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Efficiency of erosion prevention geosynthetics for non-vegetated slopes during extreme artificial rainfalls testing

Efficacité des géosynthétiques prévention l'érosion des pentes sans végétation lors des pluies artificielles extrêmes test

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ABSTRACT: Surface erosion prevention of yet non-vegetated slopes on transport infrastructures are of high concern for vegetation establishment and loss of quality top soil. Therefore, it is becoming a routine practice to protect such slopes shortly after the construction with erosion avoiding geosynthetic materials, both natural and synthetic. Research project to study the behaviour of the protected and unprotected slopes under an artificial extreme rainfall events is at the moment ongoing in the Czech Republic. The purpose is to propose the selection mechanism for the effective erosion prevention materials. Both natural and synthetics erosion protection geosynthetics are tested for typical slopes. The paper will present and discuss the testing methodology and up-to-date results from this practically oriented research project.

RÉSUMÉ: La prévention de l'érosion de surface sur les pentes non encore végétalisées des infrastructures de transport est très préoccupante pour l'établissement de la végétation et la perte de sol de qualité. Par conséquent, il devient de plus en plus courant de protéger ces pentes peu après la construction par une érosion évitant les matériaux géosynthétiques, tant naturels que synthétiques. Un projet de recherche visant à étudier le comportement des pentes protégées et non protégées en cas de précipitations artificielles extrêmes est actuellement en cours en République tchèque. L'objectif est de proposer le mécanisme de sélection des matériaux de prévention de l'érosion efficaces. Les géosynthétiques naturels et synthétiques de protection contre l'érosion sont testés pour les pentes typiques. Le document présentera et discutera de la méthodologie de test et des résultats actualisés de ce projet de recherche orienté vers la pratique.

Keywords: erosion protection, artificial rainfall, test site

1 INTRODUCTION

The problem of topsoil erosion not only from agricultural areas but also from the slopes of transport infrastructure earth structures is significantly increasing. The problem is not only the loss of the quality topsoil but also and maybe even bigger is the pollution of the surrounding environment and man-made structures by fines from this runoff. Therefore there is high demand for the solution, which will help with this phenomena and there will be some procedures how to determine the effectivity of different possible methods of surface erosion protection.

This task was awarded to a practical and research consortium under a grant project from Czech Technological Agency. Task of this currently running project is to test and suggest protection technologies for topsoil runoff lowering and increase of surface stability of slopes. Efficiency of particular technologies will be evaluated with the help of artificial raining and numerical modelling. And furthermore, optimization of technological and/or construction procedures for surface protection will be suggested.

Most common type of slope erosion is the surface disruption of newly created slope by drops of intensive rain and consequently runoff of topsoil. For reduction of this phenomena erosion protection mattresses, grids or geocells are currently used. For shallow slopes temporary or biodegradable materials are generally sufficient, however for steeper slopes permanent materials should be used.

2 TEST SITE JIRKOV

Test site that was selected for this project is located in Jirkov on the premises of company STRIX Chomutov, which is one of the project members. On this site there were prepared 5 testing areas of 4,25m long and 2,4m wide with different slopes each in separate old container. The containers are placed on structures, which allows to modify the testing slope of the area. Middle three of these areas are equipped by artificial raining device. The slopes of individual areas are fixed for the duration of this project and are 1:1.5, 1:1.75 and 1:2.5, which correspond to the suggested slopes in code of practise for design of Road and motorway embankments and cuts as well as for design of Railway earthworks. The photo of the actual setup is presented at Figure 1.

Figure 1: Photo of the testing setup with 5 areas (containers) with indication of the applied slopes

The containers used as test areas are 1,6m deep. Before positioning the containers into their final slopes they have been infilled. The bottom 0,4m was infilled with free draining light weight aggregates to keep the total weight of container down and allow the infiltrated water to drain of. Than followed filing with typical soil that is used for embankment constructions in Czech Republic in 4 0,3m thick layers. The final 0,15m thick layer was made of topsoil, which was slightly compacted by hand operated roller.

On site there is installed standardized rain-gauge that records the rainfall in minute intervals. Within the containers there are gauge that were installed in 2 layers during the filling of soil for measuring volumetric water content, suction and soil temperature. One monitoring level is within the topsoil and the second is within subsoil. The schematic position of the mentioned monitoring devices is presented at Figure 2.

