EUROPEAN ASSESSMENT DOCUMENT

EAD 230025-00-0106

June 2016

FLEXIBLE FACING SYSTEMS FOR SLOPE STABILIZATION AND ROCK PROTECTION

The reference title and language for this EAD is English. The applicable rules of copyright refer to the document elaborated in and published by EOTA.

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD applies to Flexible Facing Systems for Slope Stabilization and Rock Protection, which should be made up of one or more identical functional panels placed in sequence, which permits adjusting the horizontal and vertical distance between the nails and their lengths according to the project-specific requirements. The Flexible Facing Systems for Slope Stabilization and Rock Protection are made from steel wire mesh/net to prevent and control the rolling and falling of rocks on slopes and to stabilize unstable slopes by covering them with either drape or nailed solutions.

Only the characteristics of the chain link wire mesh/spiral rope net construction products, connections and spike plates are included in this document. Upper, lower and lateral ropes and anchors and/or soil nails for fixing the chain link wire mesh/spiral rope net to the unstable slope are not covered by this EAD.

The Flexible Facing Systems according to EN 14490:2010 (Figure 1) for Slope Stabilization and Rock Protection are made up from (Table 1):

a) Surface components, which has the function of absorbing the resulting driving forces and transmitting them via the system spike plate or wire ropes to the nailing or anchorage and thus to the subsoil;

b) Soil / rock nails, which act as tension/shear elements and transfer the load acting from the mesh/net via the spike plate into the subsoil;

c) Secondary (optional) individual parts, which have the function to fasten the mesh/net as closely as possible against the subsoil respectively fastening and reinforcing the edge areas.

Chain link mesh rolls are connected together with clips (see Figure 2a and 3) while spiral rope net rolls are connected using shackles, see Figure 2b). Seamy ropes are also possible to be used.

Table 1 – Description of the elements of the system

Part	Component	Function
Surface components	Steel wire mesh/spiral rope net (Figure 4)	Absorbs forces resulting from sliding and transmits them to the soil via the system spike plate or wire ropes to the nailing or anchorage.
	Elements for connecting the mesh/net panels to each other	Transmit the transverse tensile strength of the mesh, limiting the deformations under the load.
	Secondary mesh (optionally for rock protection systems): with smaller openings and usually made from mild steel	Protects against smaller parts to slide through the mesh openings.
Soil / rock nails	Adequate main nails with nuts	Act as tension/shear elements and transfer the load into the subsoil.
	System spike plates (Figure 5)	Ensure the mesh-nail contact and transfer the load from the mesh into the nail.
Secondary (optional) individual parts	Short intermediate nails with plates, boundary wire ropes, spiral wire rope anchors	Fasten the mesh/net as closely as possible against the subsoil respectively fasten and reinforcing the edge areas.

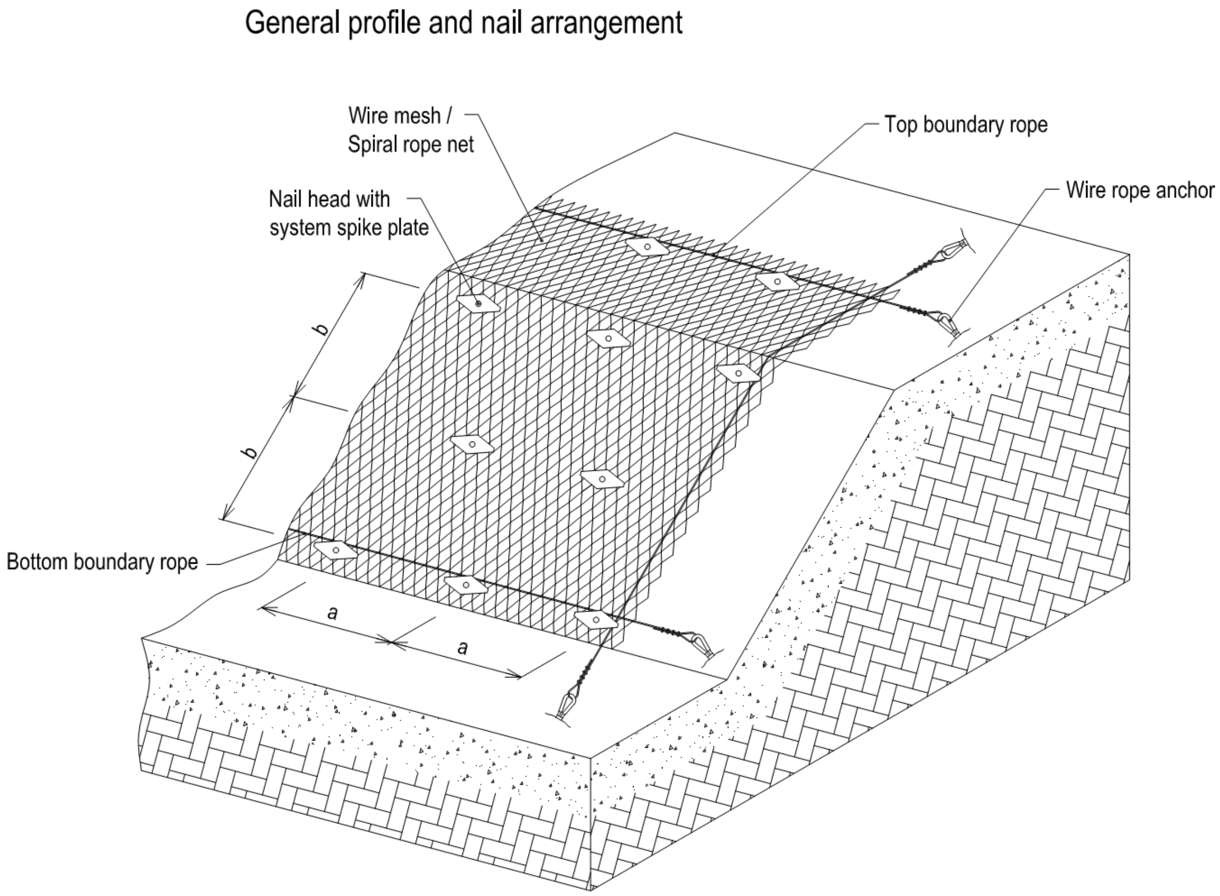


Figure 1 – Example of flexible facing system

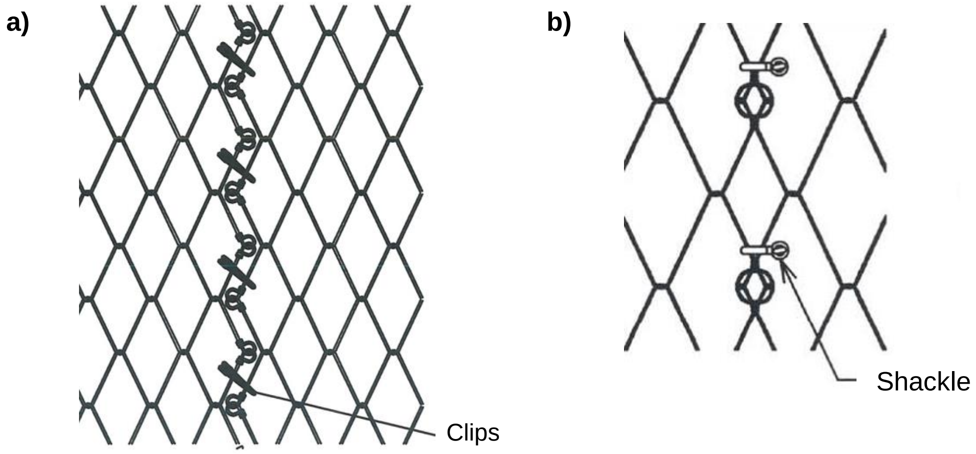


Figure 2 – Connection between: a) chain link mesh rolls, b) spiral rope net rolls

