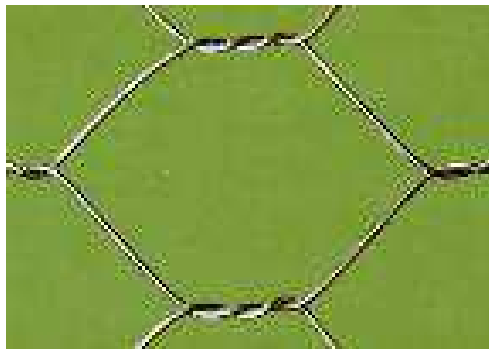


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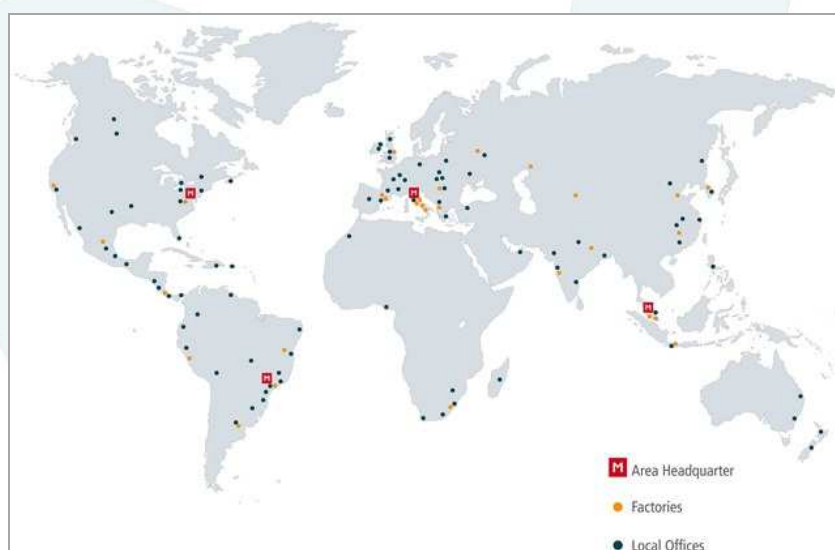
Installation Manual



Double Twist Mesh (Galvanized or PVC)

Table of Contents

1. Introduction
2. Installation Guidelines – Steelgrid HR & HR-PVC
 - a. Product Information
 - b. Definition of Installation Related Terms
 - c. Stages of Installation
 - d. Tables of Connection Specifications
3. Maintenance Information
4. Accessory Products
5. Closing Information



1) Introduction

Important notes regarding mesh installation

This document gives technical specification data and installation recommendations for the Double Twist range of mesh products.

It must be noted **that this document is NOT a design document** and is provided only for the information of engineering designers, installers and installation supervisors. Any recommendations provided in this document are provided for the purposes of information only, they are generalized and will not apply to some sites and may not be relevant under all geotechnical / geological conditions.

The information provided in this document should be used by designers and installers to help them to create a site/project-specific installation method statement that is suitable and correct for their site. The site-specific installation method statement (developed by the designer) should be checked and approved for use by suitably experienced and qualified personnel BEFORE works commence.

It must be noted that installation can be a hazardous process involving machinery, complicated processes, working at height and potentially dangerous substances. Installation should only be undertaken by suitably experienced and qualified persons using all appropriate personal protective equipment and the correct tools and machinery to the approval of the project engineer and in accordance with any prevailing local or national laws or standards/codes of practice.

The connection specifications in this document are based Maccaferri best practice guidance which is developed from extensive on site experience but also comprehensive laboratory testing. It should be noted that the client/contacter may choose to use other types of rope grips, rope connection devices or ancillary items. It should be noted however that while both Double Twist wire mesh Galvanized and PVC have been tested using different types of connection it is strongly recommended that Double Twist mesh PVC coating is only connected using PVC lacing wire or Stainless Steel fasteners rings to obtain on the connections elements the same lifespan of the mesh.

2) Installation Guidelines – Double Twist Mesh (DT)

Product Technical Information

Steel woven wire mesh is used as a drapery system to prevent rocks and debris from falling onto infrastructure and property. The mesh consists of zinc coated double twisted steel woven wire mesh manufactured in accordance with ASTM A975-97. Moreover, to increase the lifespan of the product, the wire can be additionally PVC coated.

The steel wire used in the manufacture of the mesh is heavily zinc coated soft temper steel. Due to the characteristics of the double twist, the steel wire mesh can withstand the force of falling rocks without unravelling in the event of wire breakage.

Encapsulating vegetative soil pockets under the drapery system permit the establishment of vegetation if conditions permit.

Double Twist meshes are particularly suitable for use as a rockfall protection drapery system or for improvement of surface or ‘soil veneer’ slope stability. Moreover, it can be used as a cortical stabilization/pinned drapery role.

