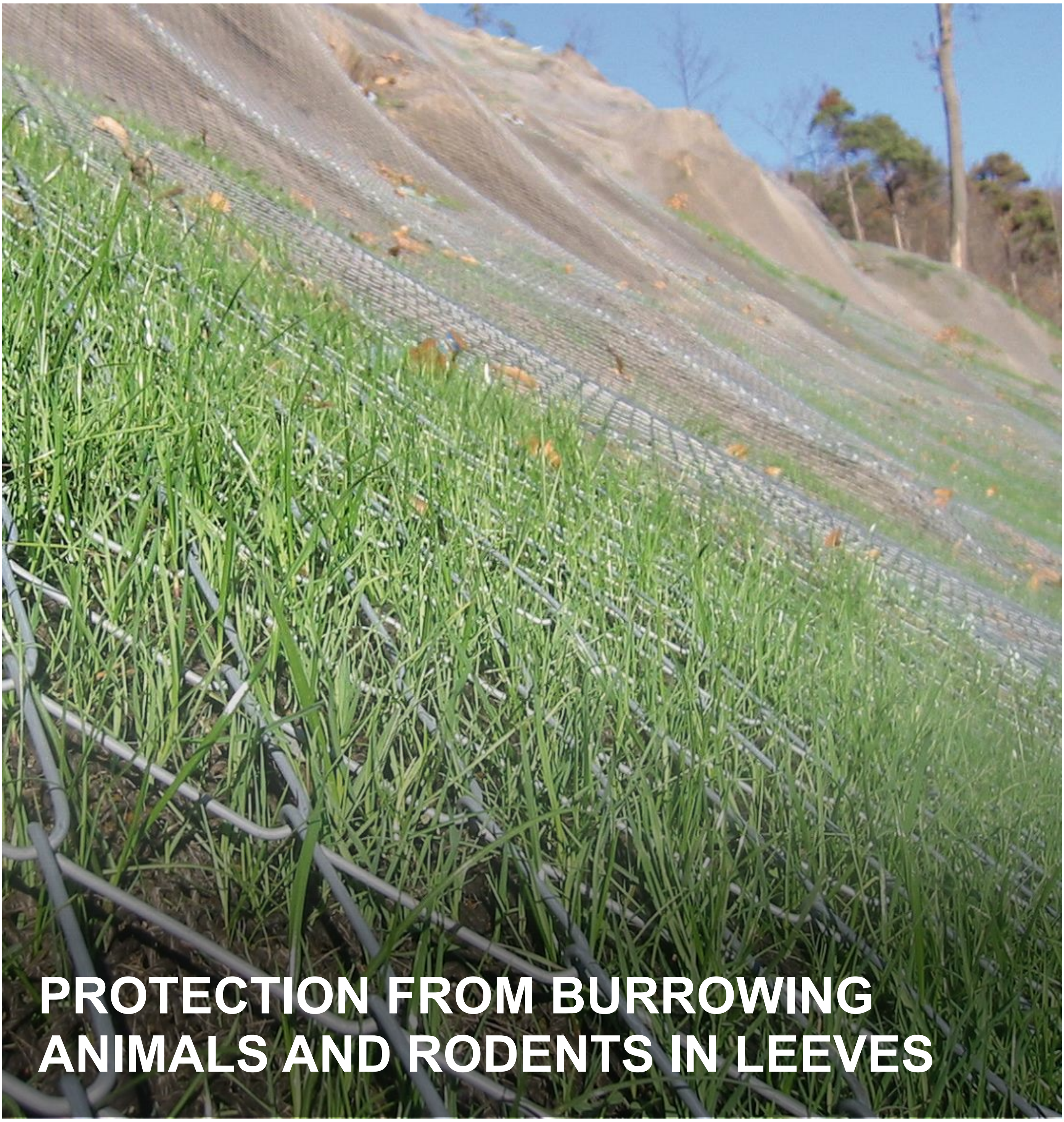

PROTECTION FROM BURROWING ANIMALS AND RODENTS IN LEEVES

Summary of studies on the bite strength, soil corrosion behaviour and mesh size of steel wire netting