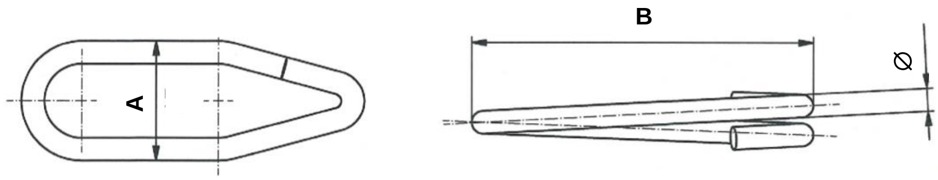
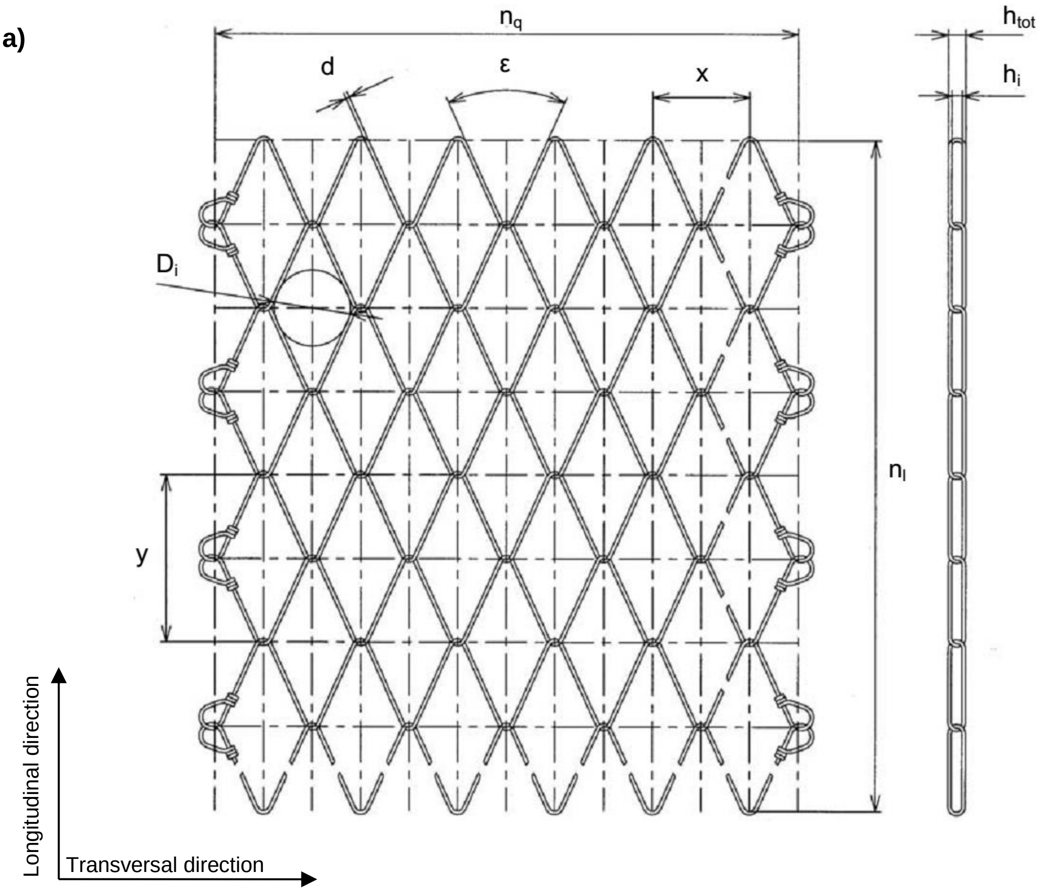
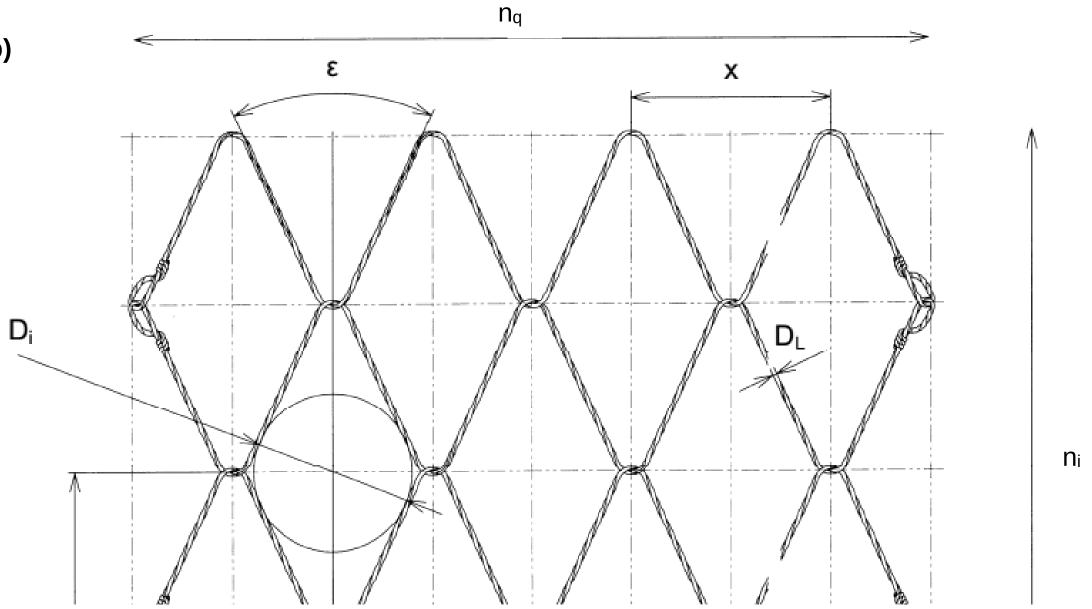


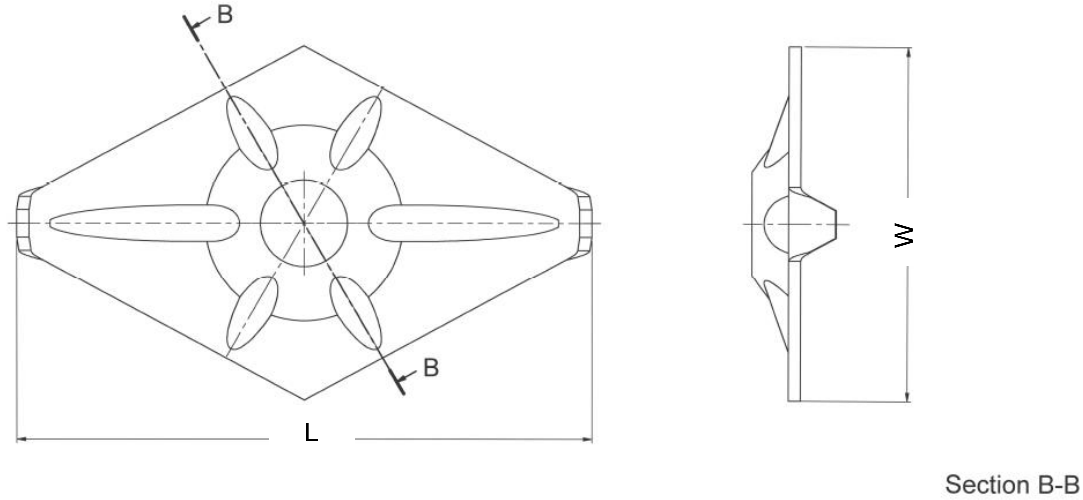
Figure 3 – Example of clips

a)


n_q
d
ε
x
h_{tot}
h_i
D_i
n_l
y
Longitudinal direction
Transversal direction

b)


n_q
ε
x
D_i
D_L
n_i


B
B
W
L
Section B-B

The chain link wire mesh and spiral rope net can be produced from non-ferrous metallic coated wires (Zn95/Al5 or other), or from non-ferrous metallic coated wires (Zn95/Al5 or other) with extruded organic coating (PET) or from stainless steel.