Exposure type (combinations of extreme conditions will reduce design life)				
	ENVIRONMENTAL AGGRESSIVITY			
	VERY LOW	LOW	MEDIUM	HIGH
Water Presence	Dry	Dry	Often	Always
Saline Presence	None	None	Occasional	Often
Wind/Water carried abrasion	None	Very little	Occasional	Often
Pollutant Exposure	None	Very little	Occasional	Often
Soil Resistivity	Very low	Low	Medium	High
Product Coating	Anticipated Design Life (years)			
Zn (*)	60	25	N/R	N/R
Al/Zn (*)	120	60	N/R	N/R
Al/Zn (*) + PVC	>120	>120	120	60
Al/Zn (**) + PA6 (***)	>120	>120	>120	120

* = Coating weight as per EN 10244-2 (Table 2 - Class A)

** = Coating weight as per EN 10244-2 (Table 2 - Class E)

*** = PA6 polymer coating offers significant environmental benefits compared to PVC coatings and is recommended for use if ‘green projects’ where environmental impact is important, regardless of design life requirement.

N/R = Not recommended by Maccaferri for use in these exposure conditions

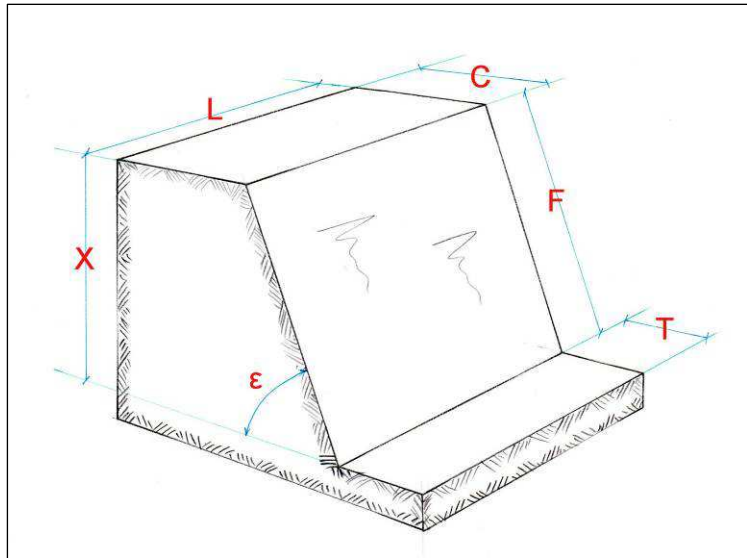
N.B. Combinations of exposure conditions can reduce the anticipated design life of the product. For technical support, on this or any other Maccaferri product, please consult your local Maccaferri office.

Definition of Installation-Related Terms

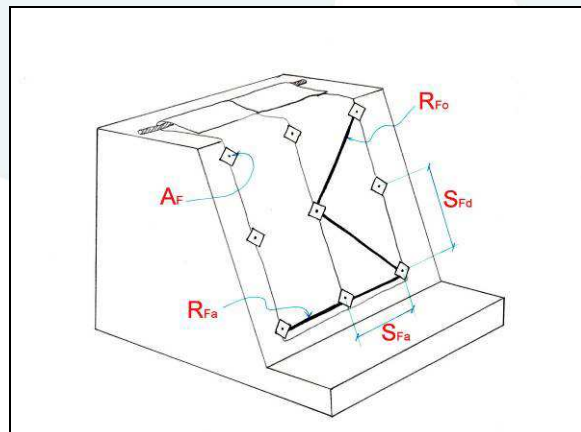
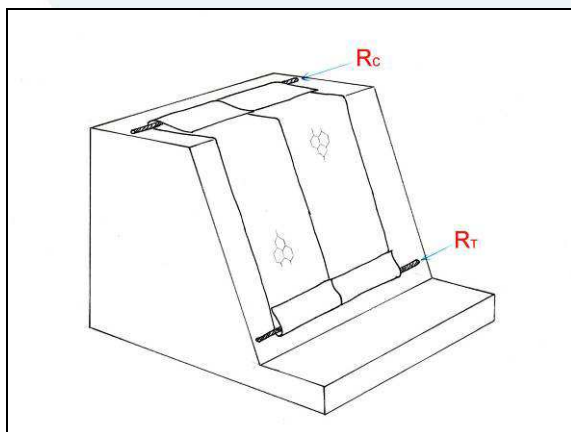
Duple Twist mesh is most commonly applied to geological or geotechnical situations and the generalized installation instructions presented in this document are related to Steelgrid HR mesh installed onto inclined rock/soil slopes. (DT mesh can also be installed in a variety of other scenarios)