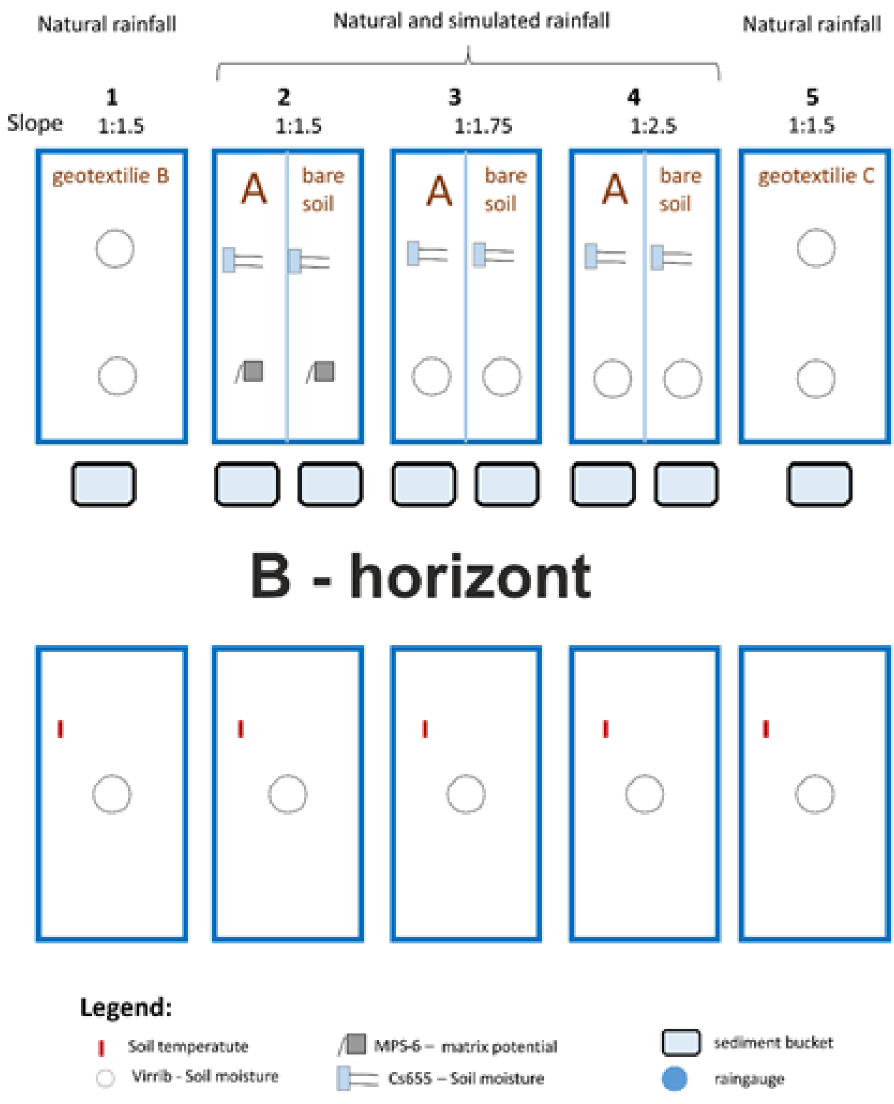

Figure 2: Schematic positioning of monitoring devices

Monitoring of volumetric water content with depth on the areas with and without erosion protection material is of key importance for experiment evaluation especially for future numerical modelling of transport processes.

Both types of erosion protection products, temporary and permanent, were selected for testing at the experimental site. Each product will be tested at all three inclinations (1:1.5, 1:1.75 and 1:2.5) under the raining simulator device. One testing lot is in average taking place during 25 days. In parallel to the experimental site there is a raining simulator at the laboratory of the Czech Technical University, which is more flexible with respect to weather independence and regarding to slope inclination. This laboratory simulator will be used to complement the experimental site test data for additional mainly steeper slope inclinations and additionally types of monitoring.

On experimental site there are 2 areas with just natural exposure to weather, where the erosion protection materials are tested for the period of 1 year, i.e. longer testing period. During the long-term testing would like to induce another type of surface erosion – slipping of highly saturated topsoil on the interface with compacted embankment subsoil. For this additional erosion type it is rather important to determine the deformation and / capacity of anchoring pins compared to the topsoil washing out from the slope surface.