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BRUGG Geobrugg

Safety is our nature

Introduction

Burrowing animals can damage earth dams, levees and irrigation canals. This can lead to dam bursts, large-scale flooding and draining of water reservoirs. Furthermore, burrowing activity on the verges of roads can lead to erosion and, in the worst case, to the collapse of the road surface. Beavers (Castor fiber), Nutria (Myocastor coypus) and other rodents and burrowing animals cause considerable damage to earthworks, especially on river banks, levees and dikes. The Bavarian State Ministry for the Environment and Consumer Protection estimates the beaver population in Bavaria in 2018 at around 22,000 animals in 6,000 territory - and the trend is upwards. Across Europe, the Bund Naturschutz in Bayern e. V. speaks of 500,000 to 700,000 beavers.

Beavers usually live along streams and rivers and build their dens close to the banks. Their dens are located both below and above the water level. The den, where they raise their young (3-4 per year), is located in the dry part of the burrow. Beavers have strong biting teeth with which they can fell trees of medium diameter. This behaviour enables them to dam rivers and regulate the water level to ensure access to their burrow and keep intruders out.

Due to the increasing proximity of beavers and other burrowing animals to human habitat and the associated infrastructure, adapted burrowing animal protection is required. This should prevent the animals from damaging the embankment or undermining adjacent roads and infrastructure. For this purpose, suitable netting is placed on the embankment, fixed and lightly covered.

In this summary, three reports studying dam protection against beavers and other burrowing animals are summarised and interpreted. urthermore, the application and installation according to the **Brandenburg Guidelines for the Application of Geosynthetic Clay Liners in Dike Construction** (Landesamt für Umwelt LfU Brandenburg 2016) and the **DVWK Leaflet 247/1997 Muskrat, Beaver, Nutria** (Deutscher Verband für Wasserwirtschaft und Kulturbau DVWK 1997) are presented. The aim is to draw a conclusion that can be used in practice as a recommendation for the planning of levee protection measures using steel wire mesh against burrowing animals. The subject of the summary is the work of:

- Mattias Denk (Company200) 2022: **Project Burrowing animals and Beaver Protection Resistance tests for biting through selected mesh and grids (in german),**
- Mattias Sorg (WITg) 2022: **Corrosion in soil, behaviour of galvanised and stainless steel (in german),**
- Maximilian Kramer (University of Natural Resources and Life Sciences & Geobrugg AG) 2023: **Wire mesh for protection against burrowing animals - preliminary study on required mesh size, GeoResources Journal (2-2023), pp. 17-19 (in german);**

Resistance test for bite-through

The report by Mattias Denk documents the results of resistance tests on various steel wire meshes and grids that can be used as protective measures against burrowing animals such as beaver, nutria and muskrat. The aim was to test the suitability of these materials in terms of shear resistance to a bite, as protection against burrowing animals.

To conduct the resistance tests, a pneumatically operated shear apparatus was used, which was developed and constructed to simulate the bite of a burrowing animal (Figure 1). The test apparatus allows the different meshes to be loaded with forces between 62 and 274 kg. Six different samples of meshes and grids were tested, including meshes of the TECCO series from Geobrugg AG with different mesh openings and wire diameters, as well as different grids and a PVC-coated hexagonal mesh. A detailed description of the tested samples and their technical specifications are available in the report.