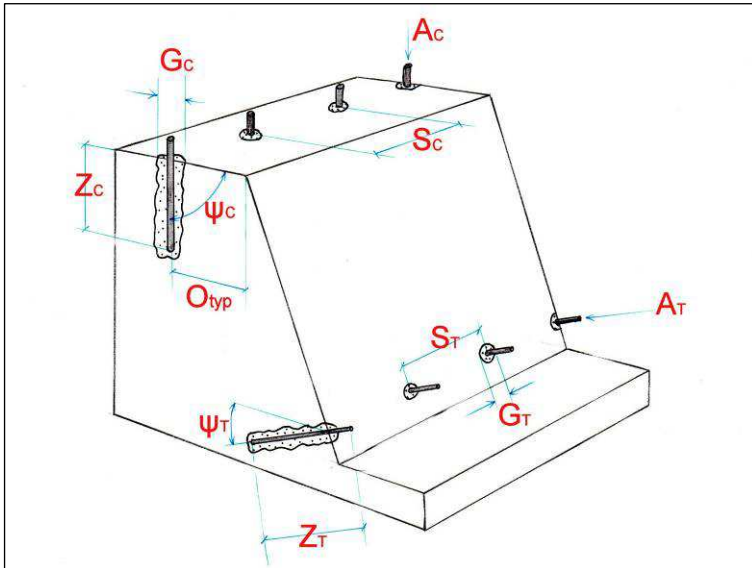
Slope terminology used in this manual includes the following:

- C** Crest area of the slope,
- F** Face of the slope
- T** Toe area of the slope
- ϵ Slope face angle
- X** Effective total height of slope
- L** Length of a slope



Mesh is most commonly installed - in geological and geotechnical situations - either as simple drapery (below left) or as cortical stabilization (below right). In simple drapery, the mesh is hung as a curtain, suspended by ropes at the crest and toe (R_C and R_T). In cortical stabilization installations the mesh curtain is additionally retained using a network of anchors (A_F) located at calculated spacings (S_{Fa} or S_{Fo}) and fitted with wire ropes (R_{Fa} or R_{Fo}).

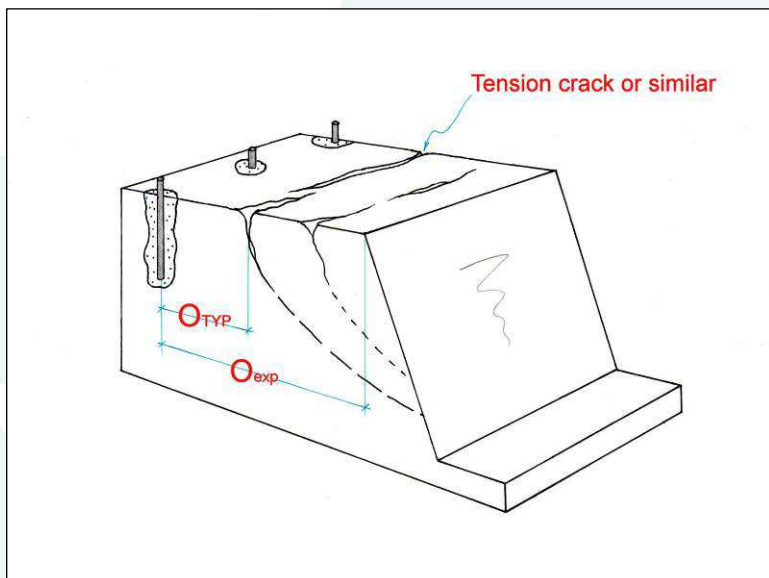




The mesh and any imposed loads are supported from anchorages. These can be positioned in the crest (A_C), toe (A_T) and face (A_F) of a slope depending on site-specific factors. Anchorages are normally placed in a line and fitted with suitable terminations (eye nuts or similar) to accept the ropes. At the toe of the slope it is also common for a

row of anchors (A_T) and a rope (R_T) to be installed however other restraints are sometimes used. **All anchorage details must be in exact accordance with the engineering design.**

It is most common for the crest anchors to be offset some distance back from the break of slope (O_{typ}). The offset (O_{typ}) will be defined by the engineer. In cases where the top of the face or the down-slope edge of the crest is unstable a larger 'exceptional' offset (O_{exp}) will be required. The layout of all anchorages must be carried out in exact accordance with the engineering design.