The spike plates are hot dip galvanized according to EN ISO 1461 or made of stainless steel.

The meshes/nets can be divided into informative groups (for design purposes) regarding their slope parallel resistance Z_R and shearing-off resistance P_R and/or regarding elongation in longitudinal tensile strength δ test are according to Tables 2 and 3.

Table 2 – Informative: groups of meshes/nets regarding tensile strength and shearing-off resistance

Group	Shearing-off resistance P_R at the upper surface of spike plates (kN)	Slope parallel tensile strength Z_R (kN)
1	$P_R > 135$	$Z_R > 50$
2	$80 < P_R \leq 135$	$29 < Z_R \leq 50$
3	$50 < P_R \leq 80$	$19 < Z_R \leq 29$
4	$25 < P_R \leq 50$	$4 < Z_R \leq 19$
5	$0 < P_R \leq 25$	$0 < Z_R \leq 4$

Table 3 – Informative: groups of meshes/nets regarding relative elongation in longitudinal tensile strength test

Class	δ
A	≤ 6
B	6 to 10
C	10 to 14
D	> 14
$\delta = \Delta L_{work}/L$ Δl_{work}: see Annex B	

The product is not covered by a harmonised European standard (hEN).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

Flexible Facing Systems for Slope Stabilization and Rock Protection is intended to be used for:

- Stabilization of steep slopes of unconsolidated soil and rocky material and for prevention of stones and blocks in disintegrated, loose or weathered rock faces from breaking out (Slope Stabilization System);
- Securing of rock slopes, spurs, overhangs or individual section of loose rock (Rock Protection System);
- Protection system for safety application like not sudden impact of objects.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account an assumed working life of the Flexible Facing Systems for Slope Stabilization and Rock Protection for the intended use of 50 years for corrosivity category C2 for both, non-ferrous metallic coated and non-ferrous metallic coated+organic coated products in accordance with EN ISO 9223, when installed in the works and when durability tests are performed according to cl. 2.2.5 in this EAD, moreover for non-ferrous metallic coating and non-ferrous metallic coating+organic the number of hours in exposure is 1000.
These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[1].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Specific terms used in this EAD

1.3.1 Flexible Facing Systems for Slope Stabilization and Rock Protection

Construction system consisting of net/mesh (main component) spike plates, nails, ropes and connection components.

1.3.2 Mesh/net opening D_i (in mm)

Diameter D_i (in mm) of inner circle of rhomboidal mesh/net (Figure 2).

1.3.3 Mesh/Net

Load bearing element acting as a surface.

1.3.4 Mesh/net designation

Definition of the chain link wire mesh/spiral rope net type related to the typical construction and dimensions.

1.3.5 Clips

Elements which serve to connect chain link wire mesh rolls.

1.3.6 Shackles

Elements which serve to connect spiral rope mesh/net rolls.

---

[1] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

1.3.7 Spike plates

Special diamond-shaped construction element which serve to fix the mesh to soil or rock nails

1.3.8 Nails

Load bearing elements which transmit the load into subsoil.

1.3.9 Ropes

Tensioned elements to reinforce boundary areas.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 4 shows how the performance of Flexible Facing Systems for Slope Stabilization and Rock Protection is assessed in relation to the essential characteristics.

Table 4 – Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance (level, class, description)
Basic Works Requirement 1: Mechanical resistance and stability			
1	Mesh/net roll: Number of meshes transversal Number of meshes longitudinal Mesh distance transversal Mesh distance longitudinal Angle of mesh Total height of mesh/net Clearance of mesh/net Roll width Roll length Mesh opening	2.2.1	 n_q (pcs/m) n_i (pcs/m) x (mm) y (mm) ε (°) h_{tot} (mm) h_i (mm) b_{Roll} (m) l_{Roll} (m) D_i (mm)
2	Spike plate characteristics: Dimensions Bending resistance	2.2.2	 description $M_{s,k}$ (in kNm)
3	Bearing resistance of the system: Tensile strength and Elongation of mesh/net Slope parallel resistance Puncturing resistance Shearing-off resistance in nail direction	2.2.3	 z_k (kN/m) δ (%) Z_R (kN) D_R (kN) P_R (kN)
4	Connection member resistance	2.2.4	$z_{c,k}$ (kN/m)
5	Durability: Neutral salt spray test on wire samples Hot dip galvanized spike plate	2.2.5	Exposure time with surface DBR ≤ 5% surface (hours) description

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

2.2.1 Mesh/net roll dimensions, mesh opening, connection clip dimensions

The chain link mesh (Figure 4) and spiral rope net rolls (Figure 4) dimensions: number of meshes transversal in n_q (in pcs/m), number of meshes longitudinal n_i (in pcs/m), mesh distance transversal x (in mm), mesh distance longitudinal y (in mm), angle of mesh ε (in °), total height of mesh h_{tot} (in mm), clearance of mesh h_i (in mm), roll width b_{Roll} (in m), roll length l_{Roll} (in m), mesh opening D_i (in mm) shall be measured by calliper and/or measuring tape on at least three samples. Each nominal dimension and its tolerance and also the number of meshes in both directions shall be given in ETA.

2.2.2 Spike plate characteristics: bending resistance

The bending resistance of the spike plate $M_{s,k}$ (in kNm) is determined by characteristic bending resistance. The test procedure for bending resistance is described in Annex A in this EAD. The 5%-fractile of bending moment measured in a test series (at least three test results z_i, ($i \geq 3$)) shall be calculated according to D7, EN 1990 for normal distribution and known coefficient of variation and value of k_n depending on the number of test series. The characteristic value $M_{s,k}$ (in kNm) shall be expressed in ETA.

2.2.3 Bearing resistance of system: tensile strength and elongation of mesh/net, slope parallel resistance, puncturing bearing resistance, shearing-off resistance

The tensile strength and elongation of mesh/net is determined by characteristic tensile strength z_k (in kN/m) and corresponding mean value of maximum elongation δ (in %) of mesh/net in longitudinal direction. The test procedure for tensile strength of mesh/net is described in Annex B in this EAD. The 5%-fractile of tensile strength measured in a test series (at least three test results z_i, ($i \geq 3$)) shall be calculated according to D7, EN 1990 for normal distribution and known coefficient of variation and value of k_n depending on the number of test series. The characteristic value z_k (in kN/m) and the mean value of maximum elongation δ (in %) shall be expressed in ETA.

The minimum value of slope parallel resistance Z_R (in kN) (from at least two test results when tested according to Annex C in this EAD) of mesh/net shall be recorded in ETA.

The minimum value of puncturing resistance D_R (in kN) and shearing-off resistance in nail direction P_R (in kN) (from at two test results when tested according to Annex D in this EAD) of mesh/net-spike plate combination shall be recorded in ETA.

Specific provisions: The shearing-off resistance P_R shall be verified by full scale test according to Annex E in this EAD by comparison of measured shearing-off forces $P_{R,test}$ with shearing-off resistance P_R. The difference between the results of two test methods (Annex D and Annex E) shall be maximum ± 20%.

2.2.4 Connection member resistance

The connection member resistance shall be assessed based on tensile strength of mesh/net in transversal direction (real loading direction acting on connection members). Tests on at least three samples according to Annex F shall be performed for each mesh/net – connection type combination. The 5%-fractile of tensile strength measured in a test series (at least three test results $z_{c,i}$, ($i \geq 3$)) shall be calculated according to D7, EN 1990 for normal distribution and known coefficient of variation and value of k_n depending on the number of test series. The characteristic value $z_{c,k}$ (in kN/m) shall expressed in ETA.

2.2.5 Durability: Neutral salt spray test with general condensation of moisture of non-ferrous metallic coated and non-ferrous metallic coated + organic coated wire samples

Neutral salt spray (NSS) test on wire samples shall be carried out according to EN ISO 9227. For Zn/Al alloy and Zn/Al + organic coated mesh/net samples, the number of hours of exposure after which each sample does not show more than 5% of DBR (Dark Brown Rust) shall be given in ETA. The organic coated samples shall be assessed without removing the organic coating.