Apart from monitoring the topsoil and subsoil with gauges as described above, we are using high resolution photogrammetric monitoring of surfaces. Precise geodetic measurement of reference points is used to increase the quality of 3D model of slope surface made from photos. 3D models are generated before and after each raining campaign and theirs differences are used to calculate the amount of topsoil washed out from the surface.

3 EVALUATION METHODOLOGY

Erosion development either aerial or scour, its intensity, etc. is predetermined by many factors that are related between each other. Basis for erosion modelling and design of appropriate measures is a large enough measured data set with reasonable amount of repetitions. Individual evaluation of the influence of particular measure is necessary to relate to reference surface. For our purposes we decided to define such reference surface as properly finished surface without any erosion protection measure. While keeping the initial and boundary conditions of the test, i.e. slope inclination, intensity and duration of rainfall and topsoil properties it is possible to monitor the influence of tested measure on erosion process. Quantification of measure influence could then be simplistically presented as a ratio or difference between amount of eroded material.

However, the aim of the project is to monitor also other causes of erosion processes under given conditions of extreme slopes. Key processes for subsequent modelling are:

- Monitoring of the initiation erosion phase at unsaturated (dry) soil profile;
- Monitoring of surface water runoff and eroded topsoil particles transport;
- Monitoring of eroded material particles size distribution (PSD) and comparison with PSD of original topsoil;
- Evaluation of erosion scours development and monitoring using detailed 3D models;
- Monitoring of repetitive rain events influence on the surface with already developed scours;
- Monitoring of moisture profile during and after rainfall event in both topsoil and subsoil.

High resolution photogrammetric monitoring uses standard camera with high resolution photos of the whole surface of the tested areas. For each set of photos for one tested area we use between 50 and 100 overlapping photos with captured reference marks that are 5cm in diameter. The photos are processed in Agisoft PhotoScan software. This software firstly connects the overlapping photos together and creates big detailed photo to which based on the reference marks is added scale and 3D information, which is later transferred into a point cloud, texture, final orthophoto and digital model of terrain. The digital model of the terrain is further processed in ArcGIS software where the differential models are created and different analyses performed. Differential 3D model before and after raining event indicate the washed out / deposited volume and possible scouring of the monitored surface.

The monitoring campaign consists of 4 raining events of 12 minutes. First event is on new surface, second follows 15 minutes after the first one. Third event is done on dried surface after the second event and fourth even follows the third again after 15 minutes break.

4 MONITORING RESULTS

The measuring campaigns of 3 materials – biodegradable full surface covering coconut mattress (biomac-c), coconut grid with unit weight of 700g/m^2 (K700) and permanent 3D mattress from polypropylene with thickness of 9mm (Macmat 9.1) – will be compared hereafter. It compares the surfaces with erosion protection material (TRUE) and with bare soil (FALSE) for different slope inclinations: kont02~1:1.5, kont03~1:1.75 and kont03~1:2.5.

On Figure 3 is presented cumulative surface water runoff in litres from each test area in relation to time (length of raining event) in minutes. On Figure 4 is presented cumulative washout of topsoil in grams from the tested area in relation to time. And finally Figure 5 presents relationship between cumulative topsoil washout and cumulative surface water runoff for given slope inclination and erosion protection material.

