

## Geomats reinforced with steel wire meshes to prevent embankment damage by burrowing beavers and other rodents

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**ABSTRACT:** Recent studies show an increase in the population of beavers, nutria and other rodents in vast regions of central Europe over the last 15 years. Unfortunately this caused in many instances considerable damages on large rivers along dykes and earth-works in the floodplain areas, leading to an increased risk of bank failures. However, most of these mammals belong to protected species.

This work is aimed at showing positive experiences in cooperation with universities, research institutes and environmental agencies regarding measures to permanently safeguard the banks using composite erosion control systems with polymer coated steel wire net (as flexible reinforcement component) and geosynthetic (to promote vegetation growth). The steel mesh component works as an effective long term barrier against the intrusion of mammals, discouraging them from digging inside the core of the dyke. An analysis of the sensitive areas to be protected led also to define the characteristics of these interventions (length, shape, escape ways, population areas, etc). The study will present several additional benefits when using polymer steel nets along dykes, such as: 1) high and durable erosion protection in overflow areas, 2) promote fast and effective vegetation growth (increasing stability), 3) surface protection against ice impacts (in northern regions), 4) ease of installation, maintenance, 5) ability to conform to irregular shapes of the slope.

This work will present the positive outcome of case studies along the dykes in Germany, Austria and in Italy.

*Keywords: beavers, nutria, polymer coated steel net, dykes, erosion control.*

### 1 INTRODUCTION

Beavers, Nutria and other rodents can sometimes cause fairly large damage on bank slopes, along dykes or in earth-filled embankments. In isolated cases such damage caused by these mammals could lead to an increased risk of global slope failures with serious consequences of overflowing for the communities living in the area. Cavities created by beavers can be of high risk for the stability of the dyke. The highest risk is beavers digging through the impermeable layers. This leads to increased flow through the dyke, leading to erosion and water seeping through reaching the dry side. However, one must keep in mind that these species of rodent belong to protected species.

According to a study published in 2011 [1], [2] by the Bavarian State Office in charge of environmental protection, the beaver population across Germany was estimated at around 25,000 units, with an increasing trend. An estimate across Europe in the same year was of approx 800,000 beavers. (Figs. 1 and 2).



Fig. 1 Beaver population in Europe



Fig. 2 The Netherlands' beaver population is expected to grow from 700 to 7,000 by 2032

Measures to be undertaken to permanently prevent such effects depend on the sensitivity of local authorities for potential hazards caused to people and to infrastructure, as well as on costs required for the interventions and on the sensitiveness for the endangered species. The correct approach consists in identifying critical areas of the dyke (Fig.3).



Fig. 3 Effects of beavers in floodway encroachment zones

The prevention against the intrusion of beavers, nutria, rodents and other protected species on dykes has been discussed for over 15 years and documented in studies carried out by academic Institutes and in works developed by the work of technical expert groups.

## 2 CONCEPT AND SUMMARY OF RESEARCH

Safe and durable protection against intrusion in dykes consists in identifying a suitable environmentally friendly barrier system. Steel meshes have been used for this purpose for decades. In recent times steel meshes have been developed combining the strength of the steel with the ability to promote vegetation provided by a three-dimensional geomat extruded during manufacture. The wire used for the steel mesh is protected with a Zinc-Aluminum alloy and additionally by a polymer coating. The strength of the steel mesh will act as the impenetrable barrier for the rodents who will not be able to dig a hole through the steel net. The geomat will combine the antierosion function during flooding events and, by holding moisture, it will promote vegetation during the low flow season. These erosion mats may be delivered in rolled form and require very simple installation steps (Fig. 4).



Fig. 4 Installation of beaver netting

In order to gain confidence about the effectiveness of steel meshes as beaver protection, several trials were carried out in channels and dykes, some of which were under the monitoring of technical Universities. To date there is wide experience that steel mesh systems perform satisfactorily to this purpose.

### *2.1 Italy: Guidelines from Ministry of Environment and long term studies after 10 years of observation*

Italy has had a flourishing fur industry over the last century. In the 1920's the population of beavers and nutria actually grew, to feed this sector of the industry. As fashions changed in the 70's, and awareness of protecting endangered species grew, factories shut down and the animals released into the wild. This caused an increase of this population, which consequently led to more damage occurring to embankments. Observations on slopes previously protected by stone-filled mattresses, showed no damage due to rodents, as opposed to other sections nearby where damage was visible. This was deemed as proof that mammals were actually living in the area, but they could not damage slope sections protected with an armoured lining.

Based on these observations, the Ministry of the Environment, in coordination with the "National Institute for the Wild Fauna" and the "Institute for the Protection and Environmen-

tal Research (ISPRA)” [3] promoted a long term study aimed at monitoring remediation measures against the intrusion of rodents into the canal banks. A testing canal (Zabarelle) in the Rovigo Province was chosen as representative of the significant damage across the flood-plain of the river Po (Fig. 5).