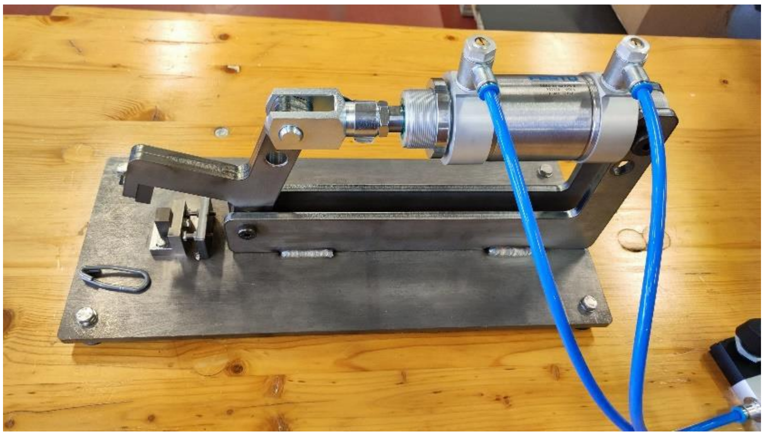

Fig. 1: Test apparatus for simulating the bite force on different wire meshes.

The resistance tests were carried out in two series. In the first series, the patterns were tested in steps up to and beyond the maximum biting force of a beaver. The forces were increased in steps of 50 kg. In the second series, the samples were loaded with the maximum biting force of a beaver and it was examined whether and to what extent the wire surface and the coating were damaged by the beaver bite.

The results of the resistance tests show that all tested meshes and grids can withstand the biting force of a beaver. It was found that the meshes of the TECCO series can even withstand twice this load. However, at higher forces, the grid and the rectangular mesh broke. Damage to the wire surface and coating was minimal in most of the meshes, with minor nicks and scratches noted. However, the PVC-coated hexagonal mesh exhibited complete separation of the PVC coating.

The report discusses the results of the resistance tests in the context of rodent protection. It is emphasised that all tested materials are basically suitable for protection against burrowing animals, but that there are differences in terms of resistance and damage to the surface.

It is noted that the tested meshes and grids withstood the resistance tests against the biting force of beavers. The TECCO meshes proved to be particularly resistant. The minimal damage to the surface was acceptable in most cases.

Corrosion in soil

The report of the Institute for Materials Systems Engineering Thurgau at the University of Applied Sciences Konstanz deals with research on corrosion in soil and the behaviour of galvanised and stainless steel. The aim of the research is to compare different materials and make recommendations for their use in hydraulic engineering and dam construction.

By way of introduction, the importance of the physical and chemical properties of soils for the corrosion of metals and alloys is pointed out. Factors such as oxygen content, salinity, pH, temperature and microbial influences play a decisive role in the corrosion reaction in soils. The structure of the soil, including different layers, can also lead to the formation of corrosive elements. Standards and regulations are shown that classify and investigate the corrosion probability of components in soils. These include criteria such as soil type, soil moisture, pH and other factors that can influence corrosion.

The remainder of the report discusses the use of stainless steel in soil. It is pointed out that stainless steels are passive above a certain effective sum but can still be susceptible to corrosion phenomena such as pitting, crevice corrosion and stress corrosion cracking, depending on the conditions. The material 1.4301 shows limited resistance in soil, while the duplex stainless steel 1.4462 shows excellent resistance. Furthermore, the use of high-tensile strength galvanised steel in soil is also assessed. Corrosion of zinc is highly dependent on the nature of the soil, pH, salinity, moisture and aeration. Well-aerated, homogeneous and low-salt soils usually lead to extensive corrosion, while higher chloride and sulphate contents can lead to localised corrosion. Surface layer formation and the presence of moisture also influence corrosion induced erosion. For the PVC and PoliMac® coatings, there is limited information on their use in soil. However, both systems are resistant to a wide range of substances and environments. PVC application may be limited by weathering, high temperatures and UV radiation, but this is not a factor in soil. PoliMac® offers advantages in terms of chemical resistance and abrasion resistance compared to PVC, according to the manufacturer. An additional coating of galvanised wires can therefore extend the service life in corrosive environments. However, damage to the coating system can lead to corrosion within the sheathing and delamination of the sheathing.

The report provides a comprehensive summary of corrosion in soil and the behaviour of galvanised and stainless steel. Important factors and standards for assessing the likelihood of corrosion are outlined and recommendations for the use of materials are given (Table 1). The results of the research can be useful for hydraulic engineering and levee construction to select the right materials and minimise potential corrosion problems. But in general, soils represent a very complex corrosion system and assessing the probability of corrosion is a complex task associated with relatively high effort.

