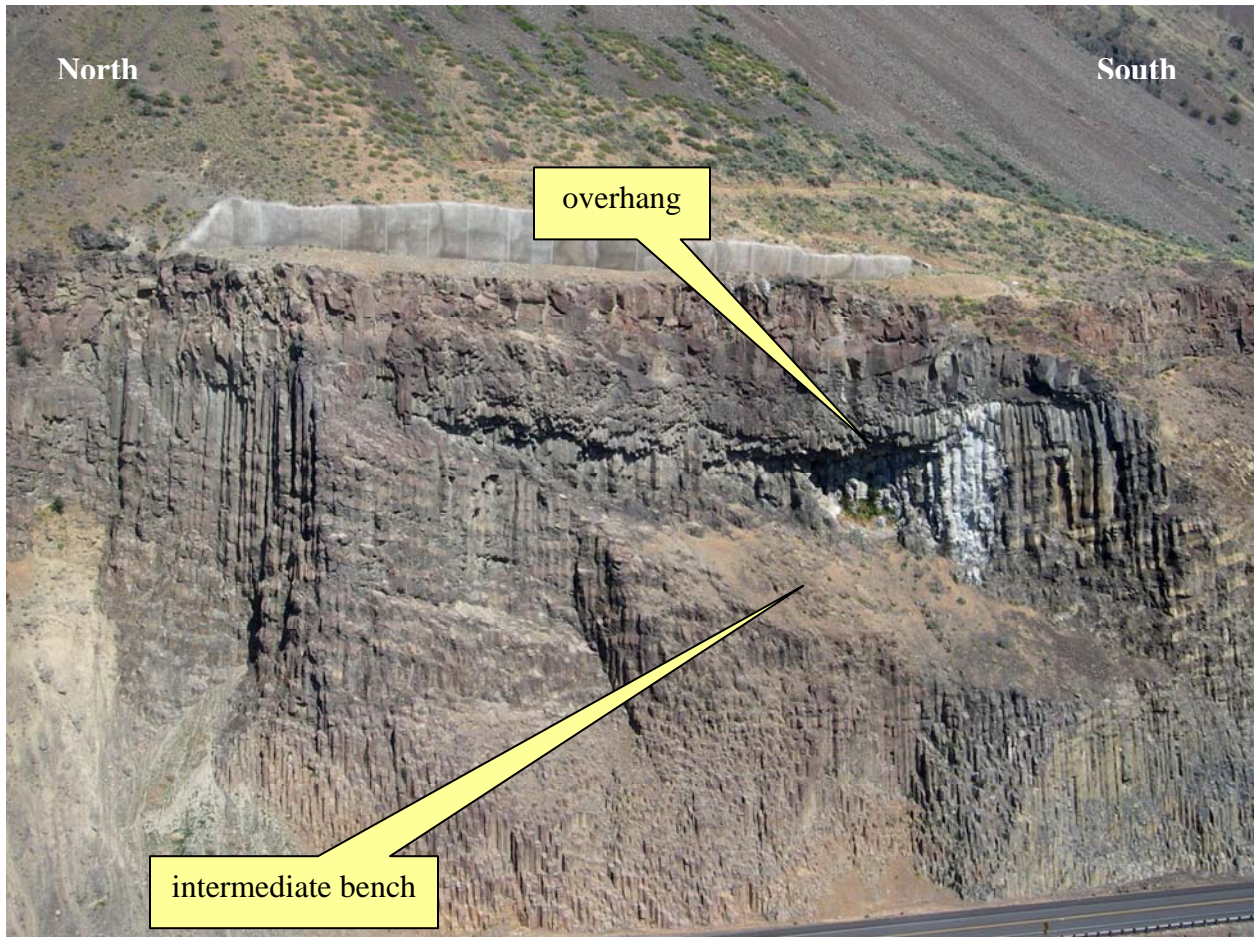


Figure 1. Project proposes draping this 300-ft-high basalt slope with ring nets.

Plan of Study

The rock slope is comprised of basalt with typical block sizes ranging from 3 to 6 feet. The slope has an irregular configuration with near-vertical upper and lower sections, a large overhang, and moderately sloping intermediate bench located in the lower half of the slope. We are proposing to use the ring nets for both a standard and modified application. The standard application entails securing the system along the slope crest and allowing rockfall debris originating beneath the mesh to be channeled sub-vertically down to the ditch. A modified application raises the top of the installation 10 to 20 ft off of the ground allowing rockfall originating upslope of the system to impact

sub-horizontally and then be channeled down to the ditch. By using the ring nets for both standard and modified applications, we can evaluate their performance for both sub-vertical and sub-horizontal impacts.

Layout

The slope area is approximately 300 feet in height and 700 feet in width. The entire upper portion would have a standard installation secured by a top horizontal rope and anchors located above the slope crest. On the north and south ends, the ring nets would extend to the base of the rock slope. The center portion would cover the overhang and extend approximately 20 feet onto the intermediate bench. The approximate coverage area for the standard application is approximately 150,000 square feet. A modified section would be constructed along the lower edge of the intermediate bench and extend to the base of the rock slope. The approximate coverage area for the modified section is approximately 50,000 square feet.



Figure 2. The green-shaded slope area depicts the ring net coverage, and the pink-shaded slope area would be the control sections of cable net coverage. The fabric coverage areas that extend to the slope crest would be a standard application secured by a top horizontal rope and series of anchors located above the slope crest. The diagonal-lined portion represents the modified installation that would be exposed to sub-horizontal impacts from rocks exiting the upper standard drapery.

We propose incorporating ring nets from numerous companies that utilize either US or foreign-made steel for both the standard drapery and modified sections. Products from different ring net manufacturers could be evaluated. Specifications and acceptance criteria have yet to be finalized.

Control Section

We would propose to include two 100-ft-wide sections of cable nets within the installation as a control fabric. One section would be for a standard section and one within the modified section.

Testing Plan

The occurrence of rockfalls and the performance of the installation will be visually monitored on a regular basis by North Central Region Maintenance and Materials Lab personnel. Significant rockfall events will be photo documented. On at least an annual basis, the installation will be visually inspected from the highway level by staff from the WSDOT Geotechnical Division to assess rockfall frequency and system performance.

Reporting

An “End of Construction” report will be written following completion of the test sections. This report will include construction details, discussion of the installation process, and installation costs. Annual summary reports will also be issued over the next five years. At the end of the period, a final report will be written which summarizes performance characteristics and future recommendations for use of ring nets for both standard and modified drapery systems.

Staffing

The North Central Region project office will coordinate and manage all construction aspects. Representatives from WSDOT Geotechnical Division will also be involved with documenting the construction and performance.

Contacts and Report Authors

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Cost Estimate

Construction Costs

We do not have documented cost information for the use of ring nets, but we do for cable nets. We expect that construction costs will be in the range of cable nets. Since the ring nets, from several different suppliers, will be installed on a Federal-aid contract, a waiver of the Buy America provisions will be required. Contractors who have handled the ring nets do not report added installation difficulties that would result in higher construction costs. Documentation costs for the initial report will be charged to the contract work order.

Evaluation Costs

Condition surveys will be conducted as part of routine maintenance activities; thus, no additional costs are anticipated to regularly inspect for installation performance following rockfall events. Annual inspection by Geotechnical Division staff can be made during other routine visits to the Region; no additional cost is anticipated for these evaluations.

Report Writing Costs

The initial report will be performed and charged to the construction contract. Subsequent reports will be covered by the Materials Lab.

Initial Report: 20 hours @ \$100/hr = \$2,000

Annual Report: 5 hours (1 hour each) @ \$100/hr = \$500

Final Report: 10 hours @ \$100/hr = \$1,000

Total Cost = \$3,500

Schedule

The construction is scheduled for the summer of 2008. An initial construction report would be completed in the Fall 2008 with annual reports to follow in consecutive years. A final report would be provided in Fall 2013 summarizing five years of performance.

References

Muhunthan, B., S. Shu, N. Sasiharan, O.A. Hattamleh, T.C. Badger, S.M. Lowell, and J.D. Duffy, 2005a, Analysis and Design of Wire Mesh/Cable Net Slope Protection, Washington State Transportation Center (TRAC) Report No. WA-RD 612.1, Seattle, Washington, 267 p.

Muhunthan, B., S. Shu, N. Sasiharan, O.A. Hattamleh, T.C. Badger, S.M. Lowell, and J.D. Duffy, 2005b, Design Guidelines for Wire Mesh/Cable Net Slope Protection, Washington State Transportation Center (TRAC) Report No. WA-RD 612.2, Seattle, Washington, 60 p.

APPENDIX B

♦ Revisionen ♦ CNC-Fertigung
 ♦ Engineering ♦ Seilbauwerke
 ♦ Montagen ♦ Seilabnahmen

**STS 356**

SCHWEIZERISCHER PRÜFSTELLENDIENST
 SERVICE SUISSE D'ESSAI
 SERVIZIO DI PROVA IN SVIZZERA
 SWISS TESTING SERVICE

9405 Wienacht - Tobel

Test report 3.2

Baremo No.	100'641
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Customer:**Gebrugg AG****Hofstrasse 55, 8590 Romanshorn**

Order number:	EB08-52545	LS. Nr.	EB08-52545
Date of receipt:	01.09.2008		
Date of examination:	08.09.2008		

Test object:**ROCCO 5/3/300**

Wire manufacturer: Samples from USA

Order:

3 clamped catenae drawn and breaking force measured

Test conditions:

The examination is conducted by an approved rope test facility (per ISO/IEC 17025) and in accordance with paragraph 13 of the Swiss rope ordinance of 13.12.93, for ropes of ropeways, released by the Swiss Federal Bureau of Traffic (BAV).

This test report is established per EN 10204-3.2 (2004 - formerly DIN 50049-1986), and comprises 1 page.