Fig. 5 Installation of beaver netting along Canale Zabarelle

Steel meshes, with and without an extruded geomat, were installed in test sections in 2003. The initial survey allowed the capture and marking of a number of nutria, and attachment of a GPS-transmitter, in order to trace their movements. Results soon indicated that marked animals had moved to other sections.

In 2013 a second survey was arranged by ISPRA, to inspect these sections.

Observations showed that, where steel meshes with the extruded geomat had been applied, neither loss of fine material in the water change zones nor damage to the steel net due to grass cutting were detected.

Where steel nets had been applied without the extruded geomat, loss of fines was noted. This was presumably due to the lack of the geomat at some locations where the eroded soil bank lost contact with the steel net, resulting in some damage during the grass cutting. The erosion function was not sufficiently provided by the open structure of the steel mesh alone. However, no intrusion of mammals was detected.

## *2.2 Austria: Tests on effectiveness and implementation of 300,000 sqm of protection*

For decades Austria experienced damage in waterways due to the intrusion of beavers. In 2008 the design of the protection measures along the river March (tributary of the Danube) took into consideration for the first time the effect of the beaver population with special reference to prevention of potential damage. The analysis considered the variability of the species and types of mammals and rodents (quite large), hence the required strength characteristics of the protection netting, to resist to the animal's bite and discourage even the strongest species from attempting to penetrate the protection.

Following these early studies, a first trial project was build using double twisted steel netting (300.000 m<sup>2</sup>) in a river bank application. The scientific study was part of a Diploma Thesis done for the Institute for Applied Geotechnics at the Technical University in Vienna under

the guidance and coordination of the Prof. Dipl.-Ing. Dr. H. Brandl [4]. Along with the observations and the experiences of the previous cases, the study encompassed an actual test carried out at the Research Center for Ethology at the Institute Konrad-Lorenz in Vienna.

The measures adopted were divided in two sections, where different protection systems (with and without steel nets) were used. The non metallic systems showed that after a short time a fairly large area of damage occurred due to biting of the rodents. Based on these findings, the technical university in Vienna concluded that the steel net types with the extruded geomat are the most recommended type of protection measure against beaver intrusion. The execution of the works was in the years 2008-2013. They confirmed the expectation of a permanent protection against beavers.

In recent years the beaver population further increased in Austria, extending into the upper Austria (Linz region).

Over the last few years in the southern region (Carinthia), the beaver population has also more than doubled.

### 2.3 Germany: Protective measures against beavers along the Odra riverdyke, District Sophienthal, Brandenburg 2013

Between October and December 2013, in cooperation with the State Agency for Environment, Health and Consumer Protection Frankfurt/Oder and the Water and Dike Association Oderbruch, Seelow, a beaver protection netting was installed in a trial section approximately 200 m long, near the community of Sophienthal (Fig.6).

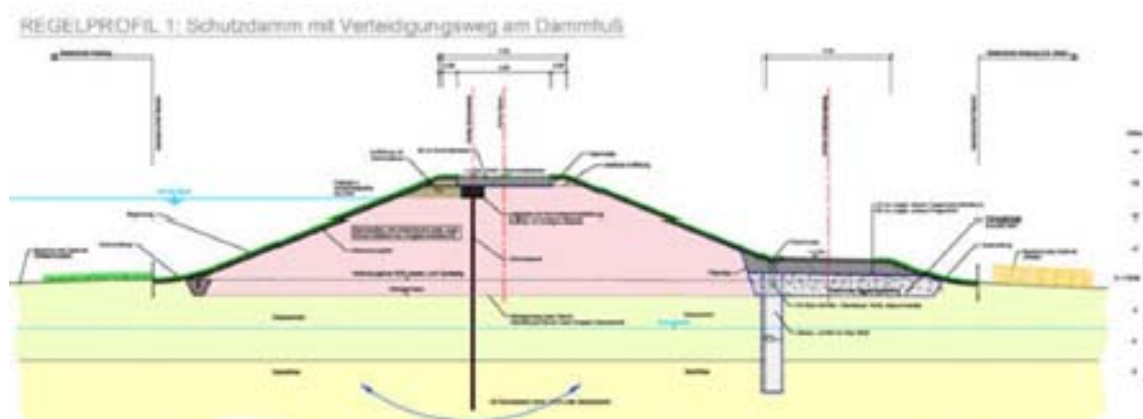


Fig. 6 Odra Dyke, Sophienthal – Cross section

Three different protection systems were installed:

1) *Hexagonal steel wire mesh with integrated three-dimensional polymer matrix (MacMat R), covered by 5 cm top soil layer (Fig. 6, left bank).* 2) *Hexagonal steel wire mesh, covered by 20 cm top soil layer.* 3) *Hexagonal steel wire mesh, covered by 20 cm top soil layer, connected to a stone mattress layer below in the water section.*

The erosion net starts from the top of the dyke and ends on the water side, in the last case connected to the stone mattress below. Since further tunnels dug by beavers were detected in other sections nearby, the interventions were extended to these sections as well.