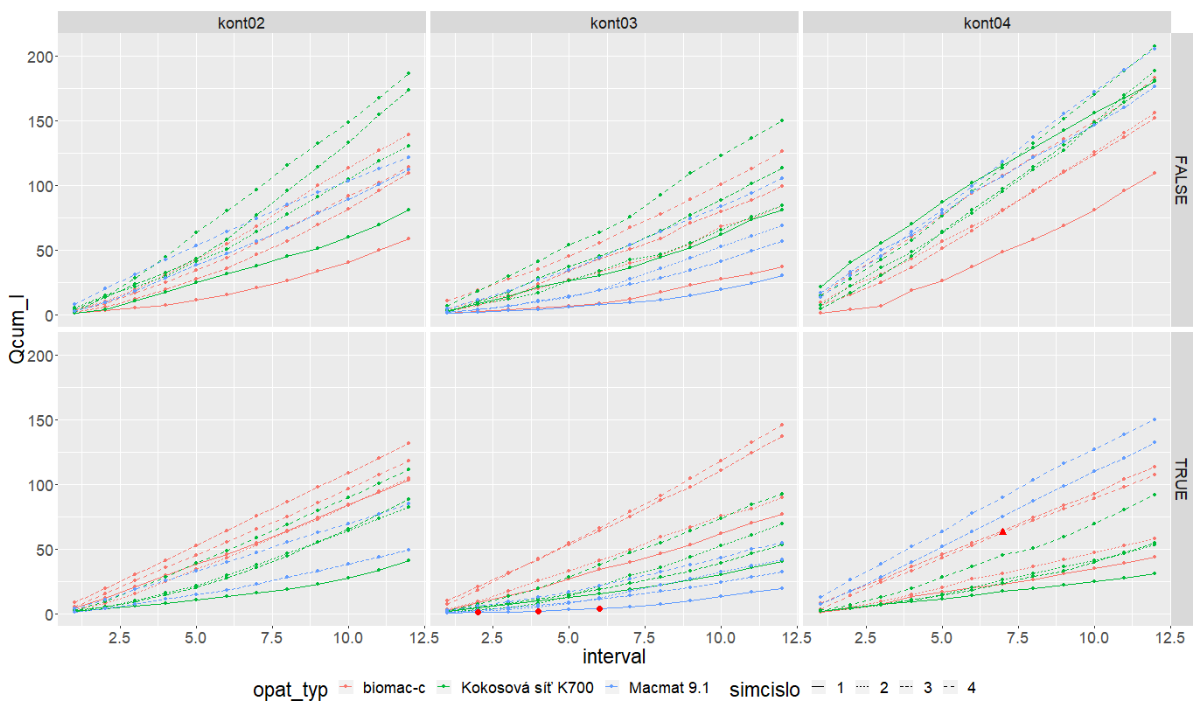

Figure 3: Cumulative surface water runoff as a function of time of raining event. Rows represent surface types (without and with erosion protection material). Columns represent slope inclinations. Line types represent raining events within campaign and colours represent tested erosion protection material.

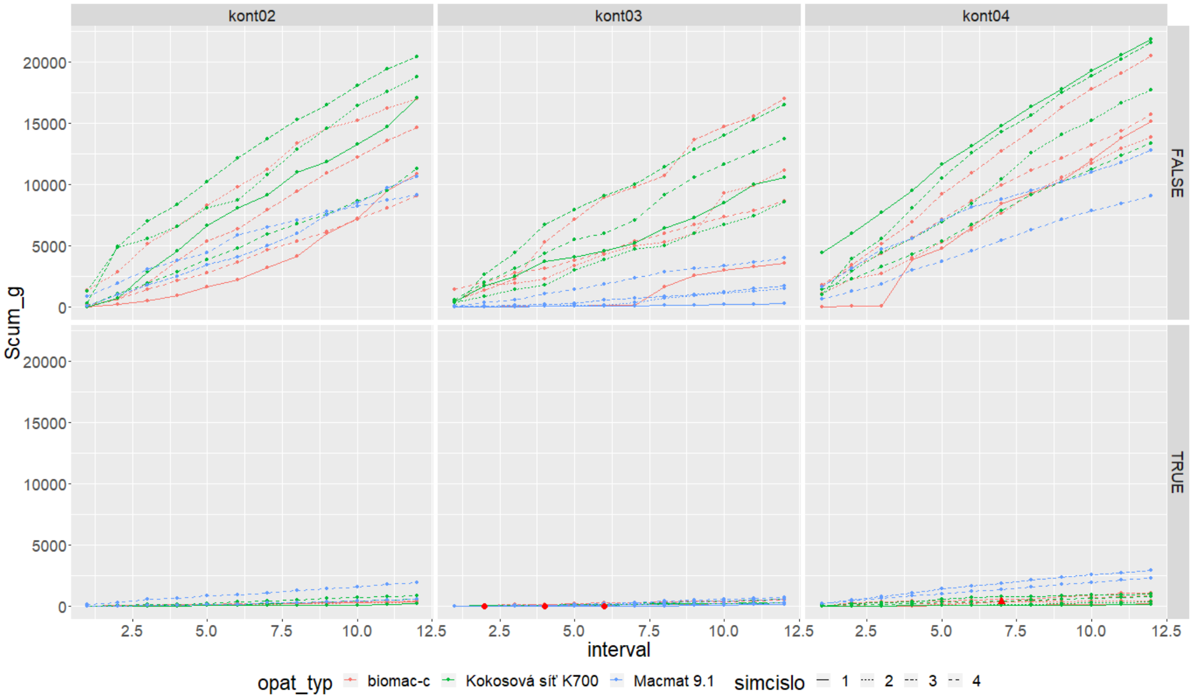

Figure 4: Cumulative topsoil washout as a function of time of raining event. Other description – see Figure 3.