Suggested/sample stages of Installation

Preliminary stages (i. to iv). are pre-works stages performed by the designer:

- i. Assessment of the slope***
- ii. Preliminary design***
- iii. Detailed design & design checking***
- iv. Preparation & checking of installation method statements***

Main installation works (1-11) for both drapery and cortical stabilization systems are:

- 1. Establishment on site and negotiation of access and logistics**
- 2. Receipt of materials and checking**
- 3. Clearing slope face and crest (loose material and dense vegetation)**
- 4. Setting out of the site (anchor and rope positions etc.)**
- 5. Installation of crest-line anchors (A_C)**
- 6. Lifting, placement and temporary securing of the mesh**
- 7. Installation of crest-line rope (R_C)**
- 8. Adjustment and permanent connection of mesh runs (β)**
- 9. Permanent connection (α) of mesh to crest-line rope (R_C)**
- 10. Installation of toe-line anchors (A_T) and toe-line rope (R_T)**
- 11. Permanent connection of mesh to toe-line rope (R_T)**

Additional stages (a-d) required to convert a simple drapery into cortical stabilization are:

- a. Setting out of face anchor (A_F) positions (S_{Fa} and S_{Fd})**
- b. Drilling and securing/grouting (G_F) of face anchors (A_F)**
- c. Installation of face anchor (A_F) termination accessories**
- d. Installation, tensioning and securing of face ropes (R_{Fa}/R_{Fo})**

Installation Stages 1 to 4

1. Establishment on site and negotiation of access and logistics
2. Receipt of materials and checking
3. Clearing slope face and crest (loose material and dense vegetation)
4. Setting out of the site (anchor and rope positions etc.)

Following materials delivery all items should be checked. Items may then need to be moved to the relevant areas on the site, at times this may require the use of mechanical handling equipment such as tele-handlers or cranes (see example below).



Before the installation of any materials the crest area and slope face should be prepared.

The crest should be cleared of all significant or dense vegetation (see right) to promote easy and safe access and to enable simple manipulation and placement of mesh etc.



Following the crest clearing the slope face must be cleared by the process of “de-scaling”. This will typically include removal of loose rocks, soil and excessive vegetation growth from the slope face using hand tools such as mattocks, rakes and pry-bars. This work must be overseen by the engineer and care should be taken to avoid excessive material removal.



Sometimes more robust methods of de-scaling may be required including mechanical methods, pneumatic or hydraulic jacking (pictured below) or controlled blasting. Safe methods of working must be developed and approved before the start of works and all necessary safety precautions must be taken.

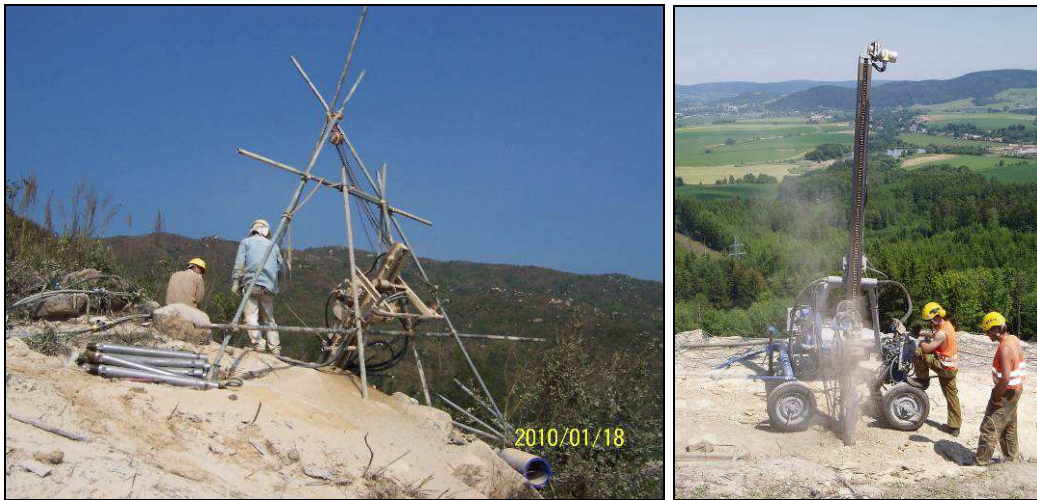


In some cases vulnerable infrastructure below the slope may require protection. This can include proprietary Maccaferri dynamic rockfall barriers installed below the works area.

Installation Stage 5

5. Installation of crest-line anchors

The drilling procedure should be carried out by suitably qualified personnel using equipment appropriate to the type of anchors specified by the engineer in the geotechnical design. Drilling may be carried out either by hand held equipment or using mechanized equipment (pictured below) to the approval of the engineer.



Following drilling of the holes, the anchors should be secured into the slope, this is most commonly carried out by the introduction of either polymeric resin or cement based grout - all anchor and grout details all specified by the engineering design.

For particular application of simple drapery systems, anchor properties (i.e. high strength and flexibility) may need to be enhanced to the stage that cable/rope anchors are required such as those offered by Maccaferri (i.e. ICAF-44 anchor shown below).



Installation Stage 6 & 7

- 1. Lifting, placement and temporary securing of the mesh**
- 2. Installation of crest-line rope (R_C)**

The runs of mesh should be placed into a suitable position on the slope to allow for temporary securing BEFORE installation of the top rope.

