EOTA®

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FLEXIBLE KITS FOR RETAINING DEBRIS FLOWS AND SHALLOW LANDSLIDES/OPEN HILL DEBRIS FLOWS

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).

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1 SCOPE OF THE EAD

This EAD covers the assessment of Shallow Landslide/Open Hill Debris Flow and Debris Flow Protection Kit for use in Works.

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.

1.1 Description of the construction product

This EAD applies to Shallow Landslide or Open Hill Debris Flow Protection Kits and Debris Flow Protection Kits, which should permit adjusting the length of the kit to the sliding site and torrent conditions and to the work to be protected.

The Shallow Landslide Protection Kits, Open Hill Debris Flow and/or Debris Flow Protection Kits are made up of:

a) An interception structure, which has the function of bearing the direct impact of the mass, deforming elastically and/or plastically and transmitting the forces to the connection components, the support structure and foundations;
b) A support structure, which has the function of maintaining the interception structure which is by nature not rigid. It can be directly connected to the interception structure or through a connection structure;
c) Connection components, which have the function of transmitting the forces to the foundation. In order to allow deformation, devices can be installed onto the structure, which permit a controlled lengthening.

The foundation is not considered as a part of the kit. The design of the foundation is in the responsibility of the designer, taking into account the national provisions and local conditions. The main components of kits are shown in Table 1 and in Figure 1 to Figure 3.

Table 1 – Description of main components of kit

Main part	Component	Function
Interception structure	Principal net: made up of cables, wires and/or bars of different types and materials. Additional layers (optionally): usually with finer meshwork than the principal net made up of cables and/or wires or other	Bears the direct impact of the mass, deforms elastically or plastically and transmits the forces to the connection components, the support structure and the foundations.
Support structure - steelworks	Posts and base structures made from different materials, geometry and length (for example steel hollow sections, rolled sections).	Maintain the interception structure in position (except for kits installed in narrow torrent). The posts can be connected to the interception structure directly or through the connection components.
Connection components	Connecting ropes, steel cables, wires and/or bars of different types and materials, wire rope grips, shackles, energy dissipating devices (elements which are able to dissipate energy and/or allow a controlled displacement when loaded).	Transmit the forces to the foundation structure during impact and/or maintain the interception structure in position.
Abrasion protection	E.g. steel section elements	Protect the upper support and winglet cable from overflowing debris
Foundation	Not covered by the EAD	Transmits the forces derived from the debris flow to the ground.

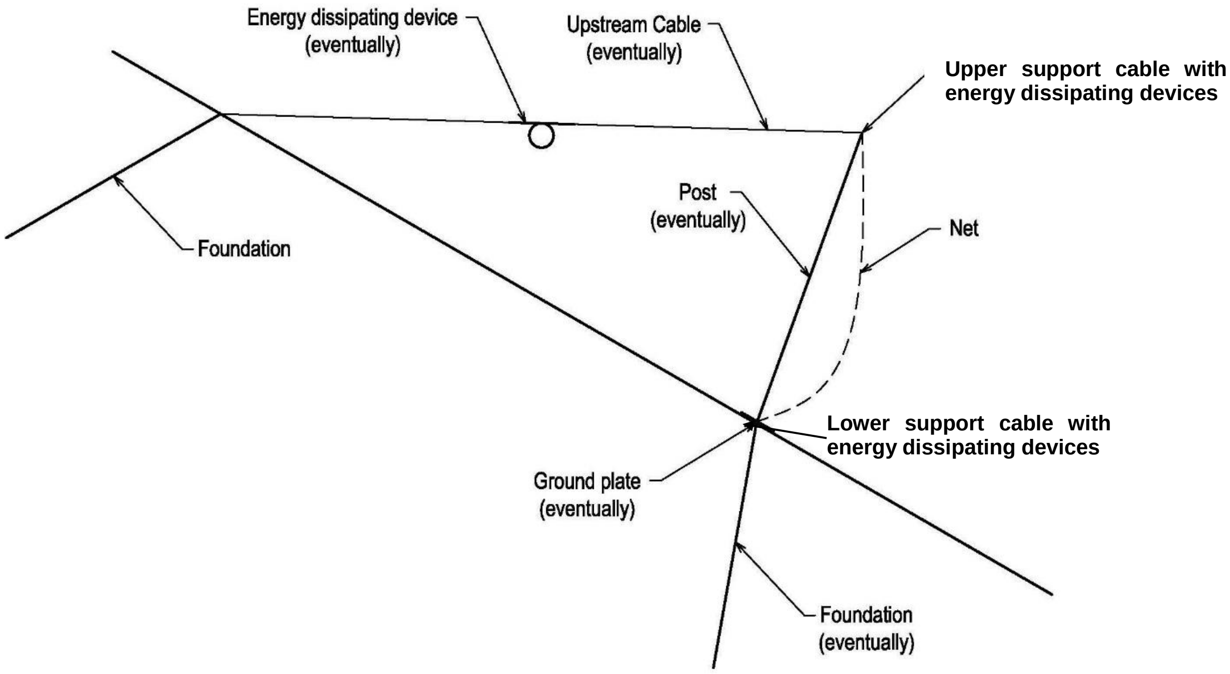

Figure 1 – Schematic drawing of shallow landslide/open hill debris flow protection kit