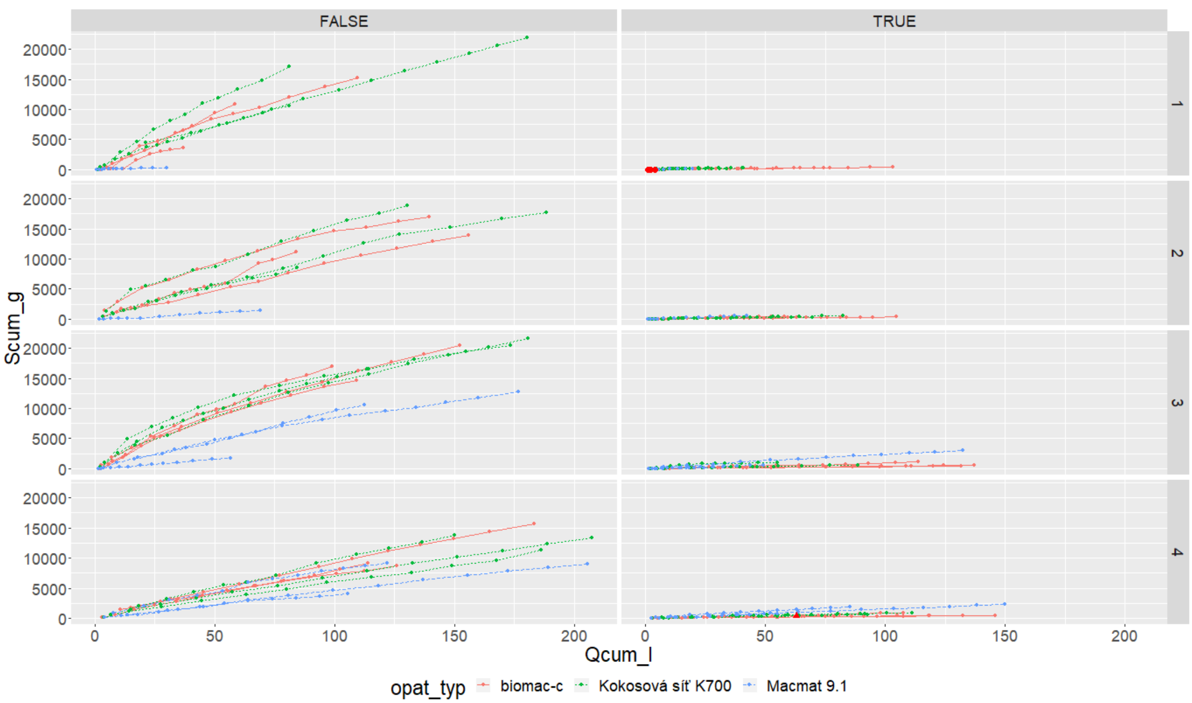

Figure 5: Cumulative topsoil washout as a function of cumulative surface water runoff.

5 CONCLUSIONS

On the experimental site we have tested different erosion protection materials under an artificial raining conditions that should represent design short term rainfall. The materials have been tested for three different slope inclinations of 1:1.5, 1:1.75 and 1:2.5. The same testing area was divided in half to directly compare erosion protection material and soil without any protection. The measured properties were surface water runoff (l) and topsoil washout (g). Within the project still several more materials are to be tested. At the moment we can conclude that tested erosion protection materials did not have any significant influence on the surface water runoff, however they significantly, more than ten times, reduced the amount of topsoil washout, mainly due to scour development prevention. From the collected data it is almost impossible to see any difference between tested erosion protection materials. This should be accounted to the limited amount of rainfall events tested. As the project will run two more years we could try to tackle this issue.

The outcome from the up to date testing we could conclude that any erosion protection geosynthetic is much better than no protection whatsoever.

6 ACKNOWLEDGEMENTS

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