Test results:

Test number	Actual breaking force
Chain 1	39.6 kN
Chain 2	43.5 kN
Chain 3	36.8 kN

Distribution:

Inspector:

E. Baumgartner

Customer 2x / archive 1x

Head of testing facility

E. Baumgartner dipl. Masch. Ing. HTL

This report must not be copied without explicit permission of Baremo GmbH!**Rechnungsadresse**

Baremo GmbH, Unterer Kapf 620, 9405 Wienacht-Tobel
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UNIVERSITÀ DEGLI STUDI
DI TRENTO

DIPARTIMENTO DI INGEGNERIA MECCANICA E STRUTTURALE

Laboratorio Prove Materiali e Strutture

Test certificate n°12145/83

Trento, 24/05/2007

Certificate requirer:

Igor S.p.A.

Via Alessandro Volta 38015 Lavis (Trento)

Content of the certificate:

LOAD TESTS ON:

- STEEL WIRE RINGS;
- SERIES OF THREE MUTUALLY CONNECTED STEEL WIRE RINGS;
- PANELS OF STEEL WIRE RINGS;
- PANELS OF STEEL WIRE ROPES.

Date of the tests:

August and September 2006 - March 2007

Date of registration:

17/04/2007

The certificate also includes two Annexes:

- Annex A: experimental diagrams of tests
- Annex B: photographic documentation

1.1 TEST SPECIMENS

Tensile load tests were performed on various components of steel rock retaining nets, following the requirements of the certificate requirer Mr. Francesco Sassudelli of IGOR S.p.A., a joint-stock company based in Lavis (Trento, Italy).

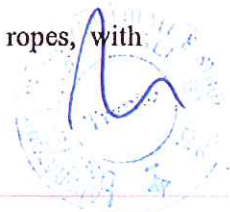
In detail, the tests listed below were carried out:

- 27 on steel wire rings
- 27 on series of mutually connected steel wire rings
- 32 on panels of steel wire rings
- 25 on panels of steel wire ropes

The steel wire rings were obtained twisting 6 times the same wire in order to obtain a 7 wire strand. The tensile load was applied by means of steel cylinders of diameter equal to 100 mm. The test set-up is shown in Figures 1 and 2, respectively. Results are reported in Section 1.2.

The series of three mutually connected steel wire rings, as shown in Figure 3, were stretched by applying the load at the two end rings by means of 100 mm diameter pins. The test set-up is shown in Figure 3 while test results are reported in Section 1.3.

Test results carried out on panels of steel wire rings and on panels of steel wire ropes, with rhomboidal mesh and with steel connectors at the corners, are reported.



In detail, net panels were connected by means of shackles to a perimeter thick steel wire rope, retained to the strong-floor at the corners, 14 m long and wound 2 or 3 times. Test results are reported in Sections 1.4 and 1.5. See Figure 1.4 in this respect.

The vertical load was applied at the centre of the panel by means of a steel-concrete element with the shape of a spherical cap of radius 1400 mm, diameter 1.010 m radius, 20 mm edge curvature radius and weight 7.4 kN.

All specimens were delivered to the Material and Structural Testing Laboratory of the University of Trento by Mr. Sassudelli of IGOR S.p.A.

1.2 SINGLE RINGS: TEST PROCEDURE

The tests were carried out following the procedure required by the customer. The ring was pulled by steel cylinders of 100 mm diameter and 25 mm thick, see Figures 1 and 2, inserted between two-sides steel plates. Each pair of plates was seized by a METROCOM universal testing machine, developing a load of 1000 kN and endowed with a class 1 load cell. A low displacement speed was applied to the ends of the ring, leading the specimens to failure. The specimen characteristics and the maximum recorded loads are collected in Tables 1a – 1e. The failure load represents the maximum load acquired during the test.

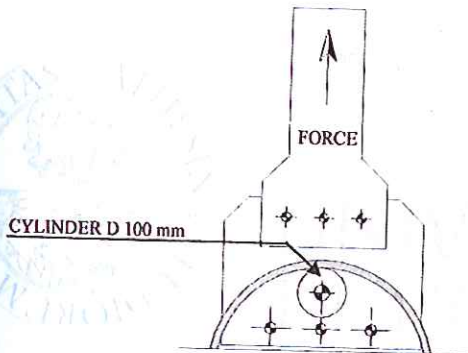


Figure 1. Sketch of the upper part of the device devoted to load application on a single ring.



Figure 2. Upper part of the device devoted to the load application on a single ring.

Table 1a. Maximum load acquired in single ring tests: 2 mm diameter wire and splice closing type.

Test number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]	Ring weight [kg]
10	2	250	splice	61.7	0.141
11	2	250	splice	59.1	0.140
12	2	250	splice	61.7	0.142
4	2	300	splice	72.9	0.172
5	2	300	splice	70.7	0.171
6	2	300	splice	75.0	0.170



Table 1b. Maximum load acquired in single ring tests: 2 mm diameter wire and curl closing type.

Test number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]	Ring weight [kg]
13	2	250	curl	62.6	0.146
14	2	250	curl	61.6	0.147
15	2	250	curl	62.0	0.148
7	2	300	curl	56.4	0.178
8	2	300	curl	62.4	0.180
9	2	300	curl	62.7	0.177

Table 1c. Maximum load acquired in single ring tests: 2.7 mm diameter wire and splice closing type.

Test number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]	Ring weight [kg]
1	2.7	325	splice	127.0	0.332
2	2.7	325	splice	125.9	0.329
3	2.7	325	splice	124.5	0.337

Table 1d. Maximum load acquired in single ring tests: 3 mm diameter wire and splice closing type.

Test number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]	Ring weight [kg]
16	3	300	splice	143.3	0.381
17	3	300	splice	143.5	0.380
18	3	300	splice	141.9	0.374
19	3	350	splice	135.9	0.435
20	3	350	splice	133.8	0.429
21	3	350	splice	136.6	0.434

Table 1e. Maximum load acquired in single ring tests: 4 mm diameter wire and splice closing type.

Test number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]	Ring weight [kg]
22	4	300	splice	242.7	0.671
23	4	300	splice	245.1	0.673
24	4	300	splice	238.4	0.671
25	4	350	splice	260.0	0.780
26	4	350	splice	248.4	0.785
27	4	350	splice	242.8	0.787



1.3 INTERCONNECTED RINGS: TEST PROCEDURE

Tensile tests on three interconnected rings were carried out by employing a hydraulic actuator MTS mod. 243.60 connected to a reaction frame. A load cell scale of 500kN was used. Two pins, characterized by a 100 mm outer diameter, were connected to the actuator and to a lower reaction beam, respectively. A displacement speed of 1 mm/s was applied up to collapse. The test set-up is shown in Figure 3.

Test results are presented in Tables 2a – 2e, while load-displacement relationships relevant to each ring type are shown in Figures A1 ÷ A9 of Appendix A.

The different location of the actuator at collapse detected on the load-displacement curves depends on the initial location of the reaction base with respect to floor.

Table 2a. Maximum load acquired in the tests of three interconnected rings: 2 mm diam. wire and splice closing type.

Test number	Specimen number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]
11	1	2	250	splice	32.1
12	2	2	250	splice	28.4
13	3	2	250	splice	29.0
20	1	2	300	splice	33.7
21	2	2	300	splice	31.4
22	3	2	300	splice	31.1

Table 2b. Maximum load acquired in the tests of three interconnected rings: 2 mm diam. wire and splice closing type.

Test number	Specimen number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]
14	1	2	250	curl	31.3
15	2	2	250	curl	29.3
16	3	2	250	curl	31.7
17	1	2	300	curl	31.3
18	2	2	300	curl	29.3
19	3	2	300	curl	31.7

Table 2a. Maximum load acquired in the tests of three interconnected rings: 2.7 mm diam. wire and splice closing type.

Test number	Specimen number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]
7	1	2.7	325	splice	60.6
8	2	2.7	325	splice	50.8
26	3	2.7	325	splice	56.9



Table 2c. Maximum load acquired in the tests of three interconnected rings: 3 mm diam. wire and splice closing type.

Test number	Specimen number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]
9	1	3	300	splice	56.2
10	2	3	300	splice	81.3
23	3	3	300	splice	75.2
4	1	3	350	splice	62.1
5	2	3	350	splice	74.6
27	3	3	350	splice	78.4

Table 2d. Maximum load acquired in the tests of three interconnected rings: 4 mm diam. wire and splice closing type.

Test number	Specimen number	Wire diameter [mm]	Ring diameter [mm]	Closing type	Failure load [kN]
6	1	4	300	splice	124
25	2	4	300	splice	112.5
24	3	4	300	splice	104.2
1	1	4	350	splice	108
2	2	4	350	splice	126.6
3	3	4	350	splice	123.4

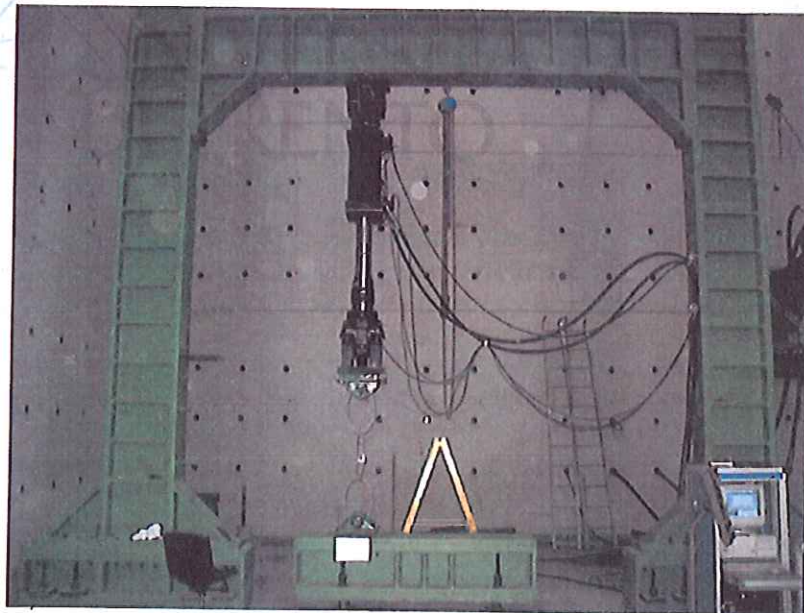


Figure 3. Test set-up and interconnected rings.