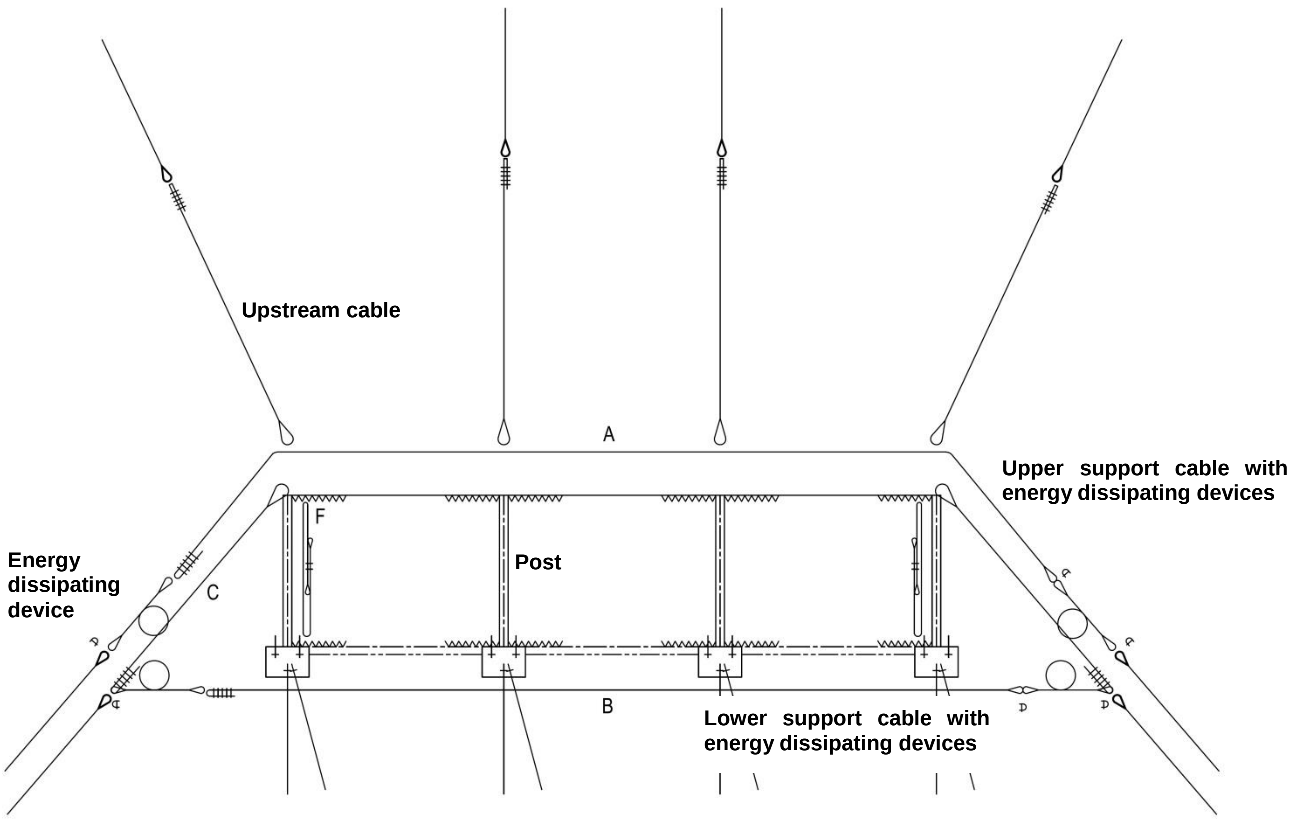

Figure 2 – Components of shallow landslide/open hill flow protection kit

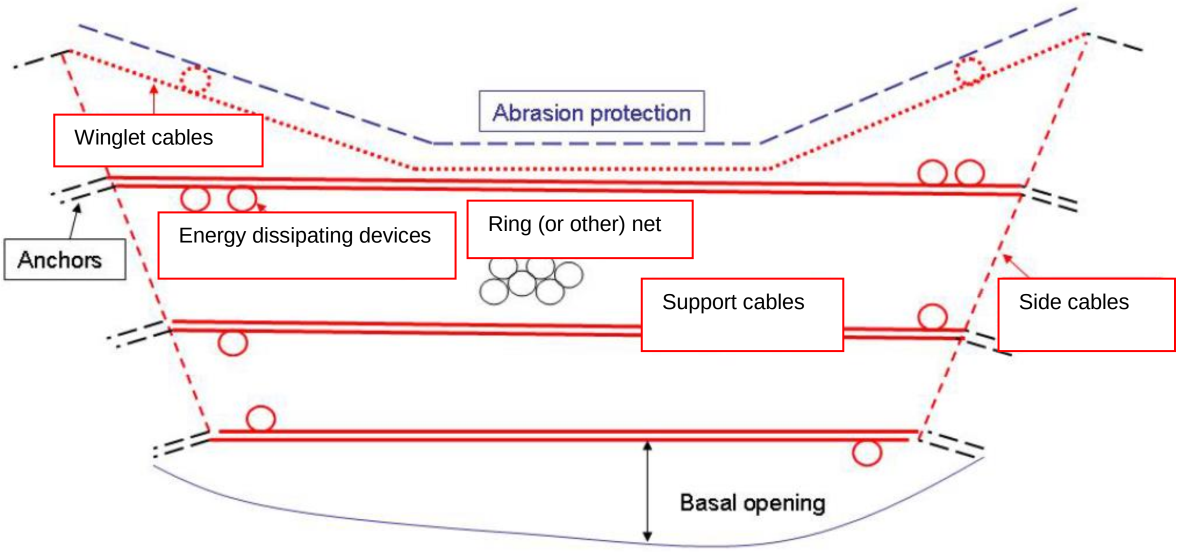

Figure 3 – Schematic drawing of debris flow protection kit

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

1.2.1 Intended use(s)

The products are used to retain:

1) Channelized debris flow (Debris Flow Protection Kit);
2) Open hill shallow landslide/Open hill debris flow (Shallow Landslide Protection Kit).

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 a working life of the Shallow Landslide/Open Hill Debris Flow Protection Kit and/or Debris Flow Protection Kit for the intended use of 25 years (without impact) when installed in the works. 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.

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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 Specific terms used in this EAD

1.3.1 Shallow Landslide/Open Hill Debris Flow and/or Debris Flow Protection Kit

Kit consisting from net (interception structure), posts and base structure (steelwork – support structure, if relevant), cables (ropes), energy dissipating devices and connection members (connection structure).

1.3.2 Net

Load bearing element acting as a surface.

1.3.3 Posts and base structure

Load bearing support structure to support the ropes and net.

1.3.4 Cables (longitudinal bearing: upper, lower, middle)

Load bearing elements to transmit the forces into the posts (if relevant) or directly to base structure.

1.3.5 Upstream cables

Upslope cables to support the post and transmit the forces to the anchorages.

1.3.6 Side cables

Cables to ensure the position of end posts or to span the debris flow net along the river channel banks.

1.3.7 Winglet cables

Cables used to form a middle section at the top for the overflowing material to avoid score problems at the river banks. These cables are protected by so called abrasion protection.

1.3.8 Energy dissipating device

Device (installed in cables) used to absorb some of the impact energy and to allow controllable deformation of protection kit.

1.3.9 Additional layer (secondary mesh)

Wire mesh connected to the net on the impacted side.

1.3.10 Anchorages and foundations

Load bearing elements to transmit the cable and post forces into the ground.

1.3.11 Calibration of numerical model

The process to calibrate and verify the numerical model based on at least tw**o** real (1:1) tests within product group (including the given net family). The results of numerical analysis resulting from calibrated model shall fulfil the requirements in cl. C3.3 in this EAD.

1.3.12 Numerical analysis

The process to design the not tested kit (assessed on the base of calculations) using the previously calibrated and verified numerical model.

1.3.13 Maximum impact pressure (p_s in kN/m^2)

Maximum pressure of debris/landslide impacting the kit in kN/m^2 evaluated according to Annex A and/or Annex B in this EAD.

The maximum input uniform pressure of debris/landslide impacting the kit in kN/m^2 when numerical analysis is used defined from the time-pressure (input) diagrams.

1.3.14 Reference slope

The slope downhill from the kit extended in the same direction to its maximum elongation.

1.3.15 Nominal height (h_N in m)

The height of kit measured orthogonally to the reference slope between the centre of lower support cable/s and the centre of upper support cable/s before the impact.

