CETRA 2018

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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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STRUCTURAL REINFORCEMENT OF GEOTEXTILES BY HIGH-TENSILE STEEL WIRE MESHES

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Abstract

For a successful and long-term stabilization of natural embankments and new cuttings in loose rock, their effective revegetation is very important. In combination with hydro or dry seeding, so-called three-dimensional erosion control mats made of polypropylene are very effective. On the one hand, the 3D structure reduces the impact energy of raindrops, and the drag force of the draining water is reduced. Geotextiles, which are used as planting aids, usually have only a low strength and are therefore only effective for low slope angles, or in combination with a stabilization measure such as wire mesh. In the last 15 years, meshes made of high-tensile steel wire for slope stabilization in combination with soil nailing have established themselves. They can transfer larger forces and thanks to a very high puncturing resistance are better to introduced the load into the nailing. Their dimensioning for the stabilization of superficial instabilities can be carried out with a design software according to the so-called RUVOLUM concept. In order to increase the range of application of the erosion control mats described above, they were combined during production with a light mesh made of high-tensile steel wire to increase their load bearing capacity to 53 kN/m. They are mainly used as roll-off protection and/or greening aids without nailing to the ground. The experience gained has now been used to produce a product that combines the advantages of high-tensile steel wire mesh and the erosion control mat. Loads of 150 kN/m and puncturing resistances of 180 kN can be introduced into the nailing when using a system spike plate. We show the development and application of both systems. Thanks to the systems described above, it is now possible to efficiently secure steep soil embankments in combination with a soil nailing system and to revegetate depending on the location.

1 Introduction

The creation and widening of infrastructure such as roads, railway lines and buildings, requires many new cuttings and the steepening of embankments in loose ground and rocks (Fig. 1). Ideally, the slopes should be at a low angle of inclination to avoid compromising the stability. If this is possible, simple greening aids such as erosion control mats are usually sufficient to protect against washouts. However, these only have a low strength and quickly begin to strain when steeper embankments have to be secured or when there are superficial or even global stability problems (Fig. 2).

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Figure 1 Ad hoc slumping on a slope in the grounds of a sports facility

Figure 2 Slumping on an embankment with a slope at approx. 25°, secured with a geotextile/erosion control mat for greening without nailing

1.1 Support of greening with erosion control mats

An effective and functional layer of vegetation must be encouraged and/or produced to ensure the long-term stabilization of embankments, (Rüegger, 2004 & 2006). Newly cut loose rock slopes are, for the most part, poor in nutrients due to the removal of the topsoil (Bosshard, 2013). Since the layer of vegetation is removed there is a lack of roots and natural seed deposits. In principle, external erosion must be reduced or controlled. In doing so, the primary erosion caused by the so-called drop effect is distinguished from the secondary erosion caused by the flow effect (Fig. 3). An erosion protection mat should minimize the impact energy of the droplets and retain soil particles in the draining water (Rüegger, 2006).
There are a variety of erosion control mats and geotextiles available to support the greening of loose rock slopes, (SN standard 640 550, Geotextilhandbuch, 2003). In principle, there are two different starting materials: synthetic geotextiles, e.g. made of polypropylene, and natural geotextiles made of organic materials, such as jute or coconut fibers. Organic natural products can be used for flatter slopes. The advantage is that they store some of the water and release nutrients as they decompose, thereby promoting plant growth. In steeper slopes, synthetic products offer advantages thanks to their low weight, which only changes when permeated by water. The synthetic options also remain resistant for longer in comparison with the organic alternatives.

Figure 3 Erosion channels caused by the flow effect of the draining water, which remove the soil and reduce and/or prevent the growth of plants

1.2 Flexible slope stabilization systems using steel wire mesh

Flexible slope stabilization systems made of steel wire meshes in combination with a soil nailing system are now widely used to secure loose ground and rock slopes. These systems have proven to be very effective if applied correctly (Fig. 4). However, due to the lack of basic principles such as standards and directives, often no or insufficient requirements are demanded for the securing systems and verification of the stability is often neglected.