Two methods are commonly used to place the mesh “**bottom-up**” and “**top-down**”. “**Bottom-up**” involves moving the rolls to the base of the slope face and then lifting the runs up towards the crestline - lifting the rolls using winches, mechanical lifting equipment such as cranes or tele-handlers or through the use of helicopters (shown below).



“**Top-down**” installation involves transporting the rolls to the crest-line of the slope and guiding them down the face to un-roll them into position (see below).



Following un-rolling and positioning of the mesh, the top rope should be installed. The specification, corrosion protection and diameter of the crestline rope (R_C) will be specified in the engineering design. It is normal practice for the crest-line rope to be divided up along the length (L) of the mesh installation. This helps to increase the overall factor of the safety of the whole installation and makes installation easier.

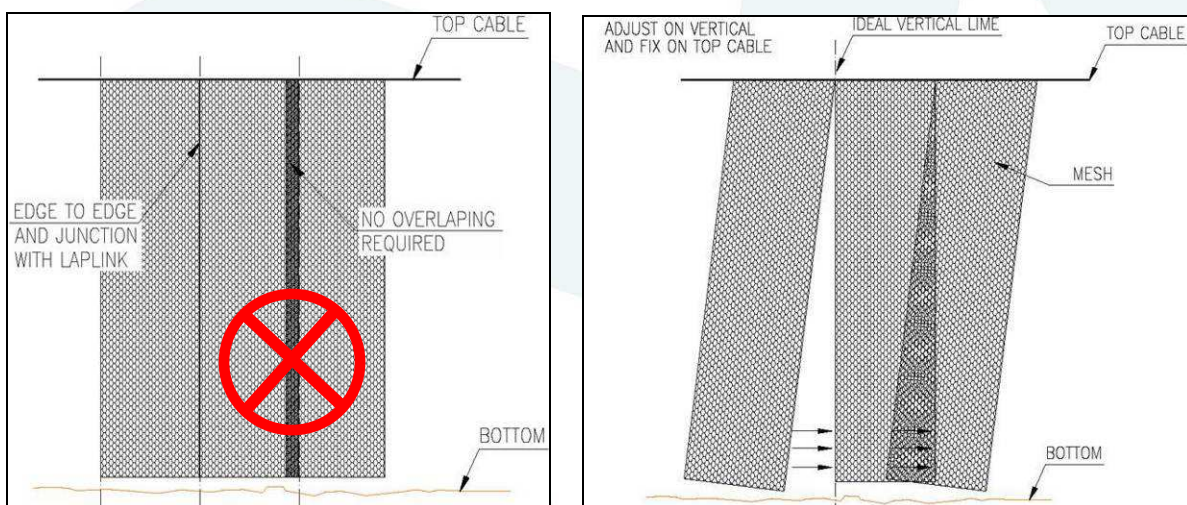
Installation Stage 8

8. Adjustment and permanent inter-connection of mesh runs

Following the installation of the crest-line rope it is necessary to carry out adjustment of the position of the mesh. This process is most frequent performed either by roped access personnel descending down across the mesh (below) however in some circumstances it can also be achieved from the basket of a ‘cherry picker’ or mobile access platform (below).



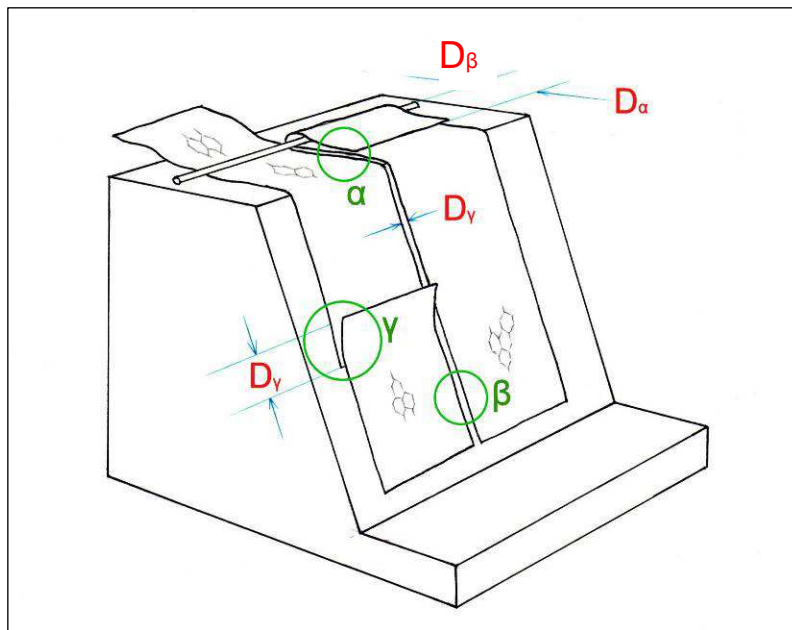
During adjustment excess slack should be removed from the mesh, the panels should be aligned to the desired orientation and any overlaps removed (below left). Any gaps that arise due to the surface topography of the slope face (below right) should be closed with a lacing of steel wire rope to the engineer’s approval (typically a similar grade and diameter to the mesh selvedge rope will be used for this purpose).