Table 1: Comparison and summary of findings on the different behaviours of steel mesh in soil

Stainless steel 1.4301	**Stainless steel 1.4462**	**Unalloyed high-strength steel with zinc coating**	**Unalloyed high-strength steel with zinc coating and polymer sheathing**
- Is only just above the resistance limit for stainless steels in earth soils - Only in inland soils with low salt content - Not in clay or loamy soils - Susceptible to stress corrosion cracking	- Excellent resistance in the vast majority of environments - Resistant even near the coast - Resistant to stress corrosion cracking	- Use only in soils with a pH value between 5 and 9. - High salt content promotes local corrosion - Different soil layers can lead to local element formation and increase corrosion - May be susceptible to hydrogen embrittlement	- Use when zinc coating is not sufficient - With intact polymer coating, significantly increased resistance - May be susceptible to hydrogen embrittlement
Only partly recommendable	Unreservedly recommendable	Use strongly dependent on soil properties	Improved resistance compared to zinc coating

Another WiTg report looks more closely at the analysis of the "PoliMac®" plastic coating. The plastic coating shows damage visible to the naked eye in the form of cracks on the surface in individual places, especially where the steel wire has been severely deformed by use and processing (Fig. 2). (WiTg, 2019)

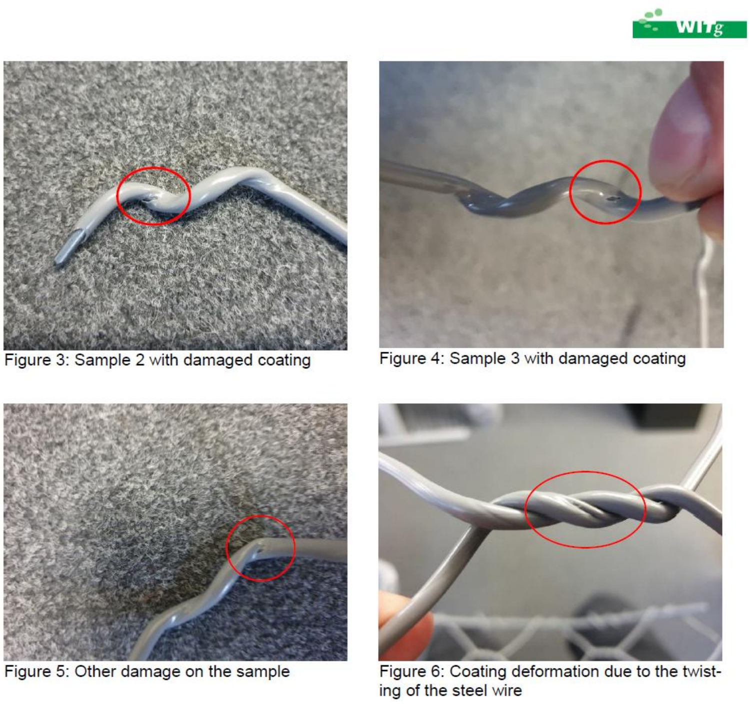

Fig. 2: Mechanical damage found on the PoliMac® braid, caused during the manufacturing process (WiTg, 2019).

Required mesh size

The article "Wire netting for protection against burrowing animals - preliminary study on the required mesh size" deals with the use of wire netting as a protective measure against damage by burrowing animals at levees, dikes and irrigation canals. In particular, beavers, nutrias and muskrats are considered as causative animals. The aim of the study is to determine the required mesh size of wire netting to ensure sustainable and economic protection without harming the protected species.

The study is based on measurements of skulls of different animal species, using skull size as a criterion for the mesh size of the nets (Fig. 3). It is found that TECCO netting with a mesh size of 45 mm and a wire diameter of 2 mm is suitable for protection against both beavers and nutrias. Under certain conditions, DELTAX mesh with a mesh size of 80 mm can also be used, but it should be ensured that no settlement of other burrowing animals is to be expected. For muskrats, no clear mesh size could be derived, as the skull sizes show a large variation. Nevertheless, the TECCO mesh with a mesh size of 45 mm could help to make digging more difficult and partially prevent the animals from entering the dam body.