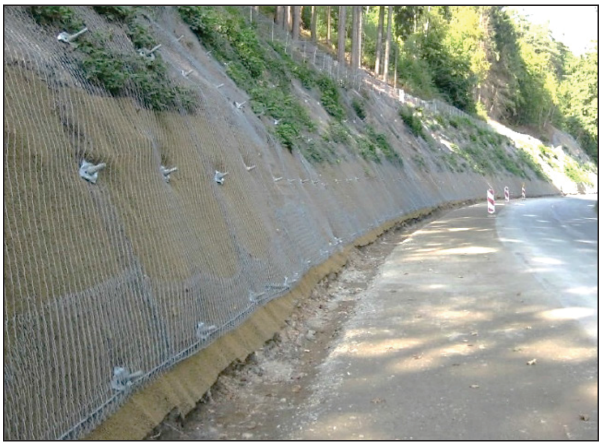

Figure 4 Slope stabilization with high-tensile steel wire mesh and erosion control mat (TECCO® G65/3 system)

As a result, suppliers offer and/or install systems that are not adapted to the local static conditions or with components that are not matched to one another. This means that the systems may fail with potentially fatal consequences resulting from the material breaking, as well as drastic levels of instability. The load-bearing resistance of a system as a whole as well as of its individual elements (nets, meshes and attachments) must be known so that suitable dimensional models can be used for the necessary verifications of the stability (Rüegger, 2002 and Flum, 2014).

1.3 Dimensioning to prevent surface-related instabilities

Superficial instabilities can be measured according to the RUVOLUM® dimensioning concept. It is universal and can be used for dimensioning the securing systems of superficial instabilities in loose ground as well as for heavily loosened rock slopes. The bearing resistances form the basis for the dimensioning; these are determined in realistic tests that can be repeated.

Rüegger described the RUVOLUM® dimensioning concept in detail in 2002 and 2004.This concept includes the study of superficial slope-parallel instabilities (Fig. 5), as well as the investigation of local instabilities between the individual nails (Fig. 6). The influence of excess hydrostatic pressure, flow pressure and seismic forces can also be taken into account. The software can be used as an online tool at www.geobrugg.com (under “myGeobrugg”).

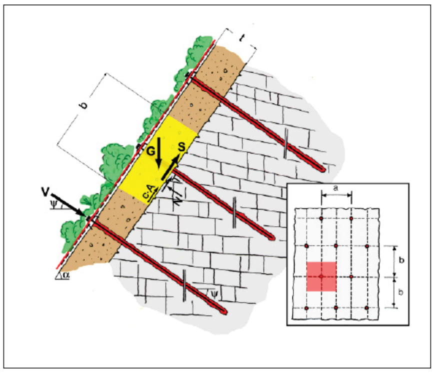

Figure 5 Superficial slope-parallel instabilities

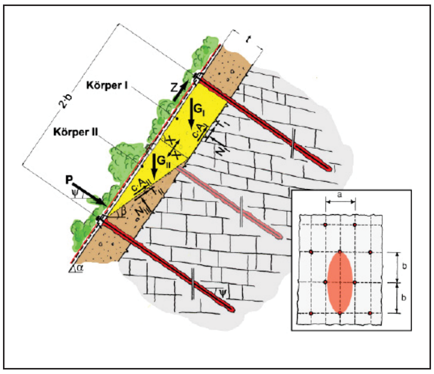

Figure 6 Local instabilities between the individual nails

2 Evaluation of an erosion control mat

Initial tests were carried out in 2000 to evaluate a suitable erosion protection mat for steeper slopes in combination with high-tensile steel wire mesh. These were expanded in 2003 with an erosion control mat that offered a wide range of applications. The following requirements were defined in cooperation with the engineering firm of Rüegger Flum:

- Good permeability through spraying for wet and dry seed to get as many seeds as possible onto the substrate
- Good adaptability to the ground
- Low surface weight, even with the ingress of water
- Good adhesion of the mat to the substrate / low risk of slipping
- Good retention properties for soil particles, organic matter and seeds
- Color-matched for a natural look / less heating

During the trials in 2000, various erosion protection mats were erected in a test area in Valais, Switzerland. The following variants were used (Fig. 7):

- Area I: Three-dimensional, very dense, three-layer anti-erosion mat made of polypropylene black.
- Area II: Three-dimensional corrugated erosion protection mat made of polypropylene black.
- Area III: Two-dimensional, flat geogrid made of polypropylene black.