1.4 RING PANELS: TEST PROCEDURE

The steel wire ring nets are made of rings identical to those described in the Section 1.3. Each ring can be connected to four or six other surrounding rings, configurations identified as 4 in 1 and 6 in 1, respectively. The panels were connected to a perimeteral 26 mm diameter wire rope, attached to the reaction-floor at the corners of the ideal square surrounding the panel; the test set-up is shown in Figures 5 - 7. The wire rope length, equal to 14 m, was approximately 15% greater than the panel perimeter. The cable was retained by pins 140 mm thick; it was wound two or three times, depending on the applied load.

The reaction at restraints was acquired by means of two LCM pin load cells of capacity 906 kN in the tests carried out in 2006; and by means of an AEP TC4 load cell, class 0.5, in the tests carried out in 2007.

The corner restraints permitted the connection distance to be varied and to tighten the net panel and the free rotation in the vertical plan.

The test load was applied to the net by means of the concrete spherical cup shown in Figure 4 and described in Section 1.1.

A MTS model 244.51 actuator of capacity 1000 kN was employed in the tests performed in 2006; the tests performed in 2007 were carried out by means of a MOOG model L085-719 actuator, of the same capacity.

Ring panels were tightened, in their plane, acting on the bolts of the connection bars. The average preload is reported, together with the test results, in Tables 3a - 3d. The lengths l'_x and l'_y define the centre distance between the pins in the directions parallel and normal to that of the reaction frame, respectively; moreover, l_x and l_y define the exterior dimensions of the net panel in the same directions, as evaluated in the middle of the panel, after tightening.

The test were carried out at a speed of 2.5 mm/s up to failure, acquiring the maximum vertical load by means of the actuator load cell and the maximum reaction in the net plan by employing the load cells at the corners.

1.5 WIRE ROPE PANELS: TEST PROCEDURE

The wire rope panels are made of steel ropes of diameter equal to 8 mm, inclined approximately 45° with respect to the panel sides and are linked at the intersections by means of steel connectors, composing rhomboidal meshes. As stated by the customer, ropes are of the type 6 x 7-WSC in accordance to UNI EN 12385:2004 with 49 wires.

The test procedures were identical to those employed for the ring panels, maintaining a speed of 2.5 mm/s up to failure. Test results are shown in Table 4. The meaning of the variables is the same of that employed in section 1.4.

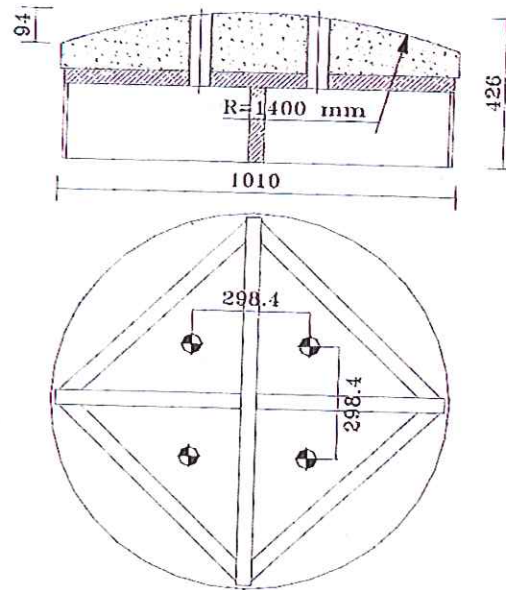


Figure 4. Load application cap: plan view and vertical section



Figure 5. Test set-up and specimen



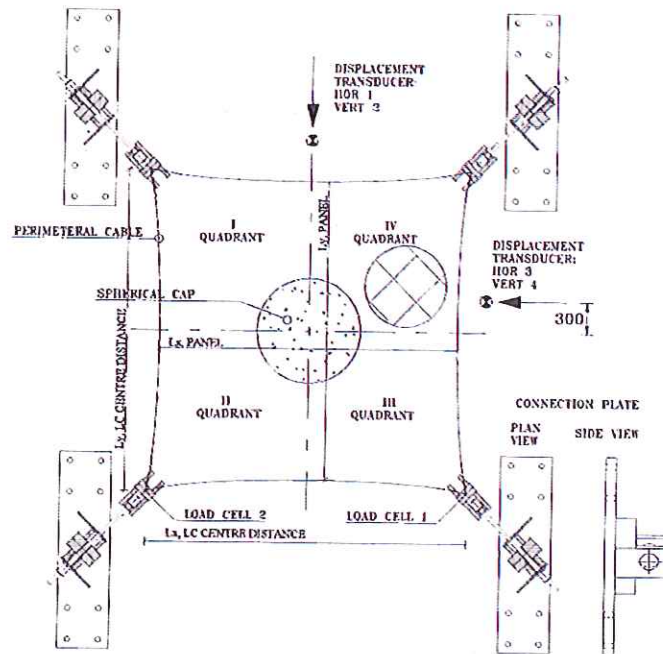


Figure 6. Plan view of the set-up exploited in 2006. The spherical cup is the hatched circle in the centre of the panel.

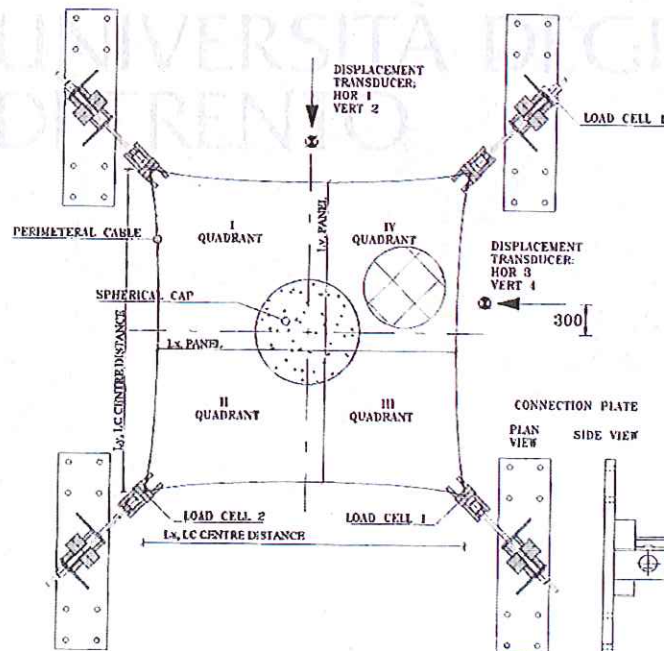


Figure 7. Plan view of the set-up exploited in 2007. The spherical cup is the hatched circle in the centre of the panel.

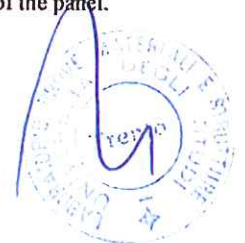


Table 3a. Maximum load acquired in the tests on ring panels: Double or triple time perimeteral cable of length 14.0 m. 2 mm diameter wire and splice closing type.

Test number	Panel denomination	Wire diameter [mm]	Ring diameter [mm]	Panel type	Closing type	Panel dimensions $l_x \times l_y$ [m]	Centre distances between pins $l'_x \times l'_y$ [m]	Average net preload [kN]	Maximum vertical load [kN]	Maximum side reaction [kN]
2 2007	PRA 4in1 D250 2 7 I (A,B)	2	250	4 in 1	splice	3.09 x 3.11	3.37 x 3.37	6.9	286.7	471.9
6 2007	PRA 6in1 D250 2 7 I (A,B)	2	250	6 in 1	splice	3.27 x 3.27	3.36 x 3.36	4.8	465.2	713.6
7 2007	PRA 6in1 D300 2 7 I (A,B)	2	300	6 in 1	splice	3.25 x 3.17	3.35 x 3.33	4.9	416.6	674.3
11 2006	PRA 4in1 D300 2 7 I (A,C)	2	300	4 in 1	splice	3.00 x 3.10	3.35 x 3.37	7.0	176.9	250.7

Table 3b. Maximum load acquired in the tests on ring panels: Double or triple time perimeteral cable of length 14.0 m. 2 mm diameter wire and curl closing type.

Test number	Panel denomination	Wire diameter [mm]	Ring diameter [mm]	Panel type	Closing type	Panel dimensions $l_x \times l_y$ [m]	Centre distances between pins $l'_x \times l'_y$ [m]	Average net preload [kN]	Maximum vertical load [kN]	Maximum side reaction [kN]
1 2007	PRA 4in1 D250 2 7 R-1 (A,B)	2	250	4 in 1	curl	3.14 x 3.14	3.37 x 3.37	11.4	341.0	555.7
3 2007	PRA 4in1 D250 2 7 R-2 (A,B)	2	250	4 in 1	curl	3.13 x 3.12	3.36 x 3.37	6.9	349.8	568.5
4 2007	PRA 6in1 D250 2 7 R-1 (A,B)	2	250	6 in 1	curl	3.19 x 3.15	3.36 x 3.37	6.0	511.8	783.0
5 2007	PRA 6in1 D250 2 7 R-2 (A,B)	2	250	6 in 1	curl	3.12 x 3.17	3.36 x 3.37	5.0	397.9	658.3
13 2006	PRA 4in1 D300 2 7 R (A,C)	2	300	4 in 1	curl	3.04 x 2.93	3.33 x 3.32	7.0	233.3	352.5
8 2007	PRA 4in1 D300 2 7 R (A,B)	2	300	4 in 1	curl	2.87 x 3.30	2.87 x 3.36	7.2	296.9	471.4
9 2007	PRA 6in1 D300 2 7 R-2 (A,B)	2	300	6 in 1	curl	3.26 x 3.14	3.35 x 3.34	6.4	343.6	592.9
10 2007	PRA 6in1 D300 2 7 R-1 (A,B)	2	300	6 in 1	curl	3.26 x 3.16	3.35 x 3.34	4.2	417.9	699.5
11 2007	PRA 4in1 D350 2 7 R-2 (A,B)	2	350	4 in 1	curl	3.16 x 3.14	3.35 x 3.34	11.9	311.6	564.4
12 2007	PRA 4in1 D350 2 7 R-1 (A,B)	2	350	4 in 1	curl	3.13 x 3.13	3.37 x 3.35	10.1	295.2	523.2
13 2007	PRA 6in1 D350 2 7 R-2 (A,B)	2	350	6 in 1	curl	2.96 x 3.06	3.30 x 3.34	5.9	342.8	593.0
14 2007	PRA 6in1 D350 2 7 R-1 (A,B)	2	350	6 in 1	curl	2.94 x 3.14	3.29 x 3.35	9.8	355.8	645.9



Table 3c. Maximum load acquired in the tests on ring panels: Double or triple time perimetal cable of length 14.0 m. 3 mm diameter wire and splice closing type.