The execution of the works was under the supervision of the Institute of Hydraulic Engineering and Applied Hydromechanics (IWD) of the TU Dresden. IWD has been working for several years on the task and supervised a Master Study on this topic in 2013.

### 3 NORMATIVE REQUIREMENTS FOR LONG LIFE

The use of steel nets in geotechnical and hydraulic applications pose questions of performance with relation to corrosion. Galvanization (using Zinc-Aluminum alloys) provides an extended life, as the protection acts as a retardant to corrosion by sacrificial nature. Additional polymer coatings applied on the galvanized wire introduce a further step up in the life expectancy, allowing tests in severe saline conditions (ISO 9277) to exceed 6000 hrs of exposure without trace of red rust on the inner steel core.

An important reference in Europe is the EN 10223-3:2013 [5] for double twisted steel wire meshes in civil engineering applications. Annex A in this standard provides (informative) guidance concerning the life expectancy of woven wire steel mesh, which defines, for polymer coated steel wire mesh, a minimum life of 120 years. In addition, 10 year old guidelines in Germany [6] and Austria already provide guidance concerning the use of steel nets as protection systems against beavers in dams and dykes.

However, DVWK 247/1997 has a limited requirement for beaver nets with respect to corrosion protection and for their use (vertical barriers) making the systems effective only for limited time. Experience shows that in numerous sections of the dykes where vertical galvanized steel nets were used, the following effects were observed:

- Tunnels still present between the embankment and the vertical barrier, with evidence of flooding and partial collapse. Progressive erosion into the bank required vertical barriers to work as supporting elements. This caused deformation in the nets, and accelerated corrosion with loss of functionality.

Tunnels ended at the vertical barrier. However this did not prevent beavers from digging new tunnels beyond the barrier into the berm, reaching in some instances even the toe of the main dyke.

- At high water flows, beavers could not reach the previously excavated tunnels, and made new ones directly into the body of the main dyke making their stability critical, as the upper portion has a reduced thickness. This triggered in some cases initial failures.

### 4 OTHER FEATURES OF BEAVER NETTINGS

#### 4.1 *Increased water conveyance*

In accordance with the State Authority for Waterways (BAW) in Germany erosion protection systems consist mainly of a layer of loose stones laid on a sand mat (a thin layer of sand between two layers of geotextiles) acting as an intermediate filter to prevent under piping through the voids of the larger rocks. Specifications for the stone size and for the layer thickness (0.50-1.0m) are determined by BAW according to their design recommendations [7]. As an alternative to loose stones, steel meshes with the integrated geomat could in many cases be a sound alternative. Tests performed on these reinforced erosion blankets have shown the

ability to resist even high flows for a given period of time [8], [9]. The advantage of using a thin layer is also in the increased water conveyance, allowing a larger discharge in the river section.

#### 4.2 *Ease of maintenance*

In case of accidental damage to the beaver erosion protection blanket, repair works would simply consist in the replacement of the damaged parts by attaching a panel of steel mesh on the surface. Connections are made with conventional steel rings, used for connecting rolls together.

#### 4.3 *Vegetation enhancement*

In hydraulic works the ability to develop a self-sustained vegetative layer, with a solid rooting system, to blend with the surrounding ecosystem is of particular importance. Newly built sections are highly susceptible to erosion when vegetation has not yet developed to a sustainable degree. The use of beaver protection with the integrated geomat allows a rapid establishment of vegetation [10], [11].



Fig. 7 Growth of vegetation in beaver nettings

#### 4.4 *Protection against ice impacts*

Embankment dykes in northern regions of the world may often experience floods during the cold season, and may frequently be exposed to the effect of ice blocks floating within the stream impacting against the banks (Fig.8). This results in damage to the bank slope and sometimes to partial failure. Steel nets with the geomat as beaver protection allow an armouring effect on the surface, further strengthened by the vegetative layer, which will grow through the mesh openings (Fig.7). This armouring effect will be particularly effective against the impact of ice blocks.



Fig. 8 Ice impacts along dykes

## 5 DISCUSSION AND CONCLUSIONS

There is an increasing interest in Germany in the use of beaver protection nettings in dyke restoration projects. Projects in Brandenburg, Sachsen and Bavarian regions have been implemented successfully.

Extensive observation in areas protected by beaver netting show that they protect against several other types of animals, like rabbits, and wild pigs, who are also frequently endangering the stability of embankments. Beavers are discouraged from digging into the embankment and migrate to other areas.

However, these results raise questions concerning how beavers can populate in floodway areas without compromising structures designed to protect human lives. The answer could be to build “ad-hoc” supporting structures in safe floodway encroachment zones where beavers could dig their tunnels without altering the embankment’s stability.

Trial projects have already started, and some authorities and research institutes have positively responded to this initiative. This is just a first step towards the development of a correct and more balanced approach to preserve our natural eco-systems and promote development in harmony with human needs.

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