If stainless steel products are used, it shall be expressed in ETA. For stainless steel products no durability tests are required.

The spike plate corrosion protection method shall be given in ETA.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 2003/728/EC.

The system is: **1**

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 5.

Table 5 – Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) including testing of samples taken at the factory in accordance with a prescribed test plan					
Manufacturer`s production					
1	**Product:** Mesh dimensions, mesh opening	. 2.2.1	Compliance with required tolerances	1 sample / type	1 / day
	Bending moment resistance of spike plate	2.2.2	For all test results (characteristic values $M_{s,k,FPC}$ calculated from FPC tests) from the whole period of surveillance within the validity of the ETA the following requirements shall be met: $M_{s,k} > M_{s,k,FPC}$	3 samples / type	1 / year
	Tensile resistance of mesh/net	2.2.3	For all test results (characteristic values $z_{k,FPC}$ calculated from FPC tests) from the whole period of surveillance within the validity of the ETA the following requirements shall be met: $z_k > z_{k,FPC}$	3 samples / type	1 / year
	Connection member resistance	2.2.4	For all test results (characteristic values $z_{c,k,FPC}$ calculated from FPC tests) from the whole period of surveillance within the validity of the ETA the following requirements shall be met: $z_{c,k} > z_{c,k,FPC}$	3 samples / type	1 / year

and next page

Table 5 – *Continued*

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Incoming product					
2	**Metallic coated wire (chain link wire net):** Outer diameter Torsion and bend test Coating mass	EN 10218-2 EN 10218-1 EN 10244-2	Compliance with required materials and manufacturer`s technical file	Inspection certificate of supplier, type 3.1 EN 10204 In addition 5 / each diameter	1 / year
3	**Organic coated wire:** Type of coating Outer diameter Visual Thickness/concentricity	EN 10245 (relevant part) EN 10218-2 EN 10245-1		Inspection certificate of supplier, type 3.1 EN 10204 In addition 5 / each diameter	1 / year
4	**Wire mechanical characteristics:** Tensile strength	EN 10218-1		Inspection certificate of supplier, type 3.1 EN 10204 In addition 5 / each diameter	1 / year
5	**Rope characteristics (spiral rope net):** Diameter Designation Wire tensile strength grade Breaking force Coating mass on wire	EN 12385-2+A1 EN 12385-4+A1 EN 12385-2+A1 EN 10264-2 and EN 10244-2		Inspection certificate of supplier, type 3.1 EN 10204 In addition 1 / each diameter	2 / year
6	**Connection components** Material, dimensions	manufacturer`s technical file		Declaration of performance of supplier	
7	**Spike plate:** Steel grade Dimensions Thickness of coating	EN 10025 (relevant part) Drawings EN ISO 1461		Declaration of performance of supplier In addition 1 sample / type (only for dimensions and thickness of coating)	1 / delivery

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance Flexible Facing Systems for Slope Stabilization and Rock Protection are laid down in Table 6.

Table 6 – Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	Ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the Flexible Facing Systems for Slope Stabilization and Rock Protection	-	Laid down in control plan	-	When starting the production or a new product line
Continuing surveillance, assessment and evaluation of factory production control					
2	Verifying that the system of factory production control and the specified automated manufacturing process are maintained taking account of the control plan	-	Laid down in control plan	-	1/year

4 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment is of relevance.

EN 10204	Metallic products. Types of inspection documents
EN 10218-1	Steel wire and wire products. General. Part 1: Test methods
EN 10218-2	Steel wire and wire products. General. Part 2: Wire dimensions and tolerances
EN 10244-1	Steel wire and wire products. Non-ferrous metallic coatings on steel wire - Part 1: General principles
EN 10244-2	Steel wire and wire products. Non-ferrous metallic coatings on steel wire - Part 2: Zinc or zinc alloy coatings
EN 10245-1	Steel wire and wire products. Organic coatings on steel wire. Part 1: General rules
EN 12385-2+A1	Steel wire ropes. Safety. Part 2: Definitions, designation and classification
EN 12385-4+A1	Steel wire ropes. Safety. Part 4: Stranded ropes for general lifting applications
EN 10264-1	Steel wire and wire products. Steel wire for ropes. Part 1: General requirements
EN 10264-2	Steel wire and wire products. Steel wire for ropes. Part 2: Cold drawn non alloy steel wire for ropes for general applications
EN 1990+A1/AC	Eurocode 0: Basis of Structural Design
EN ISO 9223	Corrosion of metals and alloys. Corrosivity of atmospheres.Classification, determination and estimation
EN ISO 9227	Corrosion tests in artificial atmospheres. Salt spray tests
EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
EN ISO 7500-1/AC	Metallic materials. Verification of static uniaxial testing machines. Part 1: Tension/compression testing machines. Verification and calibration of the force measuring system

ANNEX A – SPIKE PLATE BENDING TEST METHOD

A1 Scope

The aim of this test is to determine the bending resistance in longitudinal direction of the spike plate $M_{s,p}$.

A2 Test specimen

The spike plate specimens shall be representative as to material and geometry.

A3 Test method

The three point flexural test (in longitudinal direction of spike plate) shall be carried out. The sample is placed on two supporting pins a set distance apart and a third loading pin is loaded at a constant rate until sample failure (Figure A.1). The sample failure is the state when the applied load cannot be increased. The forces shall be recorded during the entire test. The testing equipment (universal testing machine) shall be used and the load cell shall be periodically calibrated. The range of measuring shall fit the expected load.

The maximum bending moment in the centre of spike plate $M_{s,p}$ shall be calculated for the actual test arrangement.

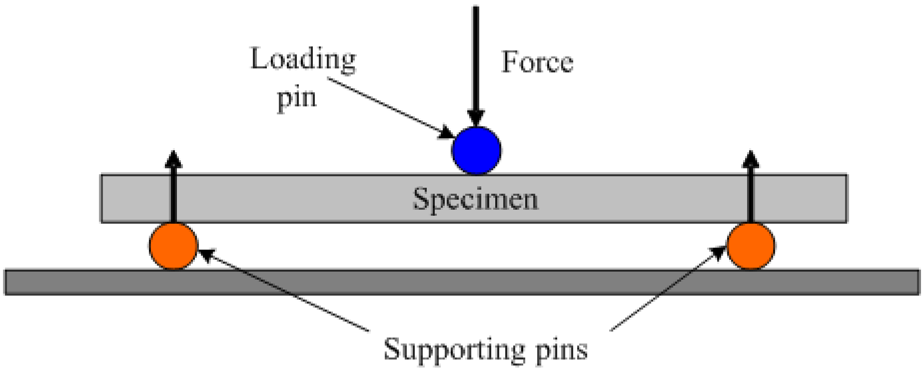


Figure A.1 – Schematic test arrangement

A4 Test Report

The test report shall include at least the following information:

- Name of laboratory and name of operator who performed the tests;
- Characteristics of the testing machine and reference to its calibration certificate;
- Test arrangement mainly the distance of supporting pins;
- Date of test;
- Identification of the tested spike plate sample (supplier and material nature of the surface treatment, dimensions, etc.);
- Documentation of test by photographs;
- Results expressed in maximum force F and corresponding maximum bending moment $M_{s,p}$.

ANNEX B – TENSION TEST METHOD FOR CHAIN LINK WIRE MESH/SPIRAL ROPE NET

B1 Scope

The aim of this test is to determine the tensile strength of chain link wire mesh or spiral rope net z_i in longitudinal direction.