Test number	Panel denomination	Wire diameter [mm]	Ring diameter [mm]	Panel type	Closing type	Panel dimensions $l_x \times l_y$ [m]	Centre distances between pins $l'_x \times l'_y$ [m]	Average net preload [kN]	Maximum vertical load [kN]	Maximum side reaction [kN]
15_2007	PRA_4in1_D300_3_7_I-1 (A,1,D)	3	300	4 in 1	splice	3.13 x 3.18	3.36 x 3.36	9.6	492.7 (474.5)	728.3 (690.1)
16_2007	PRA_4in1_D300_3_7_I-2 (A,D)	3	300	4 in 1	splice	2.86 x 2.98	3.30 x 3.33	13.0	497.9	681.0
17_2007	PRA_6in1_D300_3_7_I-1 (B,2,D)	3	300	6 in 1	splice	2.86 x 2.98	3.30 x 3.33	10.2	869.4	1066.5
18_2007	PRA_6in1_D300_3_7_I-2 (B,2,D)	3	300	6 in 1	splice	3.06 x 3.05	3.29 x 3.30	12.5	761.9	1012.7
19_2007	PRA_6in1_D350_3_7_I-1 (B,D)	3	350	6 in 1	splice	3.29 x 3.25	3.32 x 3.36	16.9	536.6	830.9
20_2007	PRA_4in1_D350_3_7_I-1 (B,D)	3	350	4 in 1	splice	3.29 x 3.29	3.33 x 3.34	6.9	474.3	727.0
21_2007	PRA_4in1_D350_3_7_I-2 (B,2,D)	3	350	4 in 1	splice	3.16 x 3.20	3.32 x 3.33	26.9	754.3	1097.8
21_2006	PRA_4in1_D350_3_7_I (A,C)	3	350	4 in 1	splice	2.88 x 2.97	3.31 x 3.34	7.0	498.9	698.2

Table 3d. Maximum load acquired in the tests on ring panels: Double or triple time perimetal cable of length 14.0 m. 4 mm diameter wire and splice closing type.

Test number	Panel denomination	Wire diameter [mm]	Ring diameter [mm]	Panel type	Closing type	Panel dimensions $l_x \times l_y$ [m]	Centre distances between pins $l'_x \times l'_y$ [m]	Average net preload [kN]	Maximum vertical load [kN]	Maximum side reaction [kN]
24_2006	PRA_4in1_D300_4_7_I (A,C)	4	300	4 in 1	splice	3.28 x 3.31	2.64 x 2.80	7.0	769.7	890.3
25_2006	PRA_4in1_D300_4_7_I (A,C)	4	300	4 in 1	splice	3.27 x 3.29	2.79 x 2.68	7.0	759.2	877.0
24_2007	PRA_6in1_D300_4_7_I-2 (B,2,D)	4	300	6 in 1	splice	3.03 x 3.02	3.27 x 3.35	31.1	692.2	965.3
25_2007	PRA_6in1_D300_4_7_I-1 (B,2,D)	4	300	6 in 1	splice	3.02 x 3.03	3.29 x 3.34	24.8	793.8	1044.8
22_2006	PRA_4in1_D350_4_7_I (A,C)	4	350	4 in 1	splice	3.29 x 3.22	2.77 x 2.90	7.0	571.0	709.4
23_2006	PRA_4in1_D350_4_7_I (A,C)	4	350	4 in 1	splice	3.29 x 3.33	2.92 x 2.82	7.0	631.3	792.2
22_2007	PRA_6in1_D350_4_7_I-1 (B,2,D)	4	350	6 in 1	splice	2.94 x 3.09	3.29 x 3.34	16.7	717.2	975.2
23_2007	PRA_6in1_D350_4_7_I-2 (B,2,D)	4	350	6 in 1	splice	2.95 x 3.05	3.32 x 3.33	12.0	716.1	975.7

Note 1. The net hasn't reached the collapse at the first loading ramp; the test was repeated and the failure load resulted lower than that at the previous cycle. The maximum load is reported in the table; in brackets the load reached in the repetition cycle is reported.

Note 2. The net hasn't reached the collapse for the maximum test load, reported in the relevant position.

Note A. The perimetal cable was wound two times.

Note B. The perimetal cable was wound three times.

Note C. The tests belong to the first series.

Note D. The tests to the second series.



Table 4. Maximum load acquired in the tests on cable panels: Double or triple time perimeteral cable of length 14.0 m. 2 mm diameter wire and splice closing type.

Test number	Specimen number	Panel denomination	Panel dimensions $l_x \times l_y$ [m]	Centre distances between pins $l'_x \times l'_y$ [m]	Average net preload [kN]	Maximum vertical load [kN]	Maximum side reaction: average value [kN]
29 2006	B3	PFA M250 F8	3.18 x 3.28	3.35 x 3.40	11.17	152.3	414.7
30 2006	B2	PFA M250 F8	3.18 x 3.31	3.34 x 3.40	11.50	168.5	419.1
31 2006	B1	PFA M250 F8	3.25 x 3.29	3.38 x 3.38	13.47	195.3	478.0
26 2006	B3	PFA M300 F8	3.20 x 3.28	3.37 x 3.39	6.66	181.3	435.9
27 2006	B1	PFA M300 F8	3.20 x 3.29	3.38 x 3.39	6.30	191.2	458.3
28 2006	B2	PFA M300 F8	3.20 x 3.29	3.36 x 3.40	5.38	191.0	441.5
32 2006	B3	PFA M400 F8	3.14 x 3.30	3.35 x 3.39	13.63	97.7	312.0
33 2006	B2	PFA M400 F8	3.19 x 3.30	3.35 x 3.39	7.59	169.7	426.2
34 2006	B1	PFA M400 F8	3.23 x 3.32	3.34 x 3.39	10.50	141.7	379.2

THE TECHNICIAN

Mr. *Corradini Luca*

THE RESPONSIBLE OF THE TEST

Eng. *Marco Moffinari*

THE RESPONSIBLE OF THE LABORATORY

Prof. *Eng. Riccardo Zanconini*

THE DEPUTY DIRECTOR OF THE DEPARTMENT

Prof. *Eng. Oreste S. Bursi*



PROVINCIA AUTONOMA DI TRENTO
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LA.T.I.F.
LABORATORIO TECNOLOGICO IMPIANTI A FUNE

Via Provina, 24 - 38040 Ravina di Trento - tel. 0461/495129 - Fax 0461/910440
P. Iva 00337460224 E-mail: labor.latif@provincia.tn.it

RAPPORTO DI PROVA n° 139/08
TEST REPORT n° 139/08

TIPO: Barriere paramassi - prove su elementi costitutivi
TYPE: *Rockfall barriers and protections – tests on elements*

OGGETTO: Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi
OBJECT: e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio $\varnothing_{\text{filo}}$ 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{\text{trefolo}}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm
Sample of ring net panel. The sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm.

COMMITTENTE: Officine **Maccaferri S.p.A.** Bologna
CLIENT:

Questo Rapporto di Prova è costituito da: numero 5 pagine numerate
This Test Report is made of: # 5 numbered pages
numero 0 pagine allegate
0 pages for annexes

Luogo e data di emissione / *Place and date*

Trento, 02/09/2008



Per il Direttore del Laboratorio / *For The Lab Director*
dott. ing. Fabio Degasperi
il Dirigente / *the Leader*
dott. ing. Agostino Dallago

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1. Dati generali / General data

1.1. Committente / Client

OFFICINE MACCAFERRI S.p.A., Via degli Agresti, 6, 40123 - Bologna - Italy

1.2. Oggetto della Prova / Tested element

Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio \varnothing_{filo} 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{trefolo}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm. Il richiedente dichiara che la resistenza del filo d'acciaio costituente l'anello è 1570 N/mm².

1 ring net specimens. Each sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm. The client declares that the steel wire resistance is 1570 N/mm².

1.3. Identificazione del Campione / Sample Identification

Tre anelli di fune spiroidale concatenati.

Three ring chain made with spiral rope.

1.4. Data di ricezione del Campione o/o richiesta prove / Specimen shipment data and/or test request form data

Campioni pervenuti il 25/09/2008, con richiesta prove (prot. n. 417).

Specimen supplied on September 25th, 2008, with the test request form (prot. n. 417)

1.5. Codice identificativo assegnato sul registro di accettazione del Laboratorio / Sample Id code on the Laboratory acceptance registry

122/08_A

1.6. Campionamento / Sampling

Prelievo effettuato a cura del Committente

Sampling made by the client

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. ing. Fabio Degasperl

il Dirigente/the Leader

dott. ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

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2. Modalità di Prova / Test method

2.1. Metodo di prova utilizzato / Test standards and guidelines

Le prove sono state eseguite con riferimento alle seguenti norme:

- ETAG 027/2008: Guida al rilascio del benessere tecnico europeo di Kit di barriere paramassi
- Procedura interna PT-06 Barriere paramassi - Prove sugli elementi costitutivi.