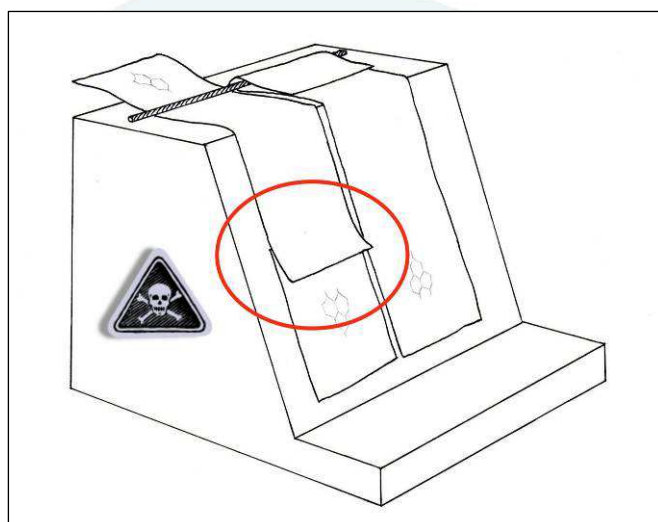
For the permanent connection of the mesh panels three types of connection are used (below) **Crest-line / overlap – ‘α’ connections** (these can be considered as similar to those required at the toe-line ropes), **Lateral / butt – ‘β’ connections** and **Longitudinal / lap – ‘γ’ connections**.

Lacing Operations

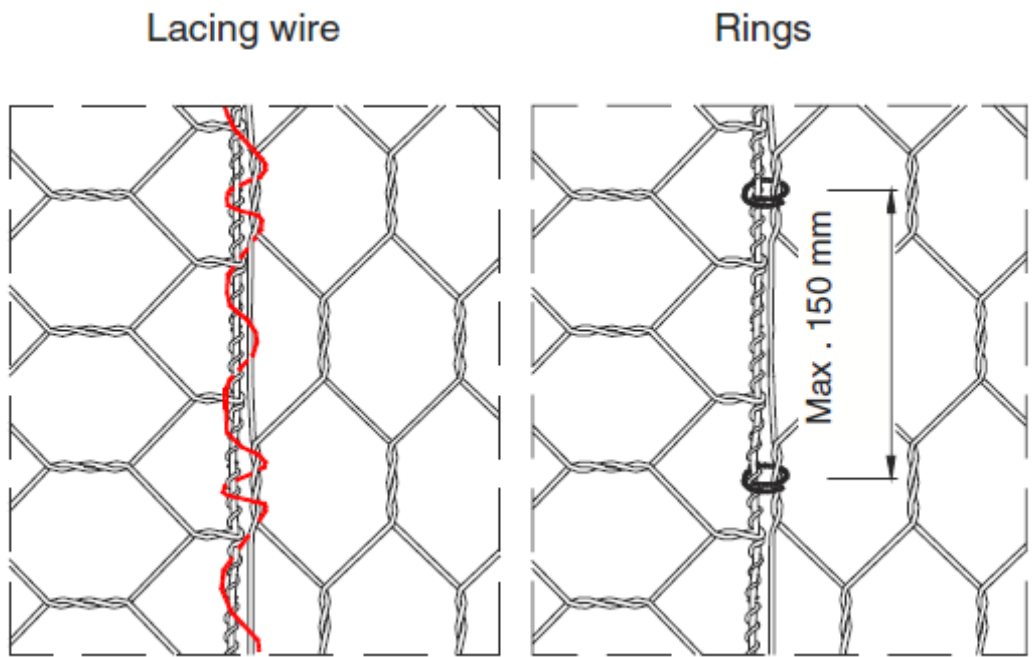
Lacing operations are made by using lacing wire. Galvanized steel ring fasteners can be used instead of, or to complement, lacing wire. Galvanized steel rings for galvanized mesh shall be in accordance with ASTM A975.