B2 Test specimen

The chain link wire mesh/spiral rope net specimens shall be representative of proper field construction as to materials and geometry. The test specimen shall be ended by the similar way as during the mesh/net manufacturing. For the chain link wire mesh, the width (dimension perpendicular to the direction of loading) of a specimen shall not be less than 10 repetitions of a mesh pattern and the length shall not be less than 5 repetitions of a mesh pattern. For the spiral rope net, the width (dimension perpendicular to the direction of loading) of a specimen shall not be less than 5 repetitions of a net pattern and the length shall not be less than 3 repetitions of a net pattern.

B3 Test apparatus

The test apparatus consists from traction machine (acc. to ISO 7500-1 class A) and rigid steel beams (*A* and *B*, see Figure B.1) to allow the specimen to be connected to them.

B4 Test procedure

The tests shall be run with the load applied in longitudinal mesh direction. The apparatus shall grip the wire in such a manner as to allow the wire failure at least one mesh/net pattern away from the gripping points. If a failure occurs in a wire/spiral rope leading directly to a gripping point that specimen shall be rejected and not included among the tests reported. The test shall be conducted with three samples and successful runs. The specimen is fixed in all opening at all four sides, longitudinal and transversal fixation points. The longitudinal fixation of sample maintains the specimen shape in transversal direction thus ensuring the uniform load distribution created by rigid transversal beam *B*, see Figure B.1.

The fixations shall rotate freely around the axis orthogonal to the plane of tested mesh/net without any friction to allow the steady longitudinal displacement of specimen. The bolts of the fixation holding the mesh shall have a diameter between 10-35% of the mesh opening (D_i)

The grips may be left loose until the preload is applied to allow the wires to seat. The load shall initially be taken to a preload of 3% of the specified minimal tensile strength. The load *P* is than applied at a uniform rate between 80 to 90 mm/minute. Loading shall then continue uniformly until first fracture of an individual wire or other damages in the system occurs. The elongation of mesh/net should be measured continuously with a proper measuring device with accuracy of 1 mm.

B5 Test report

The test report shall contain:

- Detailed and particular description of all three test specimen: mesh/net construction, mesh/net size, component characteristics (diameter of wires, breaking force of wire);
- Date of test;
- Testing body;
- Nominal dimensions *b* and *l* of test specimen, number of repetitions in both directions;
- Initial dimensions of test specimen;
- Description of testing apparatus;
- Load – elongation diagram, see Figure B.2 (the load expressed by tensile strength);
- Description of failure mode;
- Elongation Δl_{work} measured at 80 % of z_k;

- Maximum tensile strength $z = P_{max}/b$ in kN/m, where P_{max} is the breaking force and b is the nominal width of the installed specimen (centre to centre distance between longitudinal fixations).