Per fissare il campione all'apparato di trazione, sono stati utilizzati perni di diametro 70 mm.

Tests were performed in accordance with the following standards:

- *ETAG 027/2008: Guideline for european technical approval of falling rock protection kits*
- *Internal procedure PT-06 Rockfall barriers – Tests on elements*

In order to fix the sample to the tearing apparatus, 70 mm diam pins have been adopted.

2.2. Eventuali scostamenti dal metodo o sulla procedura di campionamento seguita / Differences, if any, on the standard test method or in the sampling procedure

Il.

2.3. Data e luogo di esecuzione della prova ed eventuale presenza di terzi / Date and place of test and witnesses, if any

Prova eseguita il 25/09/08 presso il Laboratorio Tecnologico Impianti a Funne alla presenza dell'ing. Paola Bertolo della Maccaferri S.p.a.

The test was performed on September 25th, 2008, in the LATIF (Technologic Laboratory for Cableway Systems) testing facility site. The tests were witnessed by Paola Bertolo of Officine Maccaferri S.p.A.

2.4. Documentazione fornita / Provided documentation

Nessuna

None

2.5. Strumentazione utilizzata nel corso della prova / Testing equipment used for the test

- | | |
|--|-------|
| - Macchina di prova materiali Galdabini PMOF 100 | MP-04 |
| - Galdabini PMOF 100 materials testing apparatus | MP-04 |

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. ing. Fabio Degasperì

Il Dirigente /The Leader

dott. ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

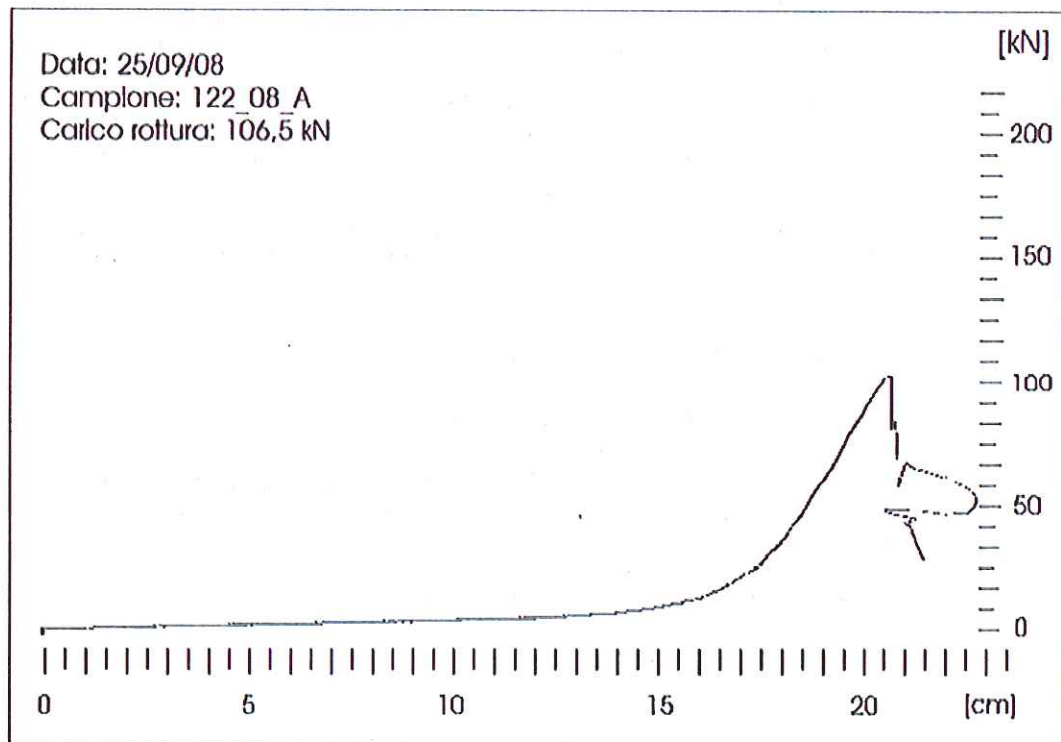
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3. Risultati delle prove / Testing results

3.1. Determinazione del carico massimo a trazione su anelli di fune / Ring chain tension test results

Codice Identificativo ID code	$\varnothing_{\text{filo}}$ prima della prova $\varnothing_{\text{filo}}$ before the test	Carico di rottura (kN) Failure load (kN)
122/08_A	3,47 mm	106,5 kN



Graph 1 – Sample 122/08_A load-displacement curve

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. ing. Fabio Degasperi

il Dirigente/ the Leader

dott. ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

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4. Documentazione fotografica / Photo report



Fig. 1 Campione 122/08_A in macchina di prova
122/08_A sample installed in test apparatus

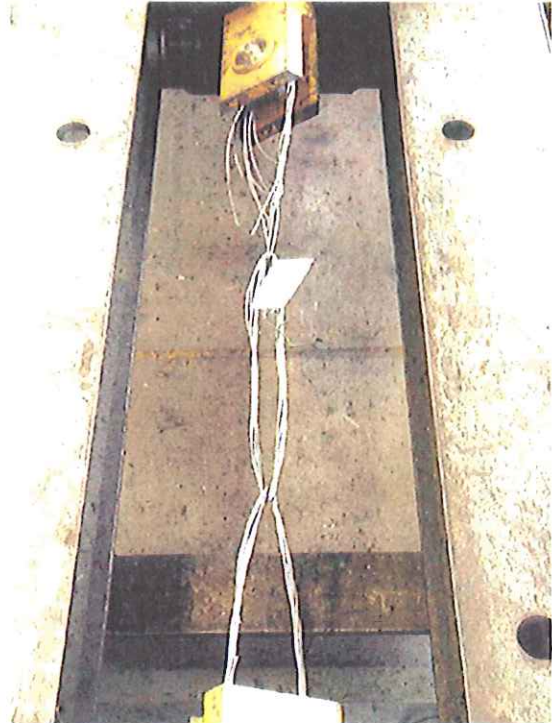


Fig. 2 Campione 122/08_A dopo prova
122/08_A sample after the test

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. Ing. Fabio Degasperl

Il Dirigente /The Leader

dott. Ing. Agostino Dallago

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P. Iva 00337460224 E-mail: labor.latif@provincia.tn.it

RAPPORTO DI PROVA n° 141/08
TEST REPORT n° 141/08

TIPO: Barriere paramassi - prove su elementi costitutivi
TYPE: *Rockfall barriers and protections – tests on elements*

OGGETTO: Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi
OBJECT: e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio $\varnothing_{\text{filo}}$ 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{\text{trefolo}}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm
Sample of ring net panel. The sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm.

COMMITTENTE: Officine **Maccaferri S.p.A.** Bologna
CLIENT:

Questo Rapporto di Prova è costituito da: numero 5 pagine numerate
This Test Report is made of: # 5 numbered pages
numero 0 pagine allegare
0 pages for annexes

Luogo e data di emissione / Place and date

Trento, 02/09/2008



Per il Direttore del Laboratorio / For The Lab Director
dott. ing. Fabio Dejasperi
Il Dirigente / the Leader
dott. ing. Agostino Dallago



1. Dati generali / General data

1.1. Committente / Client

OFFICINE MACCAFERRI S.p.A., Via degli Agresti, 6, 40123 - Bologna - Italy

1.2. Oggetto della Prova / Tested element

Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio \varnothing_{filo} 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{trefolo}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm. Il richiedente dichiara che la resistenza del filo d'acciaio costituente l'anello è 1570 N/mm².

1 ring net specimens. Each sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm. The client declares that the steel wire resistance is 1570 N/mm².

1.3. Identificazione del Campione / Sample Identification

Tre anelli di fune spiroidale concatenati.

Three ring chain made with spiral rope.

1.4. Data di ricezione del Campione e/o richiesta prove / Specimen shipment data and/or test request form data

Campioni pervenuti il 25/09/2008, con richiesta prove (prot. n. 417).

Specimen supplied on September 25th, 2008, with the test request form (prot. n. 417)

1.5. Codice identificativo assegnato sul registro di accettazione del Laboratorio / Sample id code on the Laboratory acceptance registry

122/08_B

1.6. Campionamento / Sampling

Prelievo effettuato a cura del Committente

Sampling made by the client

Il Responsabile della Prova

dott. Ing. Nicola Orsi
Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director
dott. Ing. Fabio Degasperì
Il Dirigente / The Leader
dott. Ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

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2. Modalità di Prova / Test method

2.1. Metodo di prova utilizzato / Test standards and guidelines

Le prove sono state eseguite con riferimento alle seguenti norme:

- ETAG 027/2008: Guida al rilascio del benessere tecnico europeo di Kit di barriere paramassi
- Procedura Interna PT-06 Barriere paramassi - Prove sugli elementi costitutivi.

Per fissare il campione all'apparato di trazione, sono stati utilizzati perni di diametro 70 mm.

Tests were performed in accordance with the following standards:

- *ETAG 027/2008: Guideline for european technical approval of falling rock protection kits*
- *Internal procedure PT-06 Rockfall barriers – Tests on elements*

In order to fix the sample to the tearing apparatus, 70 mm diam pins have been adopted.

2.2. Eventuali scostamenti dal metodo o sulla procedura di campionamento seguita / Differences, if any, on the standard test method or in the sampling procedure

//.

2.3. Data e luogo di esecuzione della prova ed eventuale presenza di terzi / Date and place of test and witnesses, if any

Prova eseguita il 25/09/08 presso il Laboratorio Tecnologico Impianti a Funi alla presenza dell'ing. Paola Bertolo della Maccaferri S.p.a.

The test was performed on September 25th, 2008, in the LATIF (Technologic Laboratory for Cableway Systems) testing facility site. The tests were witnessed by Paola Bertolo of Officine Maccaferri S.p.A.