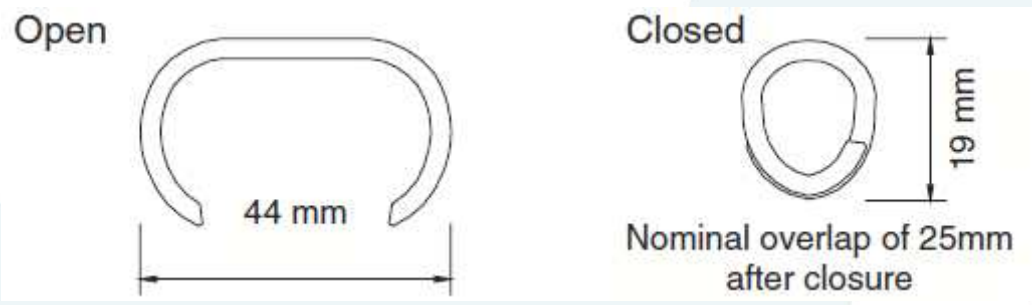
Spacing of the rings shall be in accordance with ASTM A975, Panel to Panel connection, Pull-Apart Resistance. In any case, ring fasteners spacing shall not exceed 150 mm. Ring diameter: 3.00 mm. The maximum spacing of the fasteners is determined by ASTM A975, Pull-Apart Resistance test.



N.B. mesh overlap direction is extremely important for ‘γ’ connections – the overlap direction must be of the opposite sense to roof tiles (see left). Failure to observe this critical advice can cause failure of the connection and the development of dangerous or fatal consequences.

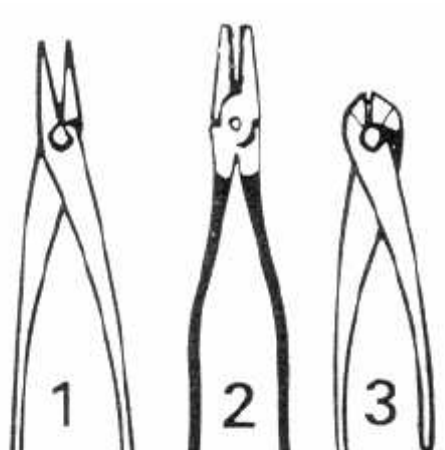




Above: β connections with Lacing Wire or Rings.



Above: Galvanized or Stainless Steel Rings used for the DT mesh connections. Left: ring opened, before the installation, Right: ring closed, after the installation.

DT meshes can be installed using standard light hand tools and require no specialist equipment. To reduce the installation time, Maccaferri suggest using a Pneumatic Spenax Tool (figure B, in the table below) to install the fasteners rings.

 <p>1) Pliers 2) Pliers with nipper 3) Nipper</p>	<p>A</p>
	<p>B</p> <p>Pneumatic Spenax tool</p>
	<p>C</p> <p>Manual tool</p>

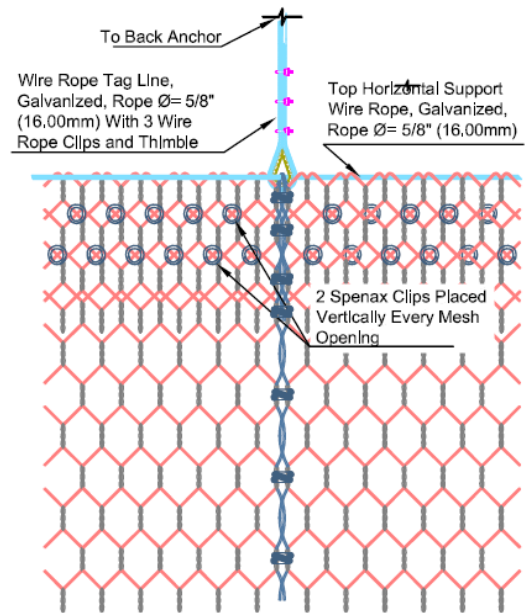


Above a Pneumatic Spenax installation tool, with a box of Spenax rings (1,600 rings/box)

Installation Stages 9 and 10

- 1. Permanent connection (α) of mesh to crest-line rope**
- 2. Installation of toe-line anchors and toe-line rope**
- 3. Permanent connection of mesh to toe-line rope**

The image on the right shows a particular up-slope connection for a Double Twist installation. Here the R_C is offset from the A_C using short lengths ('tails') of steel wire rope however the connection is fully formed and the DT mesh and wire ropes are overlapped and connected over R_C and the steel wire ropes are also connected to the crest-line anchor tails.



Toe-line anchors should be installed (photo below) in strict accordance with the engineering design. The toe-line rope should then be inserted and secured. Next it is necessary to form another ' α ' connection of the mesh to the Toe-line ropes. The

appropriate details/specification for the Toe-line ' α ' connection should be specified by the engineering design. (N.B. in some cases a toe-line rope may not be used.)

Optional Stages a & b

- a. Setting out of face anchor (A_F) positions (S_{Fa} and S_{Fd})**
- b. Drilling and securing/grouting (G_F) of face anchors (A_F)**

In certain circumstances the engineer may consider it necessary to install anchors (A_F), through the mesh, into the face of the slope, to convert a simple drapery installation into a cortical stabilization installation. Following the successful completion of a simple drapery-type installation (stages 1-11) the location of the face anchorages should be set out and drilled in strict accordance to the engineering design (to the satisfaction of the engineer).