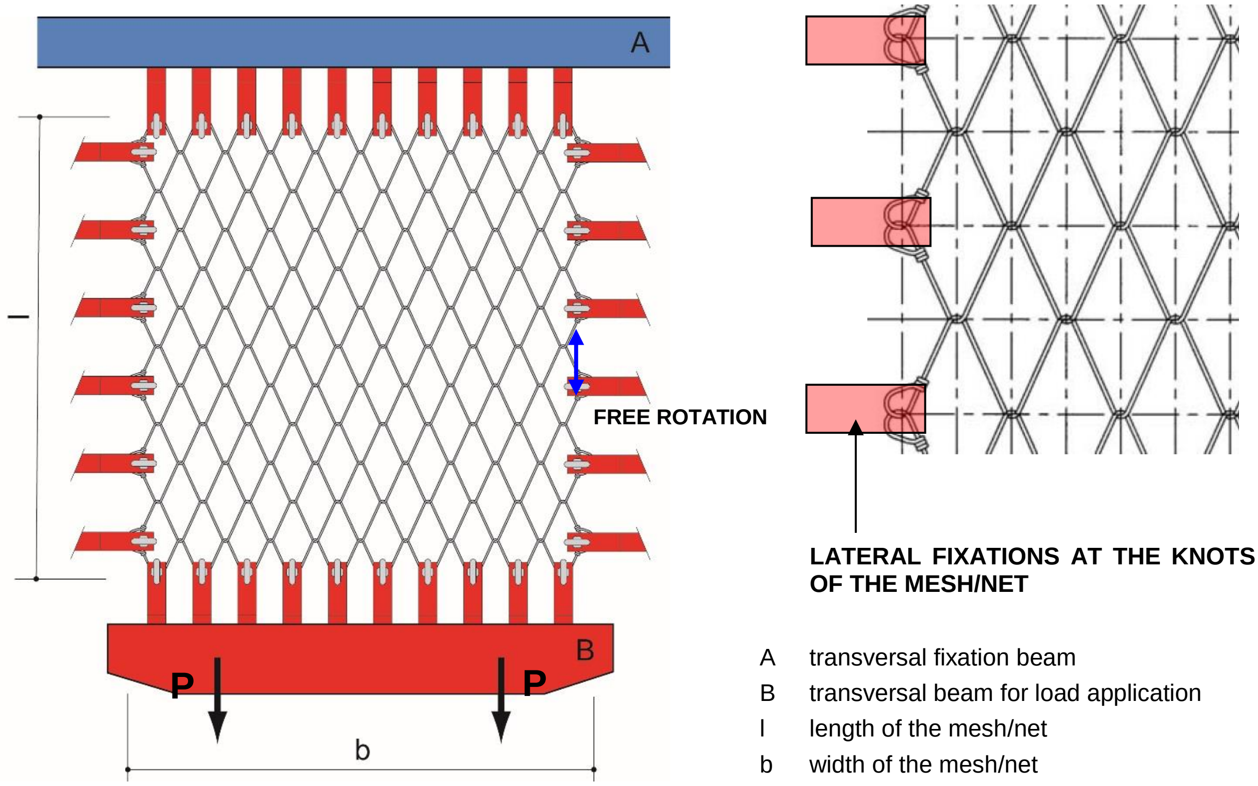


Figure B.1 – Test arrangement

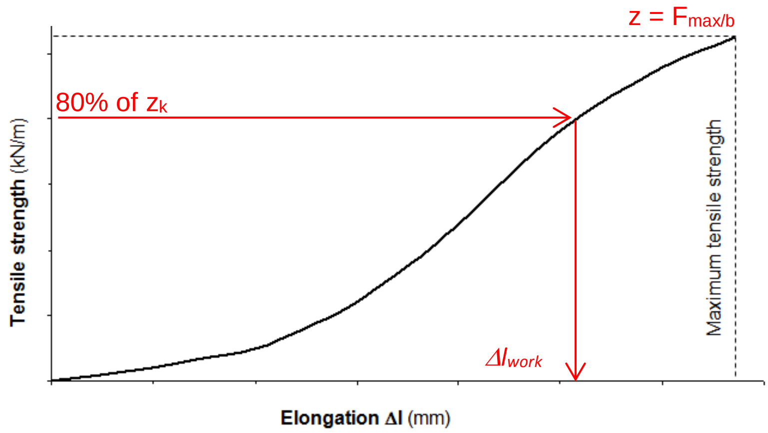


Figure B.2 - Load elongation diagram

ANNEX C – TEST METHOD FOR SLOPE PARALLEL TENSILE FORCE

C1 Scope

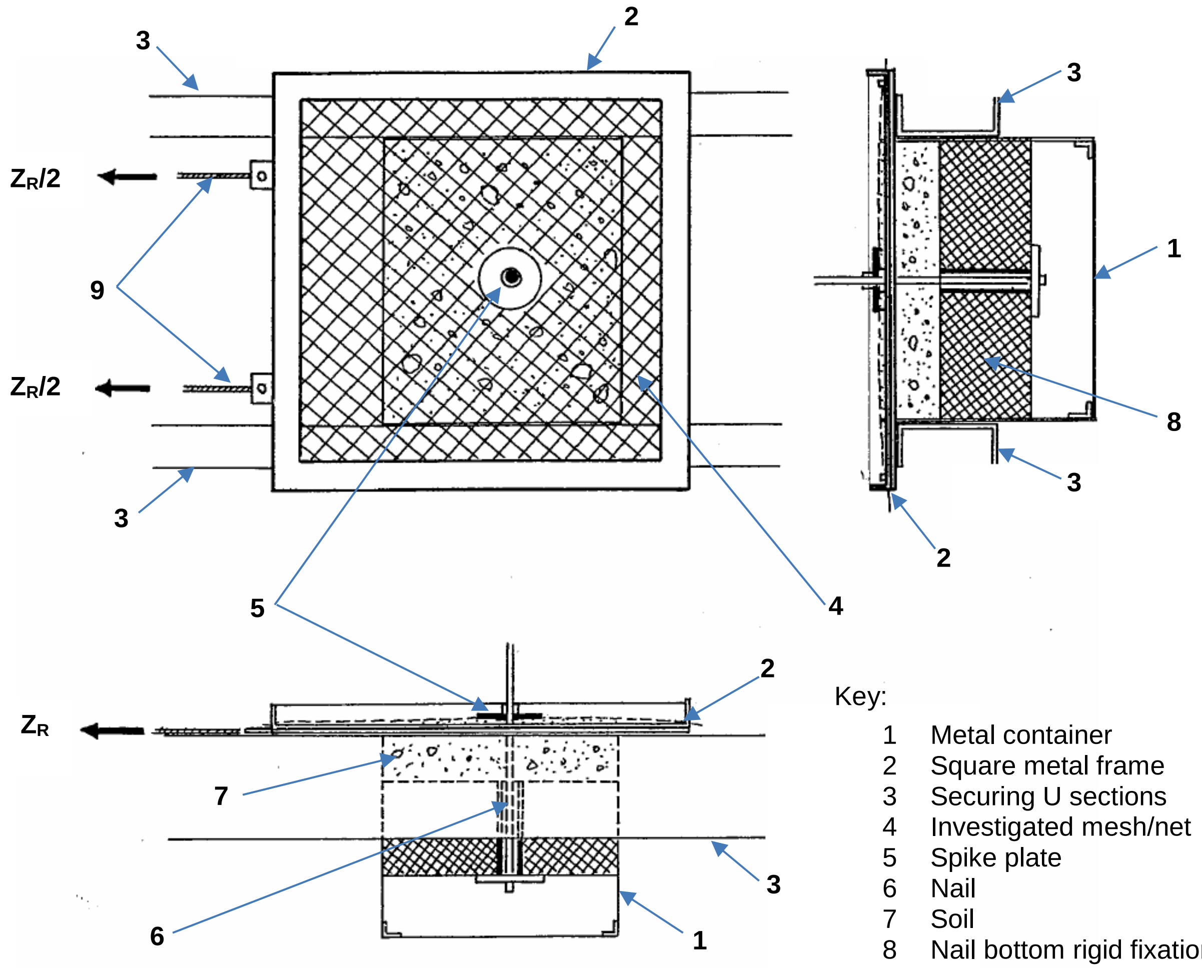
The aim of test is to determine the slope parallel tensile force Z_R which can be transferred through the mesh/net to the spike plate and consequently to the nail.

C2 Test specimen

The chain link wire mesh/spiral rope net specimens shall be representative as to material and geometry and combination of mesh/net and spike plate. The test specimen shall be ended by the similar way as during the mesh/net manufacturing. For the chain link wire mesh, the width of a specimen shall not be less than 21 repetitions of a mesh pattern and the length shall not be less than 10 repetitions of a mesh pattern. For the spiral rope net, the width of a specimen shall not be less than 12 repetitions of a net pattern and the length shall not be less than 5 repetitions of a net pattern.

C3 Test equipment

The test setup consists of a metal container (1, Figure C.1) which is rigidly secured for example with two U sections (3, Figure C.2) and of a square metal frame (2, Figure C.1) into which the mesh/net (4, Figure C.1) to be investigated is clamped (see Figure C.1).



Key:
1 Metal container
2 Square metal frame
3 Securing U sections
4 Investigated mesh/net
5 Spike plate
6 Nail
7 Soil
8 Nail bottom rigid fixation
9 Rope tensioning system

Figure C.1 – Test setup

The metal container is filled with soil to the extent that the surface of the layer of soil is flush with the top edge of the metal container. A nail is arranged in the centre of the metal container. The mesh to be investigated is held by a spike plate which is pressed onto the substrate by means of a nut.

C4 Test procedure

The rope tensioning arrangement (9, Figure C.1) pulls at two brackets fastened to the frame. The mesh clamped into the frame is centrally held by means of a spike plate. The forces $Z_R/2$ imparted over the brackets into the frame and thereby into the mesh are locally transmitted onto the nail.

The forces $Z_R/2$ shall be recorded continuously by load cells (calibrated periodically). The test ends when the mesh/net fails at the spike plate location.

C5 Test procedure

The test report shall contain:

- Detailed and particular description of test specimen: mesh/net construction, mesh/net size, component characteristics (diameter of wires);
- Nominal dimensions and / of test specimen;
- Type of the spike plate;
- Description of used soil;
- Date of test;
- Testing body;
- Description of failure;
- Maximum force Z_R at mesh failure.

ANNEX D – TEST METHOD FOR DETERMINATION OF PUNCTURING BEARING RESISTANCE

D1 Scope

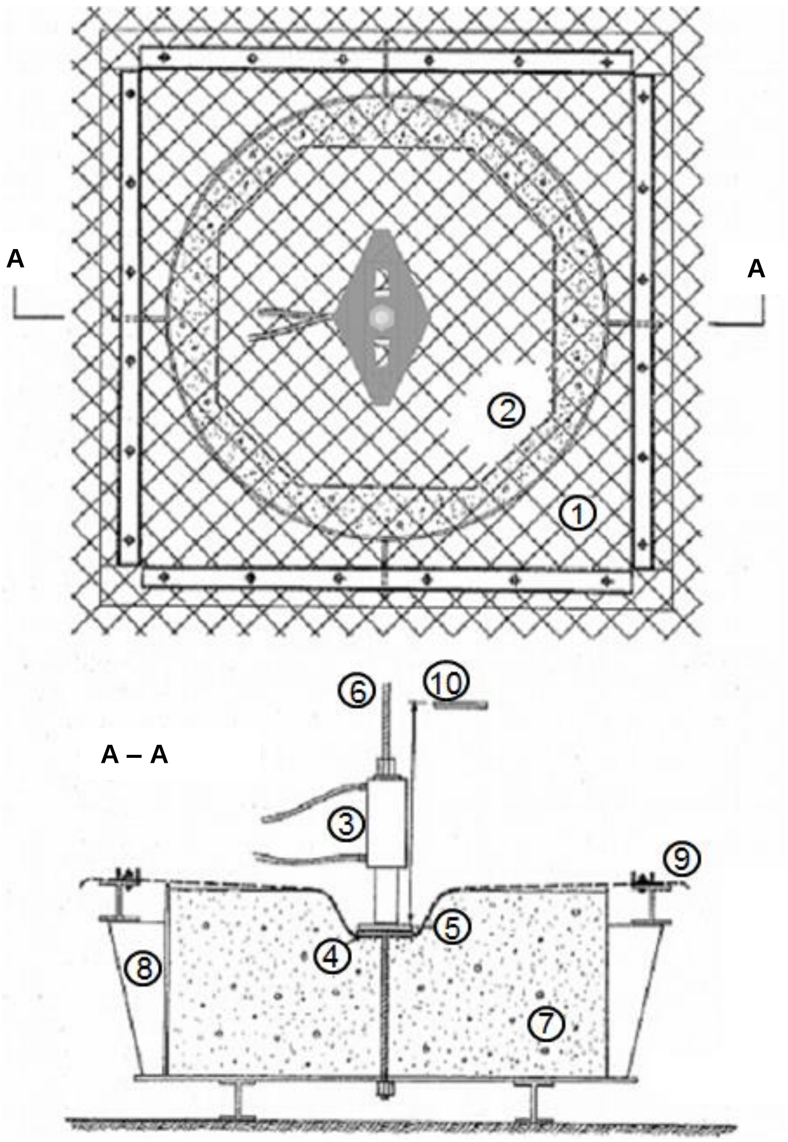
The aim of this test is to determine the bearing resistance of the mesh/net to puncturing D_R in nail direction.