2.4. Documentazione fornita / Provided documentatlon

Nessuna

None

2.5. Strumentazione utilizzata nel corso della prova / Testing equipment used for the test

- | | |
|--|-------|
| - Macchina di prova materiali Galdabini PMOF 100 | MP-04 |
| - Galdabini PMOF 100 materials testing apparatus | MP-04 |

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director
dott. Ing. Fabio Degasperì
il Dirigente / the Leader
dott. Ing. Agostino Dallago

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3. Risultati delle prove / Testing results

3.1. Determinazione del carico massimo a trazione su anelli di fune / Ring chain tension test results

Codice Identificativo ID code	\varnothing_{fibo} prima della prova \varnothing_{fibo} before the test	Carico di rottura (kN) Failure load (kN)
122/08_B	3,47 mm	97,0 kN

Data 25/09/2008
Campione 122_08_B
Carico di rottura 97,00 kN

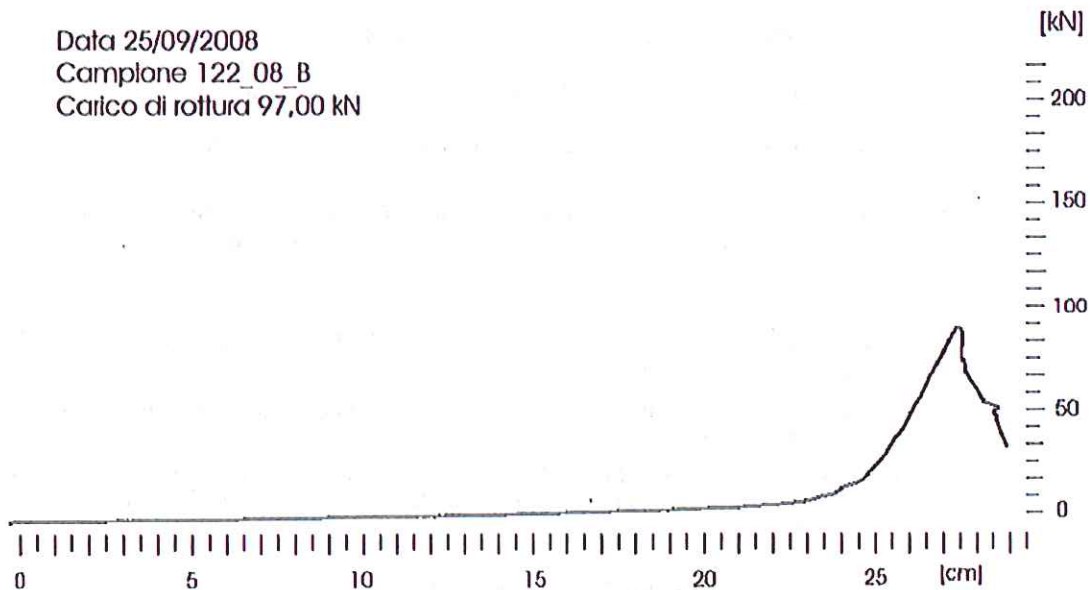


Diagramma 1 carico-corsa campione 122/08_B

Graph 1 - Sample 122/08_B load-displacement curve

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. Ing. Fabio Pedasperi

il Dirigente / the Leader

dott. Ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

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4. Documentazione fotografica / Photo report

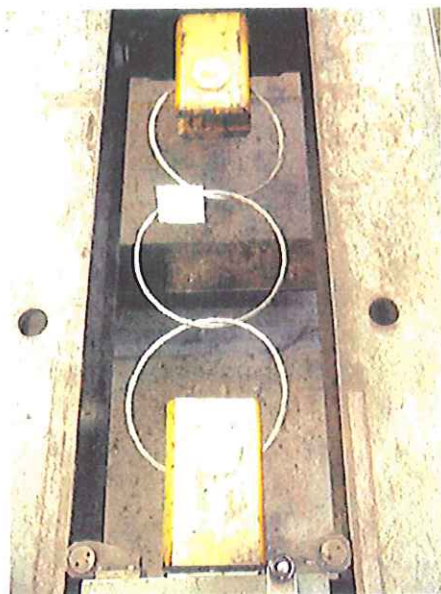


Fig. 1 Campione 122/08_B in macchina di prova
122/08_B sample installed in test apparatus

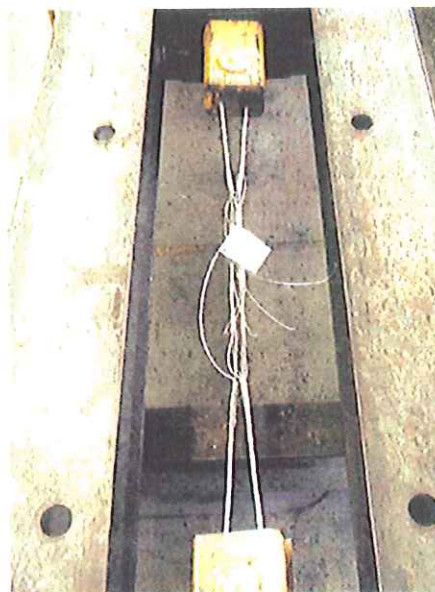


Fig. 2 Campione 122/08_B dopo prova
122/08_B sample after the test

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. ing. Fabio Degasperì

Il Dirigente / the Leader

dott. ing. Agostino Dallago

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PROVINCIA AUTONOMA DI TRENTO
SERVIZIO IMPIANTI A FUNE



L.A.T.I.F.
LABORATORIO TECNOLOGICO IMPIANTI A FUNE

Via Provina, 24 - 38040 Ravina di Trento - tel. 0461/495129 - Fax 0461/910440
P. Iva 00337460224 E-mail: labor.lalif@provincia.tn.it

RAPPORTO DI PROVA n° 142/08
TEST REPORT n° 142/08

TIPO: Barriere paramassi - prove su elementi costitutivi
TYPE: *Rockfall barriers and protections – tests on elements*

OGGETTO: Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi
OBJECT: e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio $\varnothing_{\text{filo}}$ 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{\text{trefolo}}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm
Sample of ring net panel. The sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm.

COMMITTENTE: Officine Maccaferri S.p.A. Bologna
CLIENT:

Questo Rapporto di Prova è costituito da: numero 5 pagine numerate
This Test Report is made of: # 5 numbered pages
numero 0 pagine allegate
0 pages for annexes

Luogo e data di emissione / *Place and date*

Trento, 02/09/2008



Per il Direttore del Laboratorio / *For The Lab Director*

dott. ing. Fabio Degasperì
il Dirigente / *The Leader*
dott. ing. Agostino Dallago



1. Dati generali / General data

1.1. Committente / Client

OFFICINE MACCAFERRI S.p.A., Via degli Agresti, 6, 40123 - Bologna - Italy

1.2. Oggetto della Prova / Tested element

Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio \varnothing_{filo} 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{trefolo}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm. Il richiedente dichiara che la resistenza del filo d'acciaio costituente l'anello è 1570 N/mm².

1 ring net specimens. Each sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm. The client declares that the steel wire resistance is 1570 N/mm².

1.3. Identificazione del Campione / Sample Identification

Tre anelli di fune spirale concatenati.

Three ring chain made with spiral rope.

1.4. Data di ricezione del Campione e/o richiesta prove / Specimen shipment data and/or test request form data

Campioni pervenuti il 25/09/2008, con richiesta prove (prot. n. 417).

Specimen supplied on September 25th, 2008, with the test request form (prot. n. 417)

1.5. Codice identificativo assegnato sul registro di accettazione del Laboratorio / Sample Id code on the Laboratory acceptance registry

122/08_C

1.6. Campionamento / Sampling

Prelievo effettuato a cura del Committente

Sampling made by the client

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. ing. Fabio Regasperi

Il Dirigente / The Leader

dott. ing. Agostino Dallago

Questo Rapporto di Prova riguarda esclusivamente il campione sottoposto a prova.

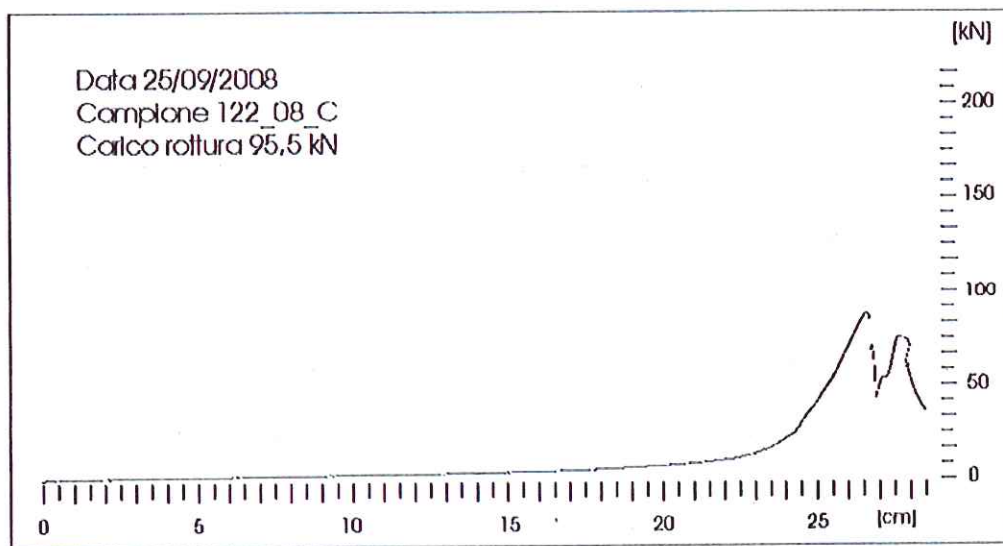
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3. Risultati delle prove / *Testing results*

3.1. Determinazione del carico massimo a trazione su anelli di fune / *Ring chain tension test results*

Codice Identificativo <i>ID code</i>	$\varnothing_{\text{filo}}$ prima della prova $\varnothing_{\text{filo}}$ before the test	Carico di rottura (kN) <i>Failure load (kN)</i>
122/08_C	3,48 mm	95,5 kN kN



Graph 1 – Sample 122/08_C load-displacement curve

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. Ing. Fabio Degasperis

Il Dirigente/In Charge

dott. Ing. Agostino Dallago

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2. Modalità di Prova / Test method

2.1. Metodo di prova utilizzato / Test standards and guidelines

Le prove sono state eseguite con riferimento alle seguenti norme:

- ETAG 027/2008: Guida al rilascio del benessere tecnico europeo di Kit di barriere paramassi
- Procedura interna PT-06 Barriere paramassi - Prove sugli elementi costitutivi.