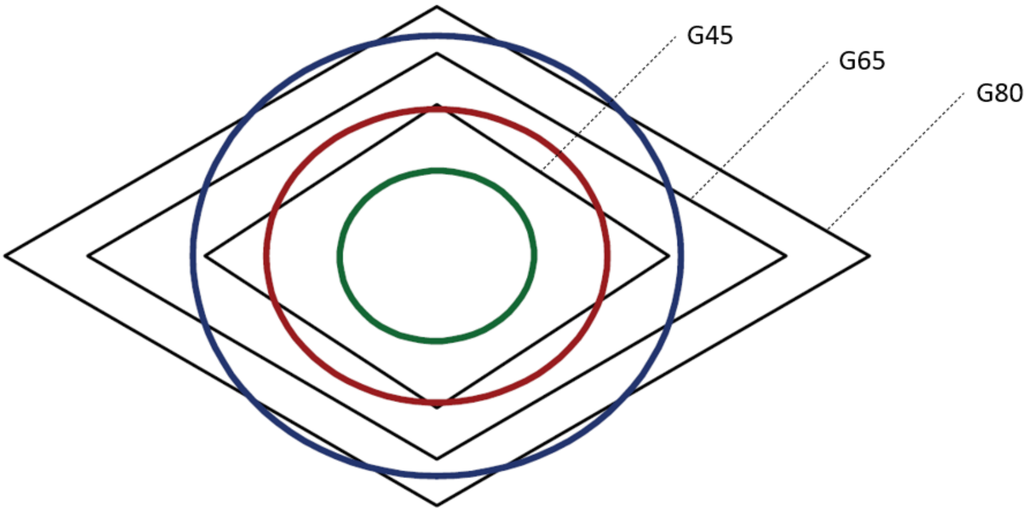

Fig. 3: Skulls idealised to scale as ellipsoids in front view and mesh sizes of the different meshes (in black meshes, blue beaver, red nutria and green muskrat).

Finally, it is pointed out that other burrowing animals such as wild boars or rabbits usually do not cause damage on the water side, but can be problematic when the dam overflows or when the water pressure increases. It is recommended to install a mesh on the air side as well to prevent their activities.

The study shows that the use of steel wire mesh can be an effective protective measure against rodent damage. The selection of the appropriate mesh size depends on the animal species and the specific conditions on site. It is recommended to use high-strength mesh such as TECCO with a mesh size of 45 mm to ensure sufficient protection against different animal species.

Application and construction

Fig. 4 shows a schematic cross-section of a river course bordered by two dams. On the left side, there is the unprotected dam body, which has been tunnelled through by water-dwelling burrowing animals for living dens. In the event of a flood (light blue), there is a risk of surface erosion in the structures, and there is also a risk of internal erosion due to the smaller absolute width of the levee. In order to prevent this, netting is laid in the right embankment crest to protect against digging activities. Basically, there are two different ways of installing the mesh in the dam body, as a surface reinforcement (black dashed line) or as a vertical barrier (grey dashed line). While the surface reinforcement prevents any burrowing activities and can also be laid on the air side to protect land-dwelling burrowing animals, the vertical barrier allows a certain amount of burrowing activity.