1.3.16 Elongation of net (δ in m)

The maximum distance between the empty kit line (see Figure A.1 and B.1) and extreme position of net parallel to the reference slope measured or calculated by numerical analysis after the impact.

1.3.17 Residual height of kit (h_R in m)

The minimum distance (over the tested kit) between the lower and upper cables, measured orthogonally to the reference slope after the completed test without removing the stopped material or calculated by numerical analysis after the last load case representing the fully filled kit and full hydrostatic pressure.

1.3.18 Abrasion protection

Protection component fixed to the upper cables to protect them against abrasion (for example steel L profile).

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2 shows how the performance of Shallow Landslide/Open Hill Debris Flow Protection Kit and/or Debris Flow Protection Kit is assessed in relation to the essential characteristics.

Table 2 Essential characteristics of the product and methods and criteria for assessing of the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Maximum impact pressure	2.2.1	p_s (kN/m^2)
2	Filled height of the net after single filling steps and after the complete filling	2.2.2	Z_i (m)
3	Forces on cables/anchors	2.2.3	F (kN)
4	Maximum elongation of net	2.2.4	δ (m)
5	Residual height of the kit	2.2.5	h_R (m)
6	Durability	2.2.6	Description

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

Characterisation of products to be assessed shall be done in accordance with available specifications, notably according to Table 3.

Table 3 List of product specifications

Drawings of kit	System drawings Drawings of connections (cables to posts, cables to energy dissipating devices, net to cables, net to net, etc.)
Principal net (type)	Drawing Breaking load of net (according to Annex B, ETAG 027) Characteristics of net components (designation of strand, diameter of wire, tensile strength, breaking force, bend, torsion and corrosion protection)
Energy dissipating device	Drawings Activation force and elongation (force – slip diagram) (according to Annex B, ETAG 027) Mechanical characteristics components Corrosion protection
Steelworks:Posts and base plates and abrasion protection	Drawings of steelworks Mechanical characteristics of components Corrosion protection
Ropes	Designation Breaking force of rope Corrosion protection
Connection members: Shackles, U-bolt wire rope grips, or other	Type Breaking load limit/working load limit (when and where relevant) Corrosion protection

The defined (by each main component) Shallow Landslide/Open Hill Debris Flow and/or Debris Flow Protection Kit can be assessed by two methods:

1) On the base of tests according to methods described in Annex A or Annex B to this EAD and applies for one single product to be assessed;
2) On the base of numerical analysis (see Annex C) by calibrated and verified (by TAB) method (see Annex C) of analysis resulting from tests. The numerical analysis applies to product types in groups.

For assessment of product group, at least two different setups of products within the product group (Shallow Landslide Protection Kits/ Open Hill Debris Flow Kits with interception structure consisting of a net family[1)] is one product group and Debris Flow Protection Kits with interception structure consisting of a net family is another product group) shall be tested according to Annex A or Annex B.

The Debris Flow Protection Kits can be divided into two types. One type is designed for higher volumes than its retention capacity (overflow is allowed and this is to be given in ETA) and the second type is only designed for its retention capacity (overflow is not allowed).

Note 1 – The typical net families include: family of ring nets, family of high tensile chain link wire/strands nets.

The calibrated numerical analysis shall be checked and agreed by the Technical Assessment Body (see Annex C). The components` characteristics used for the calculations shall be similar and comparable with the components` characteristics used in the field tests.

2.2.1 Maximum impact pressure (p_s in kN/m^2)

The impact pressure shall be evaluated minimum 1,5 m and maximum 5 m in front of the expected retention shown in Figure A.3 (Annex A in this EAD) and shall be assessed according to Annex A and/or Annex B in this EAD and shall be recorded in ETA.

The impact pressure as input data to the numerical anaysis[2)] shall be recorded in ETA.

Note 2 – In numerical analysis the kit can be filled in one impact

Assessment method

If more releases (at field test or numerical analysis) are carried out, the maximum impact pressure as the greatest impact pressure if the median from each impact peak value is at least 80% of the maximum value in both, measuring and numerical analysis[3)] approach is to be expressed in ETA.

Note 3 – For tested kit the impact pressure measured on stiff plate is on the safe side. For numerical analysis the impact pressure can be modified by drag factor.

In case of a single filling step the maximum impact pressure of that release is to be expressed in the ETA.

Specific provisions

The impact test (by field test) is passed if (during and after any release):

1) No ruptures in the connection components[4)] (which remain connected to foundations), interception structure and support structure occur. The rupture of a connection component is defined as the complete separation of the component itself into two distinct parts.

The impact test (by numerical analysis) is passed if (after any release):

1) Main components (ropes, interception structure) satisfy the utilisation less than 90% without employing any safety factors;
2) Elongation of the energy dissipation devices shall not exceed their maximum elongation capacity;
3) Posts shall satisfy the requirements in valid design codes (for example Eurocode 3).

Note 4 - Elements like mechanical fuses (predetermined braking points), which are designed to break under impact conditions, are excluded from the assessment: they shall be specifically listed in the installation document.

2.2.2 Filled height of net after single filling steps and after the complete filling (Z_i in m)

The tested (according to Annex A or Annex B in this EAD) or numerically analysed (according to Annex C) span of kit shall be filled.

2.2.2.1 Shallow Landslide/Open Hill Debris Flow Protection Kit

For the Shallow Landslide/Open Hill Debris Flow Protection Kit the tested span shall be filled up to the complete (residual) height of the kit within maximum 4 filling steps. The Shallow Landslide/Open Hill Debris Flow Protection Kits numerically analysed can be filled within a single filling step (one single load case).

Assessment method

The filled height for tested Shallow Landslide/Open Hill Debris Flow Kit shall be measured vertically to the base plates` line and the value is to be expressed in ETA after each filling step. The filled height for numerically analysed kits is to be expressed in ETA after each load case (each impact).

2.2.2.2 Debris Flow Protection Kit

For Debris Flow Protection Kit the tested kit shall be impacted and filled to its maximum height in one event.

Assessment method

The filled height for tested Debris Flow Protection Kit shall be measured vertically to the base plates` line and the value is to be expressed in ETA. The filled height for numerically analysed kits is to be expressed in ETA.

Specific provisions

a) If overflow is stated (overflow capable kit) this shall be proven by giving the volume of overflown material. The normal and shear forces (measured at the force plate, see Annex B) and the flow height of the debris flow on top of filled kit is to be expressed in ETA. When numerical analysis is used, the applied normal and shear forces are to be expressed in ETA.

b) The normal and shear forces can be expressed also as normal and shear strengths (in N/mm^2) measured on force plate together with the area on which the forces acted (force plate dimensions).

c) If no overflow is stated no overflow material has to be considered and given and in numerical analysis no additional loads shall be applied.