Per fissare il campione all'apparato di trazione, sono stati utilizzati perni di diametro 70 mm.

Tests were performed in accordance with the following standards:

- *ETAG 027/2008: Guideline for european technical approval of falling rock protection kits*
- *Internal procedure PT-06 Rockfall barriers -- Tests on elements*

In order to fix the sample to the tearing apparatus, 70 mm diam pins have been adopted.

2.2. Eventuali scostamenti dal metodo o sulla procedura di campionamento seguita / Differences, if any, on the standard test method or in the sampling procedure

//.

2.3. Data e luogo di esecuzione della prova ed eventuale presenza di terzi / Date and place of test and witnesses, if any

Prova eseguita il 25/09/08 presso il Laboratorio Tecnologico Impianti a Funne alla presenza dell'ing. Paola Bertolo della Maccaferri S.p.a.

The test was performed on September 25th, 2008, in the LATIF (Technologic Laboratory for Cableway Systems) testing facility site. The tests were witnessed by Paola Bertolo of Officine Maccaferri S.p.A.

2.4. Documentazione fornita / Provided documentation

Nessuna

None

2.5. Strumentazione utilizzata nel corso della prova / Testing equipment used for the test

- | | |
|--|-------|
| - Macchina di prova materiali Galdabini PMOF 100 | MP-04 |
| - Galdabini PMOF 100 materials testing apparatus | MP-04 |

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. Ing. Fabio Degasperi

Il Dirigente / The Leader

dott. Ing. Agostino Dallago

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4. Documentazione fotografica / Photo report



Fig. 1 Campione 122/08_C in macchina di prova
122/08_C sample installed in test apparatus

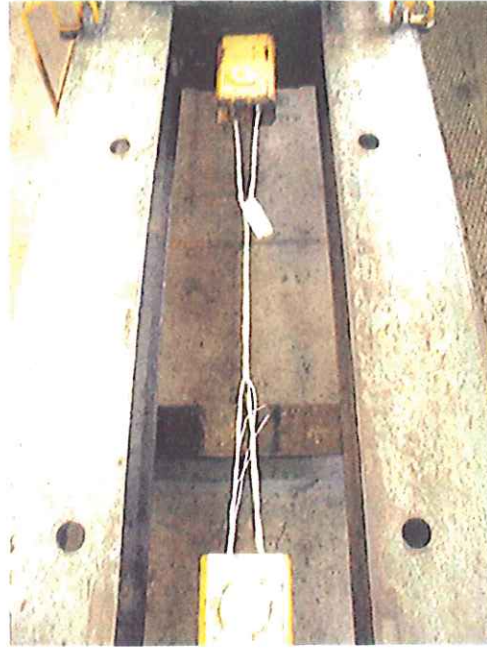


Fig. 2 Campione 122/08_C dopo prova
122/08_C sample after the test

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. ing. Fabio Degasperis

il Dirigente /the Leader

dott. ing. Agostino Dallago

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Via Provina, 24 - 38040 Ravina di Trento - tel. 0461/495129 - Fax 0461/910440
P. Iva 00337460224 E-mail: labor.latif@provincia.tn.it

RAPPORTO DI PROVA n° 143/08
TEST REPORT n° 143/08

TIPO: Barriere paramassi - prove su elementi costitutivi
TYPE: *Rockfall barriers and protections – tests on elements*

OGGETTO: Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi
OBJECT: e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio $\varnothing_{\text{filo}}$ 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{\text{trefolo}}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm
Sample of ring net panel. The sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm.

COMMITTENTE: Officine Maccaferri S.p.A. Bologna
CLIENT:

Questo Rapporto di Prova è costituito da: numero 5 pagine numerate
This Test Report is made of: # 5 numbered pages
numero 0 pagine allegate
0 pages for annexes

Luogo e data di emissione / Place and date

Trento, 02/09/2008



Per il Direttore del Laboratorio /For The Lab Director
dott. ing. Fabio Degasperì
il Dirigente /The Leader
dott. ing. Agostino Dallago

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1. Dati generali / General data

1.1. Committente / Client

OFFICINE MACCAFERRI S.p.A., Via degli Agresti, 6, 40123 - Bologna - Italy

1.2. Oggetto della Prova / Tested element

Porzione di rete ad anelli formata da catena di n° 3 anelli chiusi e concatenati. Ogni anello è costituito da filo di acciaio di diametro medio \varnothing_{filo} 3,5 mm avvolto su se stesso 7 volte e chiuso a formare un trefolo di diametro $\varnothing_{trefolo}$ 10,5 mm. Il diametro medio di ogni anello è di 350 mm. Il richiedente dichiara che la resistenza del filo d'acciaio costituente l'anello è 1570 N/mm².

1 ring net specimens. Each sample is made of three closed rings connected together forming a chain. Each ring is made by a single continuous 3.50 mm medium diameter wire, wrapped on itself 7 times to form a 10.5 mm diameter rope. The ring medium diameter is 350 mm. The client declares that the steel wire resistance is 1570 N/mm².

1.3. Identificazione del Campione / Sample Identification

Tre anelli di fune spiroidale concatenati.

Three ring chain made with spiral rope.

1.4. Data di ricezione del Campione e/o richiesta prove / Specimen shipment data and/or test request form data

Campioni pervenuti il 25/09/2008, con richiesta prove (prot. n. 417).

Specimen supplied on September 25th, 2008, with the test request form (prot. n. 417)

1.5. Codice identificativo assegnato sul registro di accettazione del Laboratorio / Sample id code on the Laboratory acceptance registry

122/08_D

1.6. Campionamento / Sampling

Prelievo effettuato a cura del Committente

Sampling made by the client

Il Responsabile della Prova

dott. Ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. Ing. Fabio Degasperi

Il Dirigente / The Leader

dott. Ing. Agostino Dallago

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2. Modalità di Prova / Test method

2.1. Metodo di prova utilizzato / Test standards and guidelines

Le prove sono state eseguite con riferimento alle seguenti norme:

- ETAG 027/2008: Guida al rilascio del benessere tecnico europeo di Kit di barriere paramassi
- Procedura Interna PT-06 Barriere paramassi - Prove sugli elementi costitutivi.

Per fissare il campione all'apparato di trazione, sono stati utilizzati perni di diametro 70 mm.

Tests were performed in accordance with the following standards:

- *ETAG 027/2008: Guideline for european technical approval of falling rock protection kits*
- *Internal procedure PT-06 Rockfall barriers – Tests on elements*

In order to fix the sample to the tearing apparatus, 70 mm diam pins have been adopted.

2.2. Eventuali scostamenti dal metodo o sulla procedura di campionamento seguita / Differences, if any, on the standard test method or in the sampling procedure

Il.

2.3. Data/e e luogo di esecuzione della prova ed eventuale presenza di terzi / Date and place of test and witnesses, if any

Prova eseguita il 25/09/08 presso il Laboratorio Tecnologico Impianti a Funne alla presenza dell'ing. Paola Bertolo della Maccaferri S.p.a.

The test was performed on September 25th, 2008, in the LATIF (Technologic Laboratory for Cableway Systems) testing facility site. The tests were witnessed by Paola Bertolo of Officine Maccaferri S.p.A.

2.4. Documentazione fornita / Provided documentation

Nessuna

None

2.5. Strumentazione utilizzata nel corso della prova / Testing equipment used for the test

- | | |
|--|-------|
| - Macchina di prova materiali Galdabini PMOF 100 | MP-04 |
| - Galdabini PMOF 100 materials testing apparatus | MP-04 |

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. ing. Fabio Degasperi

Il Dirigente / The Leader

dott. ing. Agostino Dallago

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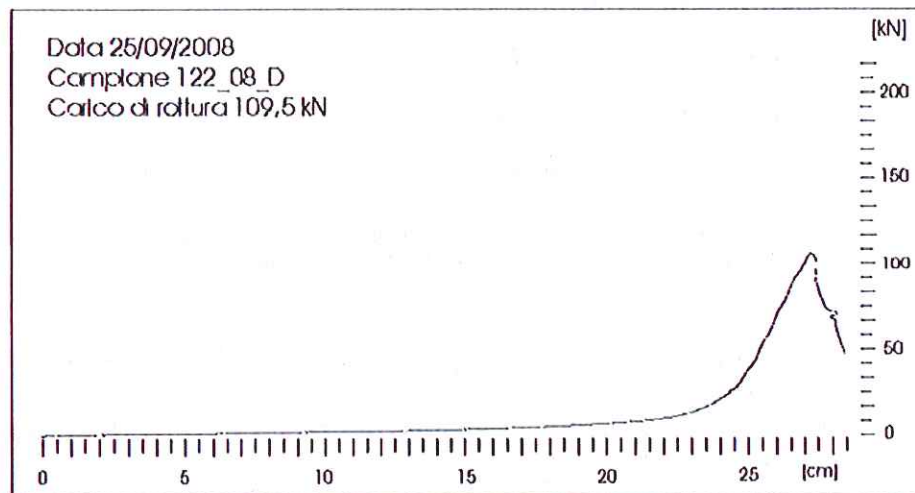
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3. Risultati delle prove / Testing results