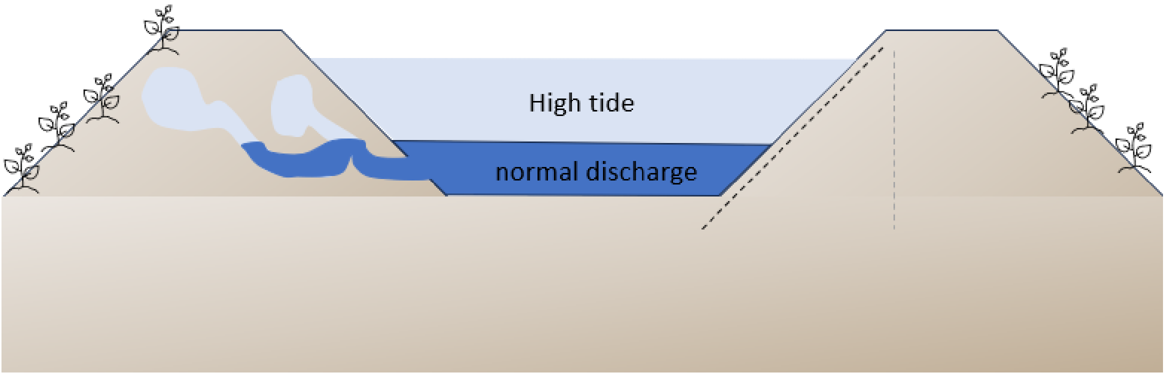

Fig. 4 Schematic representation of a river course bordered by two dams in cross-section, on the left without protective wire mesh with burrowing activity and on the right with two different installation variants of mesh.

The subsequent installation of a vertical barrier can be carried out by means of a trenchless pile driving method (IWT method). The surface barrier is laid on the unvegetated topsoil, the barrier can be combined with an erosion protection mat to promote and stabilise the subsequent vegetation, the same applies to the air side, which is thus better protected in the event of overflow. The meshes are supplied in rolls and can also be supplied as a combined version of erosion control mat and mesh **(TECCO GREEN).** This facilitates installation and the flexibility of the mesh makes it easily adaptable to special geometries. In any case, problem-free trafficability for mowing work or similar is guaranteed.

As shown in Fig. 5, the LfU Brandenburg provides for the standard installation of rodent protection in dam renovations and new constructions. The mesh is installed in the topsoil at a depth of approx. 10 cm below the surface. When installing the mesh, it must be ensured that it is not installed in the same binding trench as the geotextile seal. The binding trench of the mesh must not perforate the cohesive top layer. Furthermore, in the case of cohesive surface layers, the binding trench must be backfilled and compacted with classified mineral sealing material.

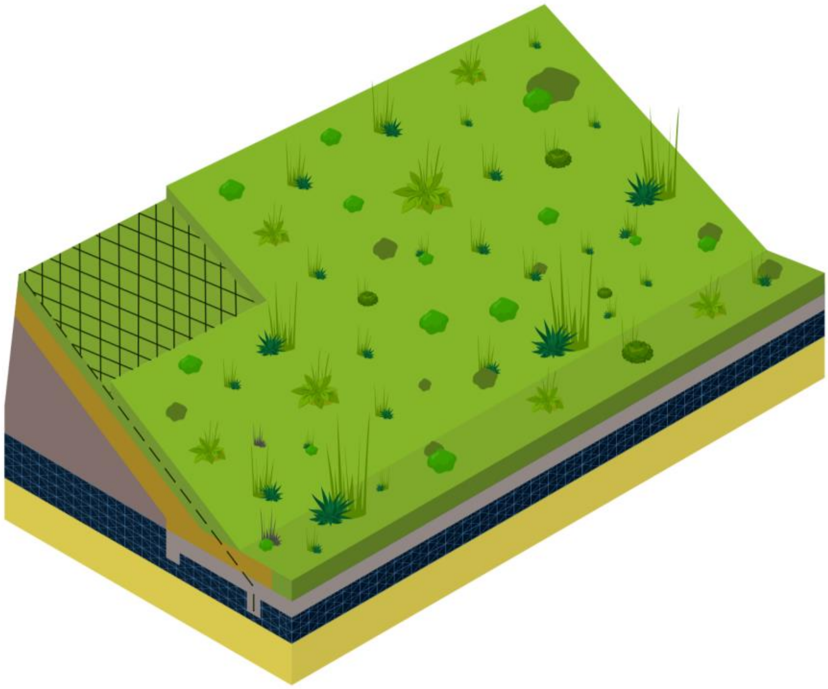

Fig. 5 Dam cross-section of a dam rehabilitation; Layers from bottom to top: Fluvial coarse sediment (yellow), dense alluvial cover layer (dark blue), old dyke (grey), embankment fill (beige), topsoil cover (green) with protection against burrowing animals