D2 Test specimen

The chain link wire mesh/spiral rope net specimens shall be representative as to materials and geometry. The test specimen shall be constituted of panels of dimensions 200 cm x 200 cm.

D3 Test equipment

The test setup (Figure E.1) consists of a round steel container which is completely filled with soil material. This filled steel container is framed by rigid frame made from four steel sections (for example HEA sections supported by stiffeners welded to the outer surface of container). The tested mesh/net is mounted to the rigid frame. A tested nail is located in the centre of container. The spike plate and consequently the mesh/net are pressed onto and into the soil.



1 Mesh/net
2 Nonwoven geotextile
3 Hydraulic press
4 Spike plate
5 Spread plate
6 Nail
7 Soil
8 Round metal container
9 Steel frame
10 Datum point of altitude

Figure D.1 – Test setup

D4 Test procedure

The tank is filled with the prepared soil material and then moderate compacted. The pressure force and corresponding vertical displacement shall be recorded during the test. The load measuring device shall be periodically calibrated.

In order to determine the pure bearing effect of the system spike plate compared to the substrate used, the spike plate is pressed by means of hydraulic press, without involvement of the mesh/net onto and into the soil until failure (shear failure) with the corresponding vertical force V_{oG} (Figure D.2a). The force V_{oG} is transmitted directly into the substrate over the spike plate.

If an analogous test is carried out but with the involvement of mesh/net, the vertical force can be further increased by a certain value of ΔV to value V_{mG} until the substrate fails in shear. The difference $\Delta V = V_{mG} - V_{oG}$ is laterally transmitted over the mesh/net via pressure and friction forces into the solid ground. Hereby the amount of V_{oG}, approximately, flows again directly over the spike plate into the substrate.

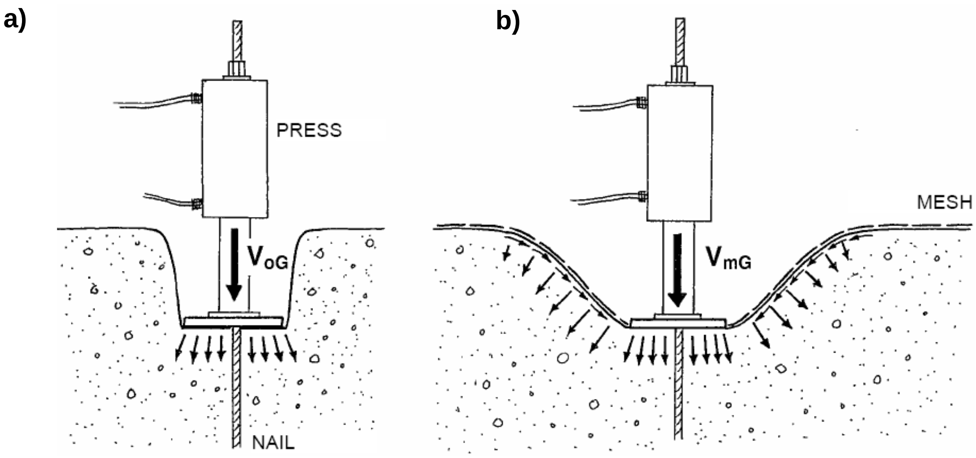


Figure D.2 – Test steps: a) pressing without mesh/net, b) pressing with mesh/net

For determination the bearing resistance of the mesh/net against puncturing (pressure strains in nail direction) D_R the corresponding differential forces (eliminated influence of ground) are taken into account. The force D_R therefore, depends on the mesh/net itself.

Accordingly, the following applies:

$$V_{mG} = V_{oG} + \Delta V$$

$$D_R = \Delta V$$

The bearing resistance of the mesh against shearing-off in nail direction at the upslope surface of the spike plate P_R can be assumed to be half of the puncturing bearing resistance of the mesh against pressure strains in nail direction D_R.

$$P_R = D_R / 2$$

D5 Test procedure

The test report shall contain:

- Detailed and particular description of test specimen: mesh/net construction, mesh/net size, component characteristics;
- Nominal dimensions and / of test specimen;
- Type (drawing) of the spike plate used;

- Description of used soil;
- Date of test;
- Testing body;
- Vertical displacement at failure and corresponding applied load;
- Load – vertical displacement diagram;
- Maximum forces V_{0G}, V_{mg} and D_R.

ANNEX E – LARGE SCALE FIELD TESTS WITH FLEXIBLE FACINGS SYSTEMS FOR SLOPE STABILIZATION AND ROCK PROTECTION

E1 Scope

The aim of this test is to analyse and better understand the load bearing capacity of the system under conditions which are as real as possible and to examine and confirm the theoretical model approach used in calculations, the underlying assumptions under realistic conditions and using of repeatable laboratory tests. The forces on nails can also be validated by this test.

E2 Test specimen

The flexible facing systems specimens shall be representative as to materials and geometry. The soil conditions have to be chosen as useful as possible for comparison purposes. The test setup shall be as large as possible to avoid border effects in a model test. A real crop out of a slope failure shall be modelled within that test setup.

E3 Test equipment

The testing apparatus consists from a rigid steel frame with possible rotation about one edge.

The minimum size of steel frame is 13 x 15 m steel frame which can be filled with soil material through a 10 x 12 m surface up to a layer thickness of minimum 1,20 m. The tested mesh/net is put on the surface of soil layer and the spike plates are connected to the frame through fixing them by nuts to the anchors.

The mesh cover has to be sewed to upper and lower support ropes and screwed to the vertical sides of the frame using steel U-profiles in order to create bedding which is immovable in the lateral direction. The nails used shall be considered to be bend-proof in its connection to the frame.

The different steps of inclination of frame shall be scanned by laser device. A pendulum and an automatic inclinometer are used to determine the inclination of the steel frame. White balls/cones or other marks together with various mirrors shall serve as orientation aids and reference points.

A rope potentiometer can be used to measure the displacements of the top middle nail. In addition, load cells shall be specially adapted to the conditions and they shall be used to determine the forces in the upper and lower support wire ropes.

Strain gauges (see Figure E.1) shall be used to determine (from measured strains) the normal and bending forces on selected nails. The positions of strain gauges depend on the test setup and length of nail.

The displacement of all nails shall be also determined from detailed laser scan using the identifiable marks (for example white balls/cones) on their heads. The bulges of mesh (deformed shape of mesh) shall be also recorded.

In addition, the forces in the upper and lower support wire ropes shall be measured see Figure E.2.

All test equipment shall be calibrated and shall be in such a range of measurement, which covers the expected measured values.

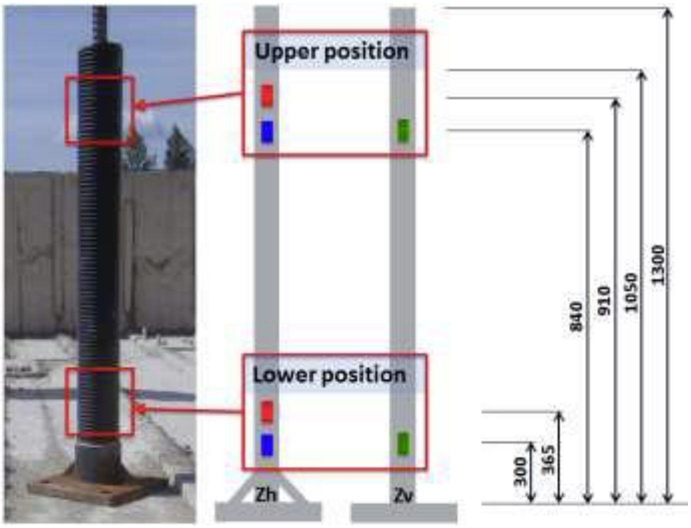
E4 Test procedure and test outputs

By lifting it with a crane, the frame inclination can vary between 0° and 85°.