2.2.3 Forces on cables/anchors (F in kN)

The forces on cables/anchors shall be measured when tested according to Annex A or Annex B in this EAD for tested kits. The forces on cables/anchors shall be calculated by numerical analysis according to Annex C.

Assessment method

The time-force diagrams in cables for tested kit or time-force diagrams in cables as results of time-dependent numerical analysis are to be expressed in ETA.

The peak force in each cable either measured or calculated is to be expressed in ETA.

2.2.4 Maximum elongation of net (δ in m)

The maximum elongation of net shall be measured when tested as stated in 1.3.16 and Annex A or Annex B in this EAD or calculated by numerical analysis according to Annex C.

Assessment method

The maximum elongation (measured when tested or calculated by numerical analysis) parallel to the reference slope is to be expressed in ETA.

2.2.5 Residual height of kit (h_R in m)

The residual height of the kit shall be measured when tested as stated in Annex A or Annex B in this EAD and calculated by numerical analysis according to Annex C.

Assessment method

The residual height (measured when tested or calculated by numerical analysis) of the kit is to be expressed in the ETA.

2.2.6 Durability of components

Assessment method

The protection against corrosion shall be assessed for different parts of interception structure, support structure (if relevant) and connection components of kit. Type, thickness/mass of corrosion protection is to be expressed in ETA.

Specific provisions

The manufacturer can supply elements with additional coating or stainless steel material: if the coating is not relevant for the performance of the kit it is possible to apply this afterwards without further test. In case the additional coating is intended to be used for cables or other components in energy dissipating devices, the additional coating could significantly modify the behaviour of energy dissipating devices. In this case tests will be performed and the results of these tests are to be expressed in ETA.

Alternative coating, subject to assessment of different elements, shall be addressed in ETA.

The manufacturer can indicate the range of ambient temperature beyond the range (-20°C; +50°C) at which he wants his kit to be assessed. The influence of the temperature at the limited value of this level, chosen by the manufacturer, shall be demonstrated by appropriate test(s)/verification (i.e. appropriate steel or aluminium alloy for low temperature brittleness test for rubber at low temperature if relevant, etc.). The results of these tests are to be expressed 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 verification of constancy of performance are laid down in Table 4.

Table 4 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)				
1	Wire of principal net : Tensile strength Breaking force Bend Torsion Corrosion protection	EN 10264-2	EN 10264-2	According to control plan	5 tests per year (from different coils)
2	Principal net: Dimensions Designation of principal net	Mass-check by machine operator	Recorded in ETA	According to control plan	By each change of production
	Breaking load	ETAG 027 used as EAD, Annex C.3	Recorded in ETA	According to control plan	5 tests per year
3	Energy dissipating devices: Mechanical characteristics of components	EN ISO 6892-1	EN 10088-3 EN 10025-1,-2,-5 or other Standard	According to control plan	5 tests per year
	Dimensions	Caliper/gauge	Relevant drawing		
	Corrosion protection	EN 10244-2 or EN ISO 1461	Recorded in ETA		
	Activation force and elongation (force-slip diagram)	ETAG 027 used as EAD, Annex C.2	Difference from the given value of activation force within 15%		
4	Steelworks: Posts and base plates Abrasion protection	Declaration of performance of supplier/manufacturer (EN 1090-1+A1), Execution according to EN 1090-2+A1, for execution class according to the component specification but at least EXC2			
5	Ropes: Designation	EN 12385-2+A1	Recorded in ETA	According to control plan	According to control plan
	Breaking force and elongation	EN 12385-4+A1	Recorded in ETA		
	Corrosion protection	EN 10264-2	Recorded in ETA		
6	Cables both sides with pressed loop: Breaking force	EN 13411-3+A1	Recorded in ETA	According to control plan	5 tests per year per rope diameter

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
7	Shackles: Breaking load limit (BLL) Corrosion protection or other connection component	EN 13889+A1 EN ISO 1461, EN 4042 Relevant standard	Recorded in ETA Recorded in ETA	5 samples for each type	Once / year

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of verification of constancy of performance for Shallow Landslide/Open Hill Debris Flow and/or Debris Flow Protection Kit are laid down in Table 5.

Table 5 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 protection kits	-	Laid down in control plan	-	1
Continuing surveillance, assessment and evaluation of factory production control					
2	Verify 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.

Guideline for European Technical Approval (ETAG) ETAG 027,	Falling Rock Protection Kit edition September 2012, amendment April 2013 used as European Assessment Document (EAD)
EN 12385-1+A1	Steel wire ropes. Safety. Part 1: General requirements
EN 12385-2+A1	Steel wire ropes. Safety. Part 2: Definitions, designation and classification
EN 12385-3+A1	Steel wire ropes. Safety. Part 3: Information for use and maintenance
EN 12385-4+A1	Steel wire ropes. Safety. Part 4: Stranded ropes for general lifting applications
EN 13411-3+A1	Terminations for steel wire ropes. Safety. Part 3: Ferrules and ferrule securing
EN 13889+A1	Forged steel shackles for general lifting purposes. Dee shackles and bow shackles. Grade 6. Safety
EN 10025-1	Hot rolled products of structural steels. Part 1: General technical delivery conditions
EN 10025-2	Hot rolled products of structural steels. Part 2: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
EN 10025-5	Hot rolled products of structural steels. Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
EN 10244-1	Steel wire and wire products. Zn/Al alloy coatings on steel wire. Part 1: General principles
EN 10244-2	Steel wire and wire products. Zn/Al alloy coatings on steel wire. Part 2: Zinc or zinc alloy coatings
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 10088-3	Stainless steels. Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes
EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
EN ISO 6892-1	Metallic materials. Tensile testing. Part 1: Method of test at room temperature
EN ISO 4042	Fasteners. Electroplated coatings
EN 1090-1+A1	Execution of steel structures and aluminium structures. Part 1: Requirements for conformity assessment of structural components

ANNEX A – TEST METHOD FOR SHALLOW LANDSLIDE PROTECTION KIT/OPEN HILL DEBRIS FLOW KIT

A1 Test site

The test site is a structure, which shall be able to accelerate a mass of debris to the test speed and to impact it onto the net fence with the necessary precision. The slope downhill to the kit should be at the same inclination as in the last 10 meters before the impact.