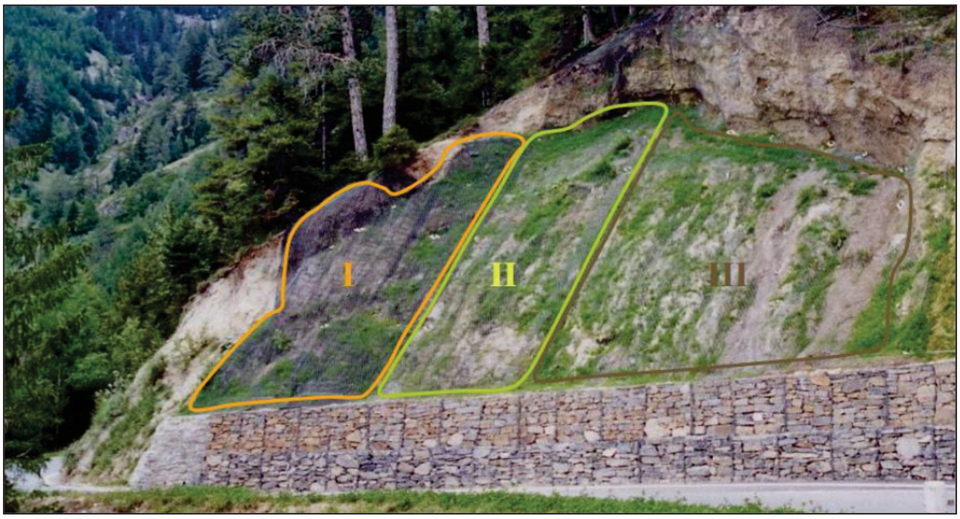

Figure 7 Test areas for the evaluation of an erosion protection mat

The test area faced south-west, in a sparse location with extreme changes in dry and wet conditions. The greening was performed using a dry seeding process. The most successful greening was achieved on the three-dimensionally corrugated mat on Area II. It is assumed that the retention properties of a two-dimensional, flat erosion protection mat, as used in Area III, are too low for soil particles and seeds. For Area I, it is assumed that the lower albedo of black surfaces causes a greater heating of the slope, which has led to the seeds drying up quickly, or not germinating at all.

Working off the basis of the previous tests, field tests were carried out in 2003 with a three-dimensional geomat. The aim was to study the mat's retention properties, its adaptability to the substrate and the extent to which it could be permeated when sprayed. The shortlist included an 18 mm-thick erosion control mat made of extruded monofilaments and a surface weight of 600 g/m^2. Its proportion of cavities is › 95 %. Figure 8 shows the test areas (Bischofszell, Switzerland).

Figure 8 Test areas and test frames at the time of sowing

The erosion control mats (geomats) as described above were inserted on the far right. The other surfaces are reference surfaces without erosion protection mats and/or similar products made from polypropylene. In order to be able to make claims about the permeability, wooden frames with an area of 1 m^2 were used. These can be seen at the bottom edge of the photo.

Verdyol (Switzerland) germinated the seeds in the test area through hydroseeding. In this process, water is mixed with the seeds, a mulch and an algae-based adhesive. The mulch is a so-called export mulch made from hollow fibers < 4 mm in length. Roughly 4 weeks after the seeds have been sown there was a heavy rainfall over the test area, which caused superficial landslides on the slope. A further 6 weeks later, a study of the area revealed that the seeds in the reference area were reduced to about 10%. Correspondingly low plant growth was visibly noted. More than 90% of the surface in the area with the geomat, which had an incline of 30 – 45°, was covered with a layer of vegetation (Figure 9).

Figure 9 Test area approx. 10 weeks after the hydroseeding process and after heavy rainfall. On the left the reference surface without an erosion protection mat with less than 10 % greening success. On the right with a geomat and a greening success of more than 90 %

Working off these results, an erosion control mat was introduced to the market in 2004 under the trade name of TECMAT with the following characteristics (Fig. 10):
- Extruded monofilaments made of polypropylene with an irregular loop structure
- Thickness 18 mm
- Surface weight 600 g/m^2
- Proportion of cavities > 95 %
- Color curry green

Figure 10 TECMAT erosion control mat in combination with a TECCO® G65/3 high-tensile steel wire steel wire mesh in the area of soil nailing

3 Examples of use

3.1 Miraflores, Panama

Slope stabilization using the TECCO® G65/3 system in a heavily irregular rock embankment. The erosion control mat TECMAT could be adapted well to the soil. The fall of the folds shows that some areas do not fit (Fig. 11). Due to the good conditions for growth, the neighboring areas are lush green. The initial signs of vegetation also appeared in the securing area.