Drilling equipment, techniques and procedures will vary widely. Hand-held drilling equipment will often be used for installation of face anchors however this practice is not permitted in some places/work environments meaning that mechanised drilling equipment will be used exclusively. It should be noted that drilling is potentially dangerous; where-ever drilling works are carried out it is of the highest importance that all safety regulations are followed and the appropriate personal protective equipment should be used.

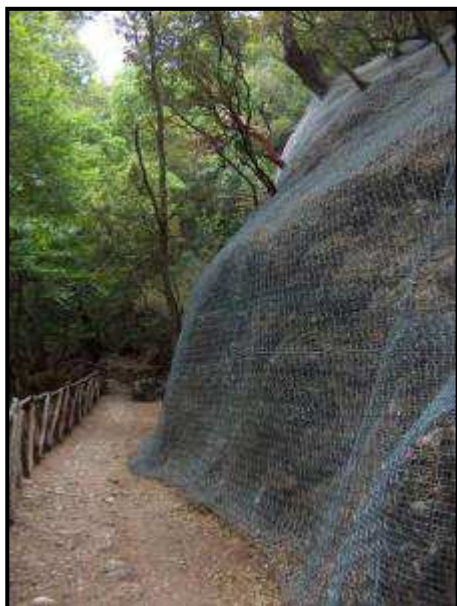


The mesh aperture size of the Double Twist meshes (83 mm nominal opening size) permit the use of relatively large diameter drill bits or self-drilling anchor bars where the procedure of works requires the anchors to be drilled after the hanging of the mesh.

Optional Stages c & d

- c. Installation of face anchor termination accessories**
- d. Installation, tensioning and securing of face ropes**

In circumstances of serious slope instability (especially soil slopes) or where the slope face (F) has significant topography the engineering design may call for installation of a network of steel wire ropes or similar, over the top of the mesh, and connected to face anchors (A_F).



In the situations where the slope face has many undulations or irregularities, individual ropes or networks of ropes can be installed to draw the mesh into the undulations and thereby reduce the potential for falling blocks to fail the mesh. This situation can occur where falling blocks are given the chance to undergo free-fall and in doing so achieve higher velocities and energies if they then ricochet into the mesh.

Where profiling ropes or external rope networks are installed over the mesh, rocks are prevented from falling and in this way the safety factor of the mesh is effectively increased.



Ropes can be restrained by a variety of terminations that are available for installation onto the free ends of the anchors (A_F). Typically the ropes are either retained under the anchor plates that are positioned to restrain the mesh or the ropes are threaded through eye nuts that may be installed on top of (or sometimes instead of) the anchor plate.



Various design philosophies are applied to the specification of slope face ropes and concerning the orientation of the ropes or the patterns formed on the face. It is recommended that the minimum rope to be used with Double Twist meshes should be 12mm diameter (1770 N/mm² grade) however it is not uncommon for 16mm ropes to be used, particularly where angular rocks are present on/in the unstable slope or where the designer takes a conservative attitude to factors of safety for system components.

DT mesh is not sensitive to the specific configuration of external rope networks. (It should be noted that the presence of the integral longitudinal ropes means that it should be unnecessary to install external

ropes in this orientation.) A diamond or “zig-zag” rope pattern (pictured left) will be simple to install and will give highly favourable performance in terms of both punching resistance but also working cooperation with the integral longitudinal ropes. The cooperation between integral and external ropes acts to further increase the mechanical stiffness of the system, which is important for the control and limitation of mesh bulging caused by movement of loose surface layers or accumulations of material (pictured right). This unique type of mechanically efficient cooperation makes DT mesh a highly effective product for cortical stabilisation or pin drapery applications.



4) Maintenance Information

All mesh systems require periodic inspection and maintenance to offer full functional performance in accordance with the engineer's design specification.

The results from the regular inspections should be compared to the post-completion inspection and approval documentation and to the results from any other periodic inspections in order to monitor the performance and condition of the installation and if these could be changing over time.

Inspection intervals are site-specific and must be specified in the engineering design. The exact inspection interval will be based on a combination of the following characteristics:

1. Material influx rate (of any spalling material)
2. Material influx characteristics (high velocity impacts or angular blocks etc.)
3. Local environmental conditions (rain, coastal proximity, aggressive conditions)
4. Local overall geotechnical/geology stability situation
5. If the mesh installation will be prone to heavy snow loading or avalanche actions
6. Corrosion on the wire

It should be noted that where water on or in the face is an issue at a site, or water control measures are part of the engineering design, specific inspection and maintenance procedures will be required on these systems and any parts of the mesh installation they inspect. These procedures will be specified in the engineering design.

In the case of installation in high corrosion areas or in aggressive environments the mesh should be inspected on a more regular basis than in general conditions. It is recommended that in these areas Double Twist PVC mesh should be chosen.