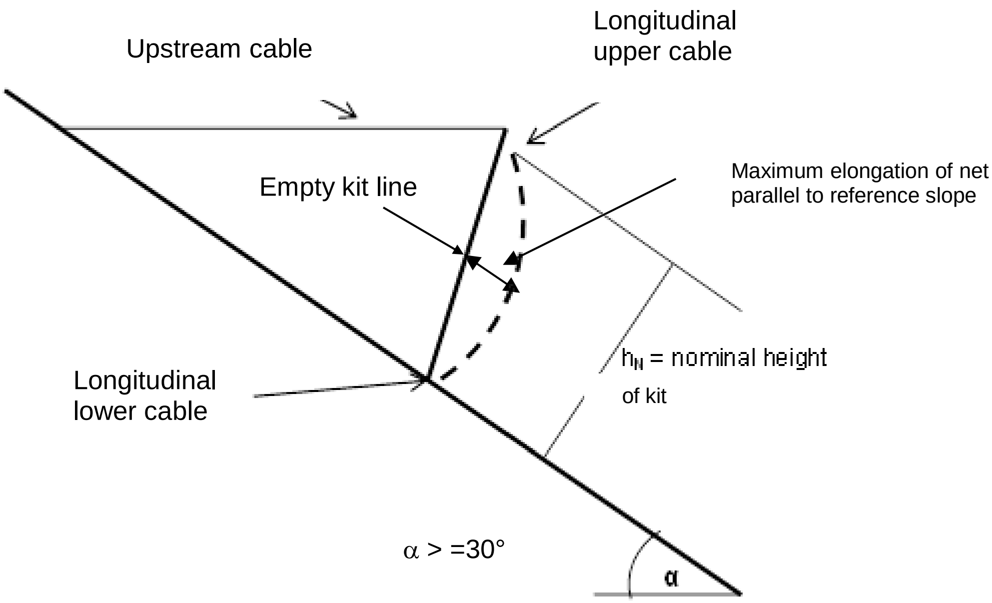


Figure A.1 – Test site slope for shallow landslides/open hill debris flow

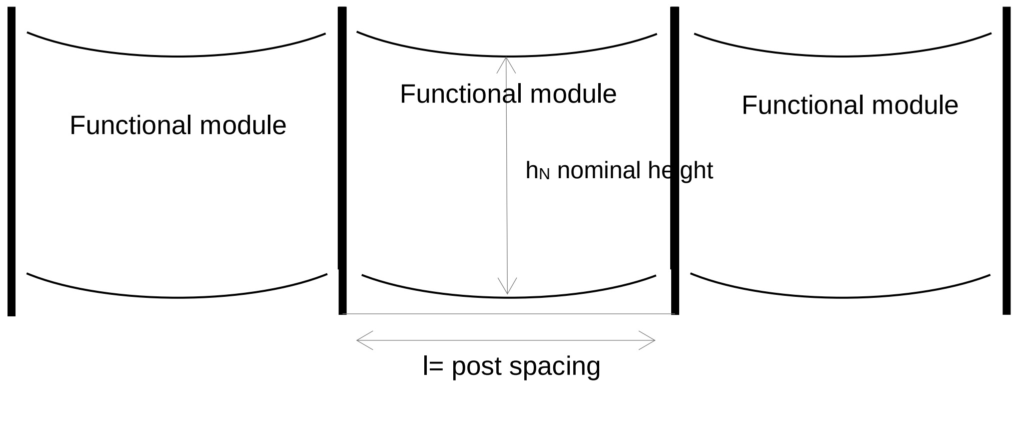
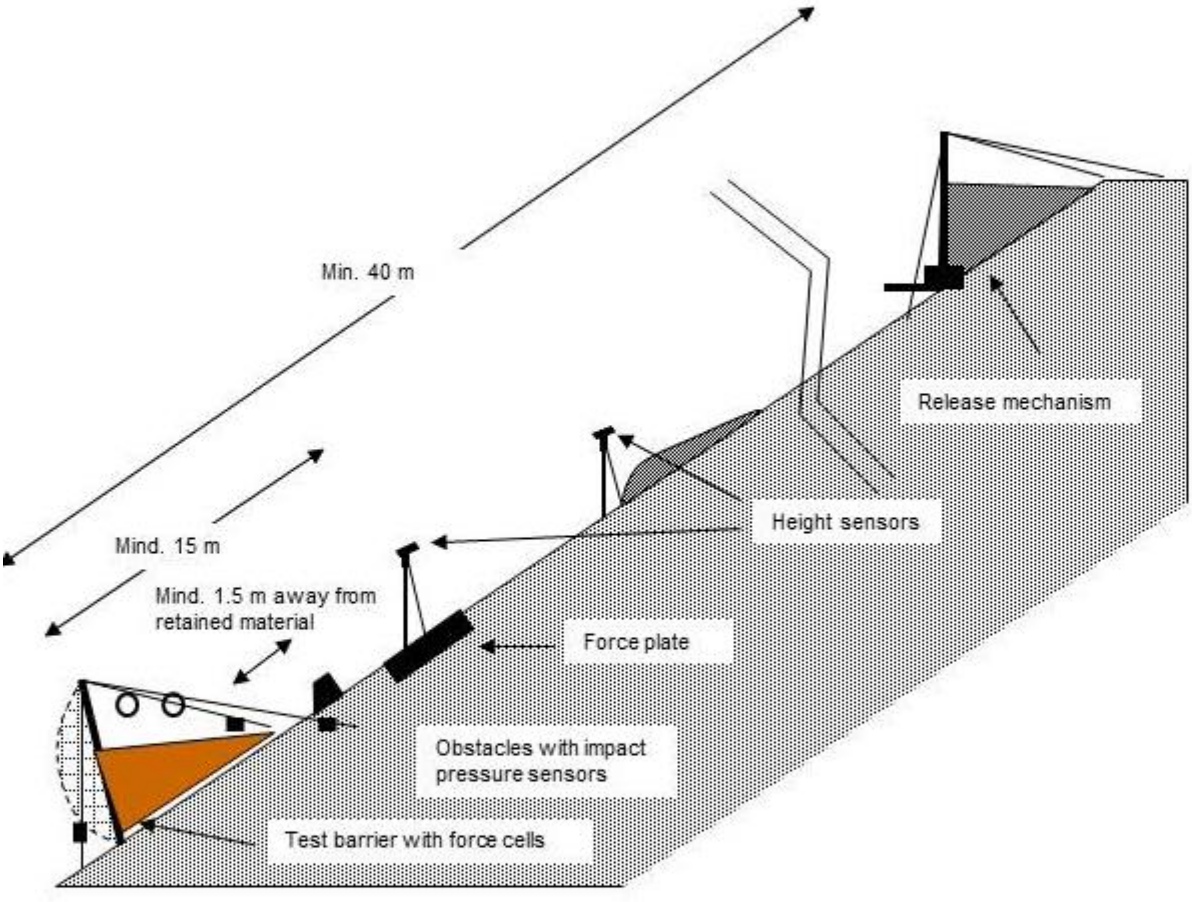


Figure A.2 – Front view on the tested kit



stopped

A2 Test equipment

A2.1 Kit installation

Three functional modules shall be used for the tests (4 posts). The manufacturer shall decide the installation geometry on the test site in accordance with the installation manual. The installation of the shallow landslide/open hill debris flow protection kit is in charge of the manufacturer following the installation manual with the supervision of the Technical Assessment Body (TAB). Recording and measurement equipment are of the responsibility of the TAB. The anchorage design shall be provided by the kit manufacturer who shall formally accept the foundation structure before all tests. An example of test arrangement is shown in Figure A.3.