Figure 11 Secured rock embankment in Miraflores, Panama. Erosion protection mat and mesh could be adapted well to the irregular slope

3.2 Remscheid, Germany

Securing measure on weathered rock with the TECCO® G65/3 system after a landslide. The growth conditions are good, as can be seen on the slope. The embankment is relatively even. It is difficult to secure the mat on a “solid” base, which is why there are slight shifts in the TECMAT, Figure 12.

Figure 12 Securing a cut slope after a landslide in the weathered rock

3.3 Dorndorf, Germany

Evenly profiled embankment of loose rock. Subsections were dug in the area of the nail heads in order to be able to harness the high-tensile steel wire mesh TECCO® G65/3. The erosion control mat could be adapted well to the embankment – close fitting with only a small proportion of cavities under the erosion protection mat (Fig. 13).

Figure 13 Evenly profiled embankment in loose rock with close-fitting erosion protection mat

The three examples show that it is extremely feasible to apply a combination of erosion protection mats and high-tensile steel wire mesh. On slopes with irregular profiles (e.g. 3.1 and 3.2) it has been found that the erosion control mat does not always lie evenly on the embankment. It is therefore important when hydroseeding that the mat can be injected with an export mulch (length of fibers ‹ 4 mm). Due to the lower water absorption capacity of synthetic mats, they are less prone to slipping under load. Depending on the conditions of the substrate, it is difficult to attach the mat. The example shown in 3.3 can be adapted well to the substrate. The mat is not anticipated to shift even when under load. Nevertheless, the mat must be suitable for spraying with a seeding process.

4 Structural reinforcement of geo-textiles with chain link meshes made of high-tensile steel wire

It was evident that the system could be optimized through corresponding combinations of erosion control mats and high-tensile steel wire meshes. Firstly, the erosion protection mat is structurally reinforced. This makes it possible to attach the securing measure with greater efficacy against slipping. A further advantage is a much simpler assembly: the erosion control mat and high-tensile steel wire mesh can be applied to the slope in a single operation.
The initial tests for a standard product were carried out in 2012 with the high-tensile chain link mesh DELTAX® G80/2. The internal diameter of the mesh is 80 mm and the wire is 2 mm thick. It has a load-bearing capacity of 53 kN/m'. It is often used without nailing as a drapery, even on steep slopes where there are likely to be just smaller stones. The reinforcement of the erosion control mat provides sufficient support to keep the small stones in place. Some systems were also applied with soil nailing. As described in Chapter 3, the erosion control mat cannot bear the loads in all applications without suffering some damage. The individual channels under the mesh are expected to shift in the fall-lines, especially if the mat is difficult to attach. In order to be able to adequately secure and green slopes subject to superficial landslides or with global stability problems, it was necessary to try and reinforce the erosion control mat with a high-tensile steel wire mesh TECCO® G65/3 (Fig. 14). The internal diameter of the mesh is 65 mm and the wire is 3 mm thick. It has a load-bearing capacity of 150 kN/m' with a puncturing resistance of 180 kN against the system spike plate with edge lengths of 33

x 20 cm. Figure 14 shows that the choice of mulch fibers is important. Long fibers are not able to sufficiently penetrate the erosion protection mat.

Figure 14 TECCO® GREEN after hydroseeding

5 Conclusions and outlook

In principle, naturally biodegradable, organic erosion protection mats are preferable. However, they reach their limits of usefulness when applied to steeper slopes. Three-dimensional geomats , e.g. made of polypropylene, offer advantages owing to the fact that they weigh less and have good retention properties. Color-matched, lighter erosion contraol mats heat up less and render superior greening results in addition to being less conspicuous.
The structural strengthening of geotextiles with high-tensile steel wire meshes, which are used as erosion control mats, increase their scope of use through their increased load-bearing capacity. Superficial instabilities can be secured up to a depth of 2 m with the high-tensile steel wire meshes that have a minimum puncturing resistance of 180 kN. They can be reliably designed according to the RUVOLUM concept. Global instabilities can also be secured if they are correspondingly dimensioned. Furthermore, the extent to which the properties of synthetic geomats can be combined with those of organic ones was also studied. A variant is to attach the mats directly and reinforce them with the fibers of coconut, jute or wood wool. Further developments of natural geomats based on paper offer another possibility. The greening of embankments is certainly a very complex subject and depends on many factors.

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