Conclusion

It can be stated that all Geobrugg AG meshes withstand the bite force of all rodents and thus provide sufficient mechanical protection. With regard to corrosion in the soil, a case-by-case consideration of the respective area is required. In any case, the stainless steel 1.4462 mesh provides durable and sustainable protection. In some cases, the mesh made of unalloyed high-strength steel wire with double zinc coating is sufficient; the decisive factors here are soil characteristics such as pH value, soil stratification, aeration and salinity. Competing products with additional plastic coating may offer greater protection, but this can easily be damaged by mechanical effects such as rodents and result in internal corrosion. CIRIA (Soil nailing - best practice guidiance) also points out that damage is to be expected with the additional plastic sheathing, especially at the bending points, and that this must be taken into consideration with regard to durability. Furthermore, the effects of plastic degradation products on animals, the environment and groundwater have not been sufficiently researched. Comparing to that, zinc only becomes a soil pollutant at very high concentrations, below which it is one of the most important trace elements for organisms that bind the zinc in the soil.

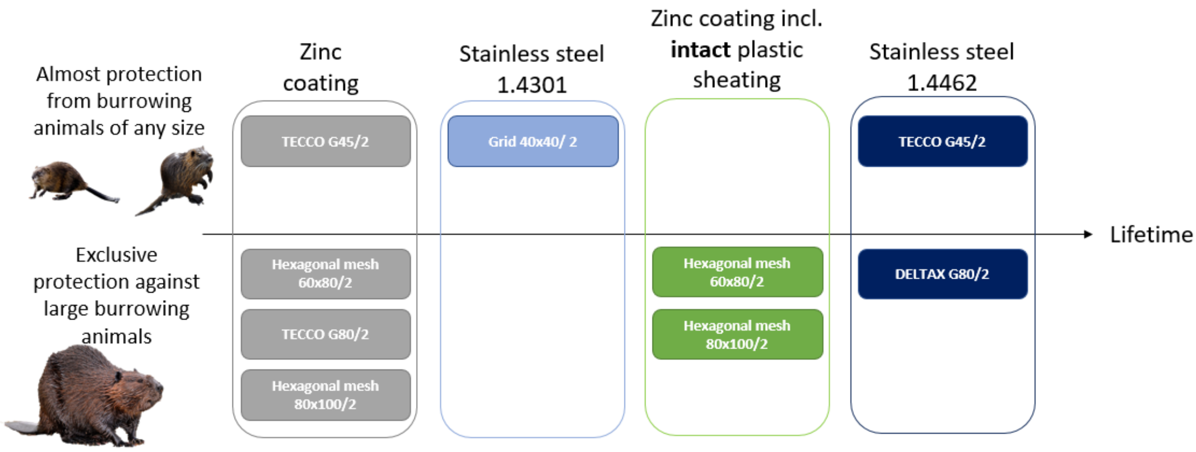

Fig. 5: Illustration of the areas of application of various meshes and grids

The mesh size required depends on the animals present in the area. If only beaver protection is required, the G80 is recommended as the most cost-effective solution; this also protects against the most common burrowing animals on the air side. If the exact animal species population is unclear or the future colonisation of further burrowing animals is likely and it is to be played safe, the G45 is recommended as a universal solution.

In conclusion, the high-strength steel wire mesh **TECCO G45/2 stainless** is the safest 100% solution. It withstands the biting force of all rodents, resists all soil conditions and the small mesh size protects against the vast majority of burrowing animals. If the occurrence is limited to larger burrowing animals such as beavers (water side) or wild boars and badgers (air side), the less expensive **DELTAX G80/2 stainless** is recommended. If soil conditions permit, a less expensive mesh with **GEOBRUGG SUPERCOATING (double zinc coating of 95% Zn and 5% Al)** can be used.

Resources

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