A2.2 Test mass

The test mass should consist of a homogenous soil material up to a grain size of 100 mm with a mass density between 1800 kg/m^3 and 2200 kg/m^3. Density, particle size distribution and water content measurements shall be performed on material taken from the test site (and kept in conditions which do not influence its characteristics) in laboratory. Further material measurements during the tests as listed in cl. A5 shall be carried out.

A3 Test conditions

The test consists in the launching of test mass described in B.2.2 into the shallow landslide protection kit measuring the impact pressure, speed and flow height of the mass before the impact. Moreover, normal and shear forces shall be measured and recorded at the force plate with special load sensors acting in directions orthogonally to the plane of plate (for normal forces) and in flow direction (for shear forces) for the measured flow height. The flow height shall be measured by radar or laser sensor installed over the force plate.

A4 Test procedure

The middle field of the tested Shallow Landslide Protection Kit/Open Hill Debris Flow Kit shall be impacted and filled to its maximum (residual) height. A maximum of 4 filling steps shall be used to fill the kit to its maximum and the minimum volume of the test mass per filling step should be not less than 50 m^3.

A5 Recording test data

The following test characteristics shall be recorded for every test:

Pre-test data

- Initial volume of filling steps;
- Density of test mass and water content at release mechanism;
- Photographs of the position and construction of the Shallow Landslide /Open Hill Debris Flow Protection Kit;
- Geometric parameters (nominal height, post distance, empty kit line, etc.) of the Shallow Landslide /Open Hill Debris Flow Protection Kit;
- Arrangement of components in installed kit according to technical specification and drawings;
- The reference position (original net position before impact).

Test data (each release)

- Impact pressure over impact time measured before the net;
- Flow height;
- Filling height of the tested kit over impact time;
- Flow speed;
- Normal and shear forces over time in front of the tested kit;
- Forces on anchors;
- Photographic/video records by means to give a complete record of the kit behaviour, including deformation, deflections;

Post test data

- Retained volume;
- Overflow volume if overflow is stated;
- Residual height;
- Elongation of net;
- Elongation of energy dissipating devices;
- Description and photographic records of damages of the tested Shallow Landslide/Open Hill Debris Flow Protection kit.

Impact pressure shall be measured using force plates or impact pressure sensors installed in front of the tested kit in undisturbed flow regime minimum 1,5 m and maximum 5 m in front of the expected material retention area (see figure A.3).

An additional force plate (to measure slope parallel and slope orthonormal forces; shown in Figure A.3) should be installed in an area where the flow regime is already stable but still undisturbed.

Density over the time can be calculated from parallel measurements of normal load at force plate and flow height.

Mass flow speed measurements shall be done using high-speed video-records at a minimum 100 frames per second and as a second verification by at least two flow height measurements (laser, radar, ultra-sonic, geophones, etc.) installed in front of the tested kit.

Flow height measurements shall use laser or radar devices. The residual height after each release shall be measured for example using laser scan.

Photographic or video cameras shall be sufficient to clearly describe the kit behaviour and filling process before and during the test. The need for additional camera layouts should be considered to cover areas of special interest.

Measurements on anchorage and ropes shall be adapted to the specific shallow landslide/open hill debris flow protection kit under test. At least 3 measures shall be performed on main ropes linked to the centre functional module. The decision shall be carried out case by case by the TAB. The forces shall be measured during the whole test. The peak forces are to be expressed and the time-force diagrams are to be provided. The recording rate of the forces shall be at least 1000 measurements per second.

The maximum elongation during impact shall be evaluated from high-speed camera records or by the laser scan.

Force measurements shall be performed with devices covered with a valid calibration certificate issued by and appropriate accredited calibration body or another body accepted under the responsibility of the TAB. The calibration at the date of the test has to have been done no more than one year previously.

The accuracies of measurements shall be stated in the ETA.

ANNEX B – TEST METHOD FOR DEBRIS FLOW PROTECTION KIT

B1 Test site

The test site shall be a natural or artificial channelized flume (Figures C.1, C.2) where the net can be installed. Natural or artificial debris flows shall occur or be triggered. The channel inclination downhill to the kit shall be at the same inclination as in the last 10 meters before the impact.

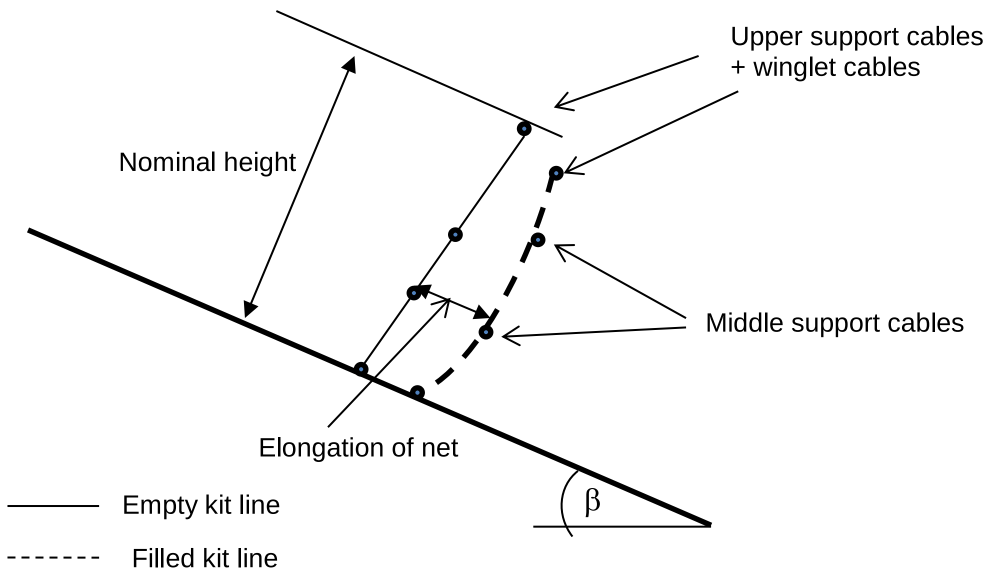


Figure B.1 – Test site slope for debris flow kit

B2 Test equipment

B2.1 Kit installation

The manufacturer shall decide the installation geometry at the test site in accordance with the installation manual. The installation of Debris Flow Protection Kit is in charge of the manufacturer following the installation manual with the supervision of the TAB. The placement, recording and measurement facilities are in the responsibility of the TAB. The anchorages design shall be provided by the kit manufacturer who shall formally accept the foundations structure before all tests.