3.1. Determinazione del carico massimo a trazione su anelli di fune / Ring chain tension test results

Codice Identificativo ID code	\varnothing_{fibo} prima della prova \varnothing_{fibo} before the test	Carico di rottura (kN) Failure load (kN)
122/08_D	3,47 mm	109,5 kN



Graph 1 – Sample 122/08_D load-displacement curve

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio /For The Lab Director

dott. ing. Fabio Degasperis

Il Dirigente/In Charge

dott. ing. Agostino Dallago

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4. Documentazione fotografica / Photo report

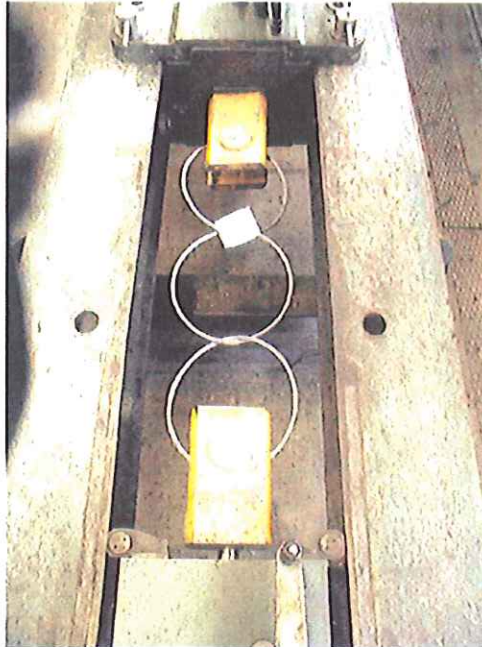


Fig. 1 Campione 122/08_D in macchina di prova
122/08_D sample installed in test apparatus

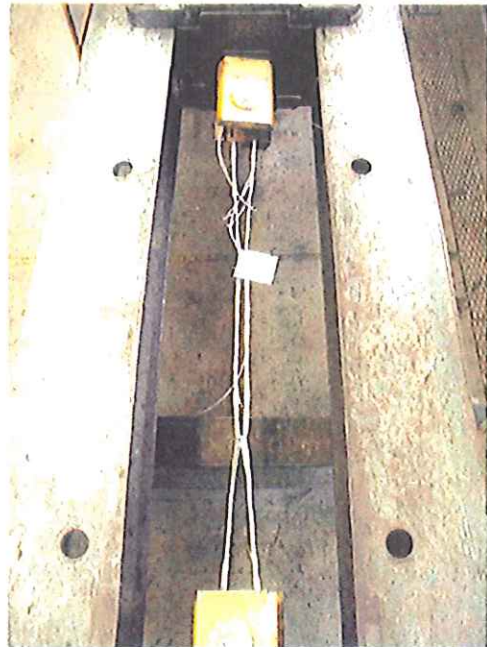


Fig. 2 Campione 122/08_D dopo prova
122/08_D sample after the test

Il Responsabile della Prova

dott. ing. Nicola Orsi



Per il Direttore del Laboratorio / For The Lab Director

dott. ing. Fabio Degasperi

Il Dirigente / The Leader

dott. ing. Agostino Dallago

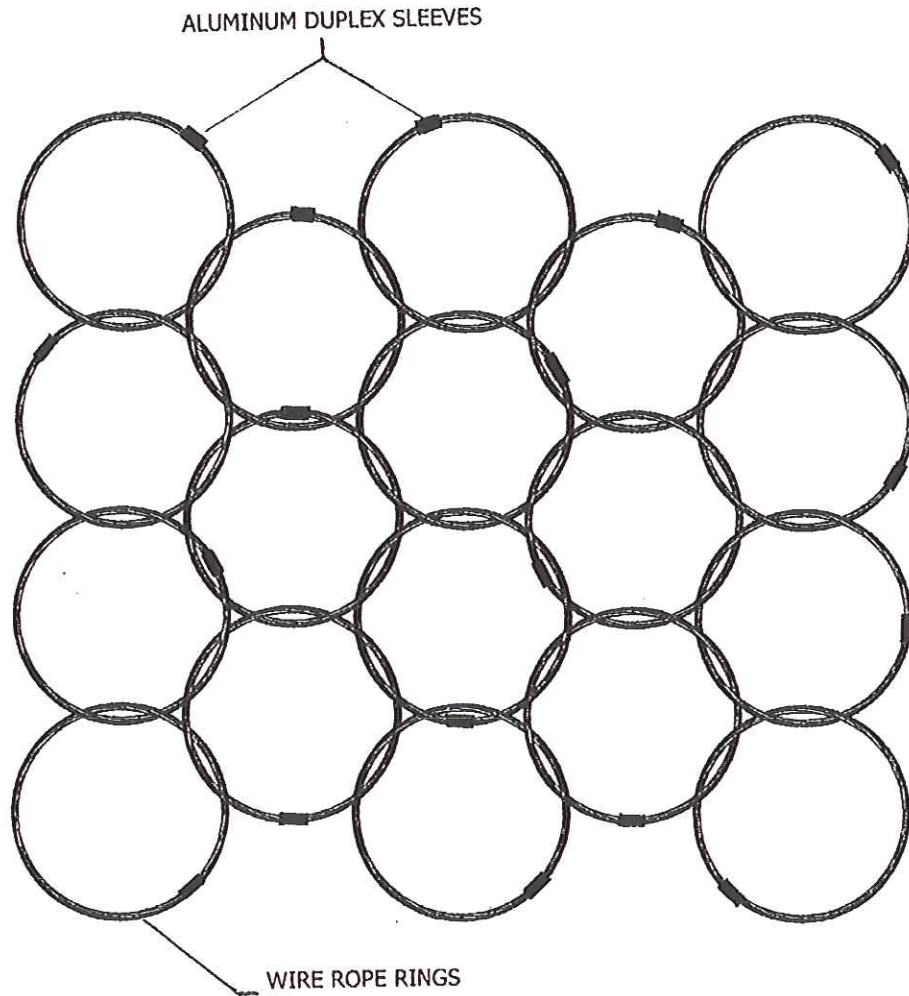
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WIRE ROPE TYPE RING NETS

APPLICATIONS: ROCKFALL BARRIERS / DEFLECTOR NET SYSTEMS
SLOPE PROTECTION SYSTEMS



RING DIAMETER	WIRE ROPE DIAMETER	WIRE ROPE NOMINAL BREAKING STRENGTH	WIRE ROPE CONSTRUCTION	ALUMINUM DUPLEX SLEEVE
12"	5/16" & 3/8"	9,800 & 14,400 LBS.	7 x 7 or 7 x 19	5/16" & 3/8"
14"	3/8" & 1/2"	14,400 & 23,600 LBS.	7 x 7 or 7 x 19	3/8" & 1/2"
16"	1/2" & 5/8"	23,600 & 41,200 LBS.	6 x 19 or 6x26	1/2" & 5/8"

GENERAL NOTE: THE RING NETS CAN BE PRODUCED DOMESTICALLY AND/OR CAN BE IMPORTED.

**CABLE
MOORE,
INC.**
RIGGING AND MACHINING



Test Certificate No 58626

CHAMA VALLEY

Form No. 4

This certificate when properly executed by a competent person is accepted by the Government of the United States of America as being in accordance with the requirements of 46 CFR 91.25(a)3, 71.25-25(a)5, & 29 CFR 9.12(a)

DESCRIPTION OF GEAR	NUMBER TESTED	DATE	PROOF LOAD
5/16" 7X19 GALV. A/C CABLE CUT 3 PCS 41" PRESS ONE SLEEVE 5/16" ALUM INTO 3 CIRCLE IN LOCKING WITH DIE # 05-10-2 ON A PRO-MAC PRESS	1 EA	8/14/08	7,000/LBS HELD FOR 1 MIN

TOOK TO DESTRUCTION – BROKE @ 13,000/LBS

Name and address of makers or suppliers: CABLE MOORE, INC.
1425 5TH STREET / OAKLAND, CA 94607

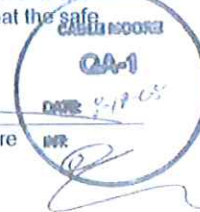
Name and address of public service, association, company or firm making the test and examination: CABLE MOORE 1425 - 5TH ST OAKLAND CA 94607

Position of signatory in public service, association, company or firm: Q.C. MANGER

I certify on the 14TH DAY OF AUGUST 2008, the above gear was tested and examined by a competent person in the Manner set forth on this certificate that the examination showed that the said gear withstood the proof load without injury or Deformation; and that the safe working load of said gear is shown.

Date: 8-17-08

Signature: 
Greg Moore



tere@cablemoore.com

CERTIFIED: SBE, WBE, MBE, HUBZONE & CCR REGISTERED
PO BOX 23036 OAKLAND, CA 94623-0036 (510) 272-0218 / (510) 832-0121

Weisner, Inc.
 DIVISION
Weisner Steel Products, Inc.
 77 MORAGA WAY, SUITE F, ORINDA, CA 94563-3019
 Phone: (925) 254-6800 Fax: (925) 254-6523
 WWW.WEISNERSTEEL.COM

MILL CERTIFICATES

Length of rope.	5000	FT
Rope diameter.	5/16	INCH
Construction.	7X19	
Kind of core.	IWSC	
Surface of wire rope.	HDG	
Nominal tensile strength.		
Nominal breaking force.	9,800	LBS.
Actual breaking force.	9,900	LBS
Lay.	RHRL	
Total weight.	16,539	KGS
Amount of reel.	45	
Reel No.	1-45	
Lube.	DRY	
Delivery date.	Apr. 04, 2008	

The manufactured and delivered wire ropes of above indicated order correspond with the technical term of delivery according to FEDERAL SPEC. RR-W-410E.

CHEMICAL ANALYSIS OF WIRE ROD

Chemical composition (%)

C	Mn	S	P	SI
0.68	0.57	0.008	0.002	0.19



9A-0035



ISO



MD00/3085/0001/11