The surface including nail heads and steel frames shall be firstly scanned in horizontal position to serve as a reference level. The scan is repeated after changing the inclination by 5° (Figure E.3).

The red marked gauges are to measure the normal forces in the nail. From strain measurements in horizontal and vertical directions, bending moments acting on nails horizontally and vertically can be calculated.

The shearing-off resistance P_R is defined as the normal force in nail, when the first mesh/net wire is broken independently on frame inclination.



Red position. for tensile force

Blue position: for horizontal bending moment

Green position: for vertical bending moment

Figure E.1 – Positions of strain gauges on nail

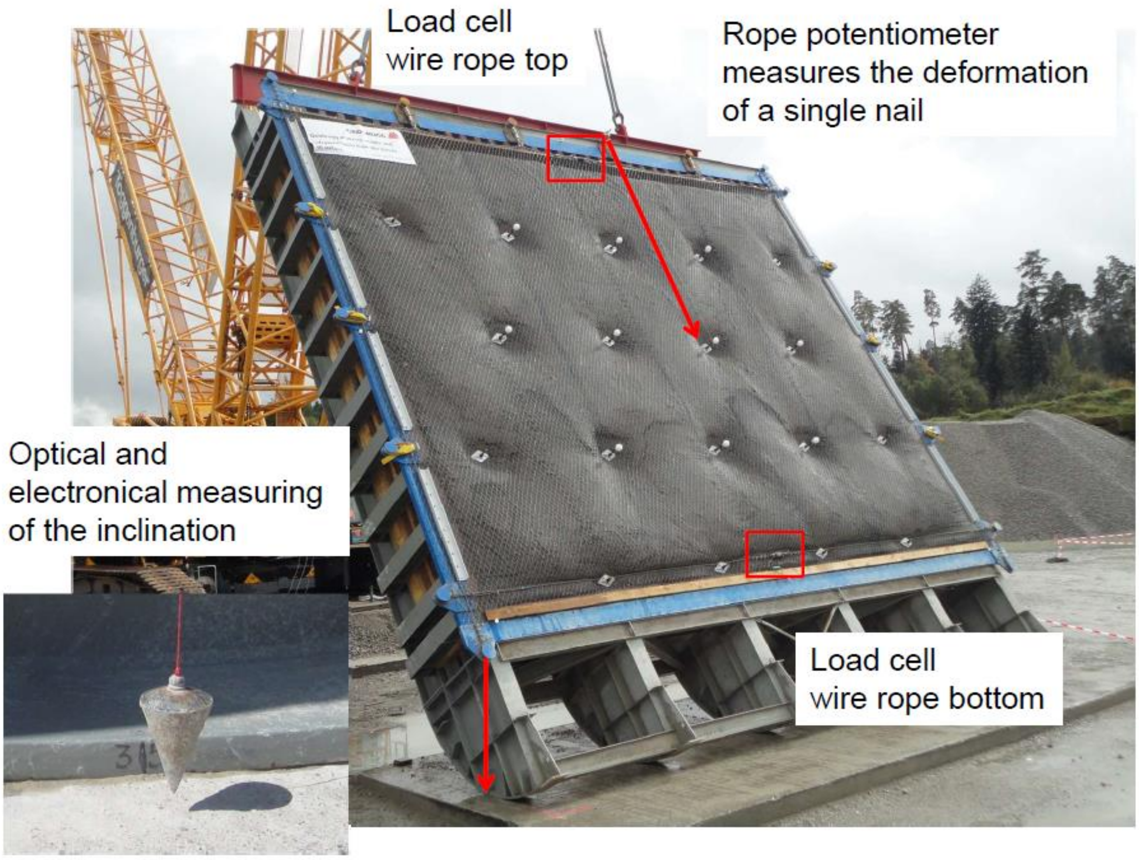


Figure E.2 – Test setup

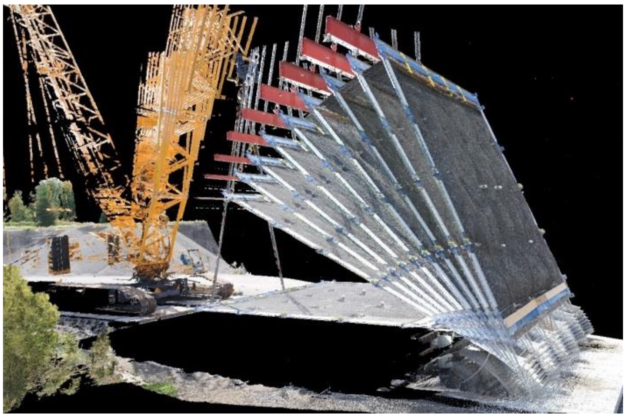


Figure E.3 – Cross –fade of individual laser scans

E5 Test report

The test report should contain:

- Detailed and particular description of test specimen: mesh/net construction, mesh/net size, component characteristics;
- Type of used spike plate;
- Type of nails used and nail pattern;
- Description of used soil;
- Date of test;
- Laser scan images showing the deformation of the system at different inclination angles;
- Measured forces on ropes in each inclined position;
- Measured strains in gauges on nail in each inclined position and relevant calculated normal force and bending moments in both directions;
- Shearing-off force $P_{R,test}$ and related inclination.

ANNEX F – CONNECTION MEMBERS TEST METHOD

F1 Scope

The aim of this test is to determine that the connection members between mesh/net panels can transfer the full transversal tensile strength of the mesh/net. The mesh/net rolls are connected on their longitudinal edges what means they shall transfer the transversal tensile strength.

F2 Test specimen

The chain link wire mesh/spiral rope net specimens shall be representative as to materials and geometry. The test specimen shall be ended by the similar way as during the mesh/net manufacturing. The specimen consists from two individual panels of the same dimensions which are connected together by means of connection members so the connection itself is located in the middle of completed sample.

The width and length of the test specimen shall be approximately 1 m x 1 m. The connection elements (number, type) need to be installed according to the indications of the flexible facing system manufacturer.

F3 Test apparatus

The test apparatus consists from traction machine and rigid steel beams (see Figure B.1) to allow the specimen to be connected to them.

F4 Test procedure

The tests shall be run with the load applied in the transversal direction of mesh/net (see also Figure 1) that the connections of the mesh are tested in. The connections shall be tested in transversal direction. (orthogonally to the chain link).

The specimen is fixed in all opening at all four sides, longitudinal and transversal fixation points. The fixation at all four sides of the sample maintains the specimen shape in transversal/longitudinal direction thus ensuring the uniform load distribution created by the rigid beam *B*, see Figure B.1.

The fixations shall rotate freely around the axis orthogonal to the plane of tested mesh/net without any friction to allow the steady displacement of it.

The grips may be left loose until the preload is applied to allow the wires to seat. The load shall initially be taken to a preload of 3% of the specified minimal tensile strength. The load *P* is than applied at a uniform rate between 80 to 90 mm/minute. Loading shall then continue uniformly until first fracture or damage of individual connection member or the whole connection occurs.

If any failure of mesh/net occurs before the individual connection member or the whole connection damage, the test cannot be accepted and the connection cannot be considered to be satisfactory.

F4 Test report

The test report shall contain:

- Detailed and particular description of test specimen: mesh/net construction, mesh/net size, component characteristics, connection member characteristics and way of connection;
- Date of test;
- Testing body;
- Nominal dimensions *b* and *l* of test specimen, number of repetitions in both directions and the connection;
- Initial dimensions of test specimen;
- Description of testing apparatus;
- Description of failure mode;
- Maximum force at failure P_{max} and corresponding tensile strength $z_c = P_{max} / b$.