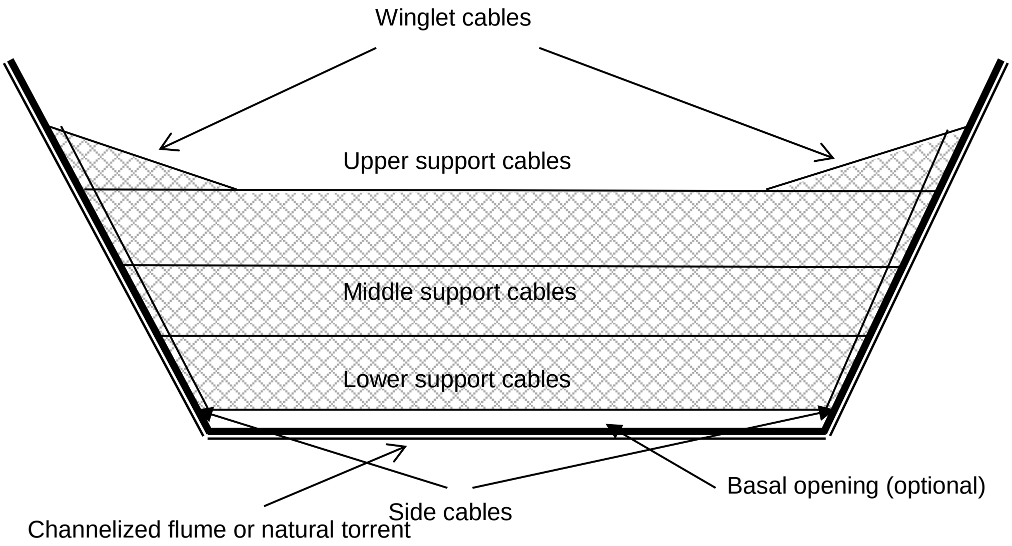


Figure B.2 – Cross section of test site

B2.2 Test mass

The test mass should consist of a homogenous debris material with a mass density between 1800 kg/m^3 and 2200 kg/m^3 which shall be recorded by a force plate installed several meters in undisturbed flow regime in front of the tested kit. The force plate can detect loads in slope parallel and slope orthonormal direction. Normal force measurements in combination with flow height measurements (radar, ultra-sonic, laser, etc.) allow determination of density of the impacting flow over the time.

B3 Test conditions

The test consists in the supervision of the debris flow impact into the debris flow protection kit measuring the impact pressure, speed and flow height of the mass before the impact.

B4 Test procedure

The tested kit shall be impacted and filled to its maximum height. The overflowing case shall be proven by declaring the volume of overflown material which has to be measured and the flow height of the overflowing material has to be measured and given as well.

The impact pressure shall be measured using force plates or impact pressure sensors installed in channel upstream or evaluated with density and speed measurements.

B5 Recording test data

The following test characteristics shall be recorded for every test:

Pre-test data

- Volume of impact/overflow material (if release is artificial);
- Density of debris flow material (if release is artificial);
- Photographs of the position and construction of the debris flow protection kit;
- Geometric parameters (nominal height, empty kit line etc.) of the debris flow protection kit;
- Arrangement of components in installed kit according to technical specification and drawings.

Test data (each filling step)

- Impact pressure
- Filling height of the net over impact time
- Normal and shear forces of the flow over time in front of the tested kit;
- Forces on anchors;
- Photographic/video records by means to give a complete record of the kit behaviour, including deformation, deflections and filling height over time;

- Stopped volume.

Post test data

- Residual height;
- Elongation of net;
- Elongation of energy dissipating devices;
- Description and photographic records of damages of the tested debris flow protection kit.

Impact pressure shall be measured using force plates or impact pressure sensors installed in channel upstream.

Mass speed measurements shall be done with video-measurement and as a second verification by at least two devices laser, radar or geophone devices installed in front of the tested kit with a certain distance in flow direction to each other providing an average impact speed.

Photographic or video cameras shall be sufficient to clearly describe the kit behaviour and filling process before and during the test. The need for additional camera layouts should be considered to cover areas of special interest.

Measures on anchorage and ropes shall be adapted to the specific shallow landslide protection kit under test. At least 3 measures shall be performed on main ropes linked to the centre functional module. The decision shall be carried out case by case by the TAB. The forces shall be measured during the whole test. The peak forces are to be expressed and the time-force diagrams shall be provided. The recording rate of the forces shall be at least 1000 measurements per second.

Flow height measurements shall use special detection devices. The residual height after release shall be measured for example using laser scan. The maximum elongation during impact shall be evaluated from camera records or laser scan.

Normal and shear forces of the flow shall be measured before the kit of the flowing material by a force plate equipped with normal and shear force devices.

Force measurements shall be performed with devices covered with a valid calibration certificate issued by and appropriate accredited calibration body or another body accepted under the responsibility of the TAB. The accuracies of measurements shall be stated in the ETA.

If the protection kit is stated as „overflow capable“, material which overflows the kit has to be measured.

ANNEX C – CALCULATION METHOD OF ESSENTIAL CHARACTERISTICS WITHIN THE PRODUCT GROUP

C1 Generally

The structural load bearing carrying capacity of flexible Shallow Landslide/Open Hill Debris Flow and Debris Flow Protection Kit is verified using a combination of field tests, simulations and numerical analysis if a complete product line is developed.

On the base of repeatable results of min. 2 large scaled field tests performed with measurement setup according to Annex A (product type 1) and Annex B (product type 2) the numerical model can be calibrated.

Product type 1: Shallow Landslide/Open Hill Debris Flow consists of one net family.

Product type 2: Debris Flow Protection Kit consists of one net family.

The possible net families are:

a) Ring net family includes ring nets of various diameter of rings, of various wire diameter and various steel grade, various number of loops, various number of crossing points, etc.;
b) High tensile chain link wire/strand net family includes nets of various shape and dimensions, of various wire/strand diameters and various steel grade, etc.

The verification of essential characteristics of Shallow Landslide/Open Hill Debris Flow Protection Kits including net family (not directly tested by 1:1 field test) therefore consists of the following steps:

1. 3 prototype kits tested according to Annex A (product type 1);
2. Numerical model calibrated on the base of (at least 3) prototype tests;
3. Numerical analysis and design.

The verification of essential characteristics of Debris Flow Protection Kits including net family (not directly tested by 1:1 field test) therefore consists of the following steps:

1. 2 prototype kits tested according to Annex B (product type 2);
2. Numerical model calibrated on the base of (at least 2) prototype tests;
3. Numerical analysis and design.

C2 Assumptions for numerical analysis

1. A numerical simulation method has to be able to perform structural and geometrical nonlinear deformations processes paired with nonlinear component behaviour over time.
2. The simulation program used shall be capable for dynamic or pseudo-dynamic analysis of components and complete kit.
3. Static component tests on mesh/net have to be performed (according to Annex B, ETAG 027 used as EAD) before implementation of the mesh/net into the numerical model.
4. Dynamic component tests of mesh/net (used directly in the analysis) have to be performed before implementation of the mesh/net into the numerical model, which leads to dynamic strength- deformation behaviour (time dependent net strength, elongation behaviour).
5. Tests on energy dissipating devices (according to Annex B, ETAG 027 used as EAD) have to be performed before to implement their load – elongation diagrams into the numerical model.
6. For rope components the nominal rope characteristics (breaking force, modulus of elasticity and elasto-plastic behaviour) shall be implemented into the numerical analysis.
7. For rigid kit components like posts, base plate, etc. there is no need for material tests and they are modelled as rigid bodies with nominal material and dimension characteristics. The model shall be calibrated also for system with post either for debris flow or shallow landslide kits.
8. The load can either be introduced using forces (impact pressure) that vary over time and act on the net area or a fluid – structure interaction that enables the direct calculation of the impact of debris material on the kit.

C3 Verification of numerical model

The verification of numerical model consists from the following steps:

1. Verification of component performance (see C2);
2. Verification of method of analysis (see C5);
3. Verification of numerical analysis outputs (see C3.3).

C3.1 Verification of component performance

The TAB within verification of numerical model shall check:

a) The completeness of modelled kit in comparison with the tested kits (geometry, used components, etc.);
b) The characteristics of input data (in comparison with the tested kits) for each components resulting from points 3 to 7 in cl. C2;

C3.2 Verification of method of analysis:

The TAB within verification of numerical model shall check:

a) The load model in comparison with the impact conditions of tested kits (including geometric conditions of the flow material);
b) The capability of software to perform (pseudo-) dynamic and nonlinear analyses.

C3.3 Verification of calibration outputs

a) The time-force diagrams in ropes obtained from numerical analysis should be in line with the tested time-pressure diagrams;
b) The measured and calculated elongation of energy dissipating devices. The maximum allowed deviation in elongation of energy dissipating device is 30%;
c) The measured and calculated elongation of net and the residual height of the kit. The maximum allowed deviation in elongation of net and residual height is 30%;
d) The maximum measured and calculated forces in cables (ropes). The maximum deviation in the cable forces is max. 15% between the measured results in 1:1 field tests and results of numerical analysis.

C4 Numerical analysis and design of kit by numerical analysis (not tested)

C4.1 Component variables

For both, Shallow Landslide/Open Hill Debris Flow Protection Kits and Debris Flow Protection Kits the following input data can be variable in numerical analysis and design:

a) Posts although the tested kit have not contained them;
b) The post type, dimensions, steel grade and their distances;
c) The rope designation, diameter and steel grade;
d) Net type within the net family;
e) Energy dissipating device type.

C4.2 Input data

The input data for numerical analysis (design of not tested kit):

a) The analysed kit geometry (taking into account cl. C4.1);
b) Selected impact pressure(s) over impact time;
c) Selected height of flow;
d) Selected density of debris flow or landslide;
e) Selected speed of flow;
f) Selected filling mechanism (filling height over impact time);
g) Selected normal and shear force simulating overflow process (if relevant).

C4.3 Output data

The output data of numerical analysis (in the process of design of not tested kit) is:

a) Maximum impact pressure (kN/m^2);
b) Time – force diagrams in anchorages/cables;
c) Peak forces in cables;
d) Filled height of kit (height of impacting pressure at each impact);
e) Residual height of the kit for the fully filled kit;
f) Elongation of net;
g) Utilisation of interception structure and cables;
h) Post design (if relevant);
i) Elongation in energy dissipating devices.

Note - The complete design of kit shall be the final output of numerical analysis.

C5 Determination of relevant load cases

To be on the safe side, the action by complete hydrostatic pressure is:

$p_{stat} = \rho * h_R * g$ in kN/m², where

ρ is the density of material in kg/m³

h_R is the residual height[C1] when the kit is filled (can be chosen based on the experience from the field test) in meter

or

$P_{stat} = \rho * h * g$ in kN/m², where

h is the flow height of each pressure surge in m

g is the gravity constant in m/s²

and hydrodynamic

$p_{dyn} = \rho * v^2 * c_d$ in kN/m², where

ρ is the density of material in kg/m³

v is the speed of flow in m/s

c_d is the drag factor[C2)].

Note C1 – The reduction in height of the system to residual height shall be considered in pressure modeling.

Note C2 – Drag factor for flexible kits can vary between 0,7-2,0 depending on the mixture and the density of the flow. Correct selection has to be given.

The complete hydrostatic pressure is assumed to be uniformly distributed over the channel width (Debris Flow Protection Kits, product type 2 acc. to Annex B) or the impact width of the Shallow Landslide/Open Hill Debris Flow Kit (product type 1 acc. to Annex A).

The value of impact pressure measured by load cell (measured over time of impact) includes both pressure components: the maximum measured pressure value ($p_{s1}=p_{stat}+p_{dyn}$) is applied to the load model shown in Figure C.5. In Figure C.5a) the impact pressure value applied to the kit (within the calibration process of model) at the first impact is shown and the subsequent filling process or surges is depicted in Figure C.5b), c) and d). The values p_{s1}, p_{s2}, p_{d1} and p_{d1} and their points of actions (z_1 and z_2) shall be calculated. The minimum time of impact per load transfer should be 0,5 sec.

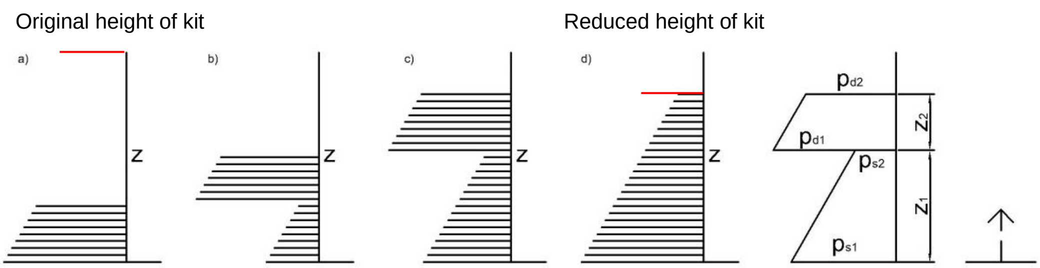


Figure C.5 – Stepwise filling model for continuous filling process: a) pressure distribution in the flow direction for the initial impact, b) and c) incremental filling process, d) overflow load case, e) pressure values and their points of actions

The overflow load case (if relevant) shall be included by acting the normal and shear forces (whether measured or selected) resulting from overflow process in combination with the hydrostatic pressure acting on the kit. The shear forces can be neglected if their magnitudes are at least ten times less than those of normal forces.

ANNEX D – TEST REPORT FORMAT

GENERAL

Technical Assessment Body (TAB):

Person in charge for TAB:

Manufacturer:

Product specification:

Product name:

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