EROSION PREVENTING OF SOIL SURFACES: RELATIONSHIP BETWEEN ARTIFICIAL ROOT VOLUME AND RESTRAINT OF SOIL

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Abstract: More than half of the areas in Europe are in different degree affected by water erosion. Long-continuing, frequent, and heavy rainfall create runoff on the soil surface that has an erosive effect. Approximately one fifths of all areas are affected by wind erosion, particularly in Southeast Europe. Erosion-protection-mattresses, made from synthetic and natural raw materials, are used as protection against erosion.

This paper deals with the results of restrained soil capacity research using different test constructions. The "artificial" slope was exposed to heavy rainfall and the eroded soil was collected and the amount was measured.

The tests were done at different slope angles using various erosion-protection-mattresses and for the purpose of comparison without erosion protection. Furthermore, the water tractive force was investigated. Therefore an erosion-protection-mattress, filled with pea gravel (2-5mm), was also tested. Eroded pea gravel was collected and the grain size distribution was determined.

An approach for the determination of "artificial root length" has been developed and was ascertained for the tested erosion-protection-mattresses. The tests led to the conclusion that there is a relationship between artificial root volume and restrained soil capacity of erosion-protection-mattresses.

Keywords: environment protection, erosion, erosion control, field performance, geomattress, vegetation

INTRODUCTION

Whenever soil is used to cover a slope it takes time until the natural vegetation is dense and strong enough to provide the necessary erosion protection. Water and wind are the forces of the nature which affect natural and artificial areas. For wind erosion it is not absolutely necessary to have an inclination of the endangered surrounding. Because this paper deals with the runoff caused by rain water it has been assumed that this take place mainly on slopes. Therefore a laboratory test has been developed which allows conclusions on the mechanisms of an eroding slope. There are no doubts that three-dimensional shaped geo-mattresses have a positive effect by preventing these failure mechanisms on the surface of such embankment. The impact of an erosion control mattress is limited to its direct ambience. The tested mattresses are engineered to control the erosion approximate 2 to 5 cm from the top of the vegetation soil layer. This should help to prevent deep cracks or channels growing into the soil structure and causing deep seating or sliding failure of the whole slope.

It has been observed on sites that different shapes of the mattress and presumably the density of the 3-D-elements have an effect on the efficiency of the erosion control sheet. To quantify the impact of the 3-D-elements an investigation for an adequate artificial root length is presented in this paper.

INVESTIGATED GEOSYNTHETICS

Colbond Geosynthetics has supplied 3 types of their erosion control mattresses to tBU. The material is manufactured from spun monofilaments moulded into pyramid shapes. A summary of the geometrical properties is given in Table 1.

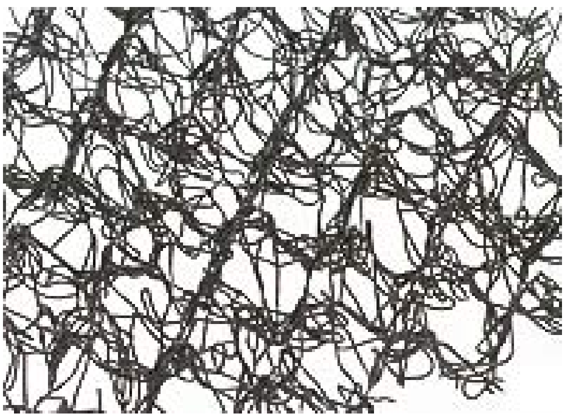

Figure 1. Structure of the tested erosion mattresses

Table 1. Material Overview

Properties	MAT 1	MAT 2	MAT 3
Polymer	Polyamid 6	Polyamid 6	Polyamid 6
Thickness	10 mm	18 mm	20 mm
Artificial Root Length	1,810 m/m²	1,290 m/m²	1,420 m/m²
Retention Net	2.28 %	1.41 %	1.75 %
Open Space	97.72 %	98.59 %	98.25 %

FACTORS INFLUENCING EROSION

This work deals with erosion caused by heavy rain on slopes between 1:5 (11.31°) and 1:1 (45.0°). Wind erosion has not been considered.

Rain Intensity

The rain intensity equals the amount of rainwater per unit time. As the rain intensity and the kinetic energy, which leads to an erosive effect, are proportional, heavy rain over a shorter period will have a higher discharge capacity than drizzle.

The literature provides various minimum rain intensities for erosion. Erosion will take place if the infiltration capacity of soil is too small for the rain falling down. This depends on the volume of water and the time of rain fall. Depending on the soil this can start at 0.3 mm/min (Breburda, 1983) and exceed an amount of 24 mm in 2 hours (Richter, 1965). The type of soil, its structure, compaction, pore volume, water capacity and layer thickness are factors for the actual erosion. Furthermore the grain size distribution is essential for the mobility of the soil particles. In general course soil with a sufficient share of course particles or clay with plenty cohesion are less sensitive to erosion then silt and sandy soils. The erosion phenomenon is a local problem which must be investigated for each construction site separately.

Slope Relief

The relief of the slope is essential for the eroding effect of the rain. The shapes of the slope as well as the slope angles are important factors. While the slope angle is influencing the velocity of the water flow the shape of the slope dictates where the water will attack the slope. The water will be collected and run down the slope depending on its shape. It can be distinguished between the following slope types:

stretched slope
concave slope
convex slope
convex-concave slope (normal slope) and various combinations.

Splash effect of raindrops

Soil particles on the surface of the slope will be made available for erosion by falling rain drops. The kinetic energy of the rain drops is a result of the fall velocity and the weight of the particular rain drop. The size of the rain drop is essential for its kinetic relations. According to (Breburda, 1983) and (Auerswald, 1998) the size of the rain drops increase with the intensity of rain. Because the velocity of the rain drops depends on the fall height and the available height for laboratory tests is limited and much smaller than the natural height, the size of the rain drops has been used to adjust their kinetic energy to the ordinary conditions. Two different test setups have been used to produce rain drops with a diameter of 2.5 mm and 4 mm with a weight of 0.027 g respectively 0.05 g. This rain drops can be considered as part of a heavy rain or a storm

For the reason that the air resistance would divide large rain drops into smaller particles the size of the rain drops is limited. Big rain drops from storms of 9 mm are not stable to reach the earth’s surface.

TEST SETUP

An artificial slope was used for this investigation. On a stable basis an adjustable wood frame was installed. Foam was used to simulate a compressible soil at the bottom. This layer was followed by 7 cm of pea gravel with organic fractions. The erosion protection matt was laid on top of this layer and filled with the same soil plus 1 cm coverage.

The soil was used with its natural water content.

The dimensions of the top frame where chosen according to a projected area of 1 m² for each test. The slope length could be adjusted to this area depending on the slope angle.

Running water was forced to drop through a panel with small holes, which where designed to produce rain drops of the needed size. The water and the eroded soil was collected and guided through a sieve to separate the soil.

The tests where done with rain intensities of 60 mm/h and 120 mm/h. Both intensities have been applied for 20 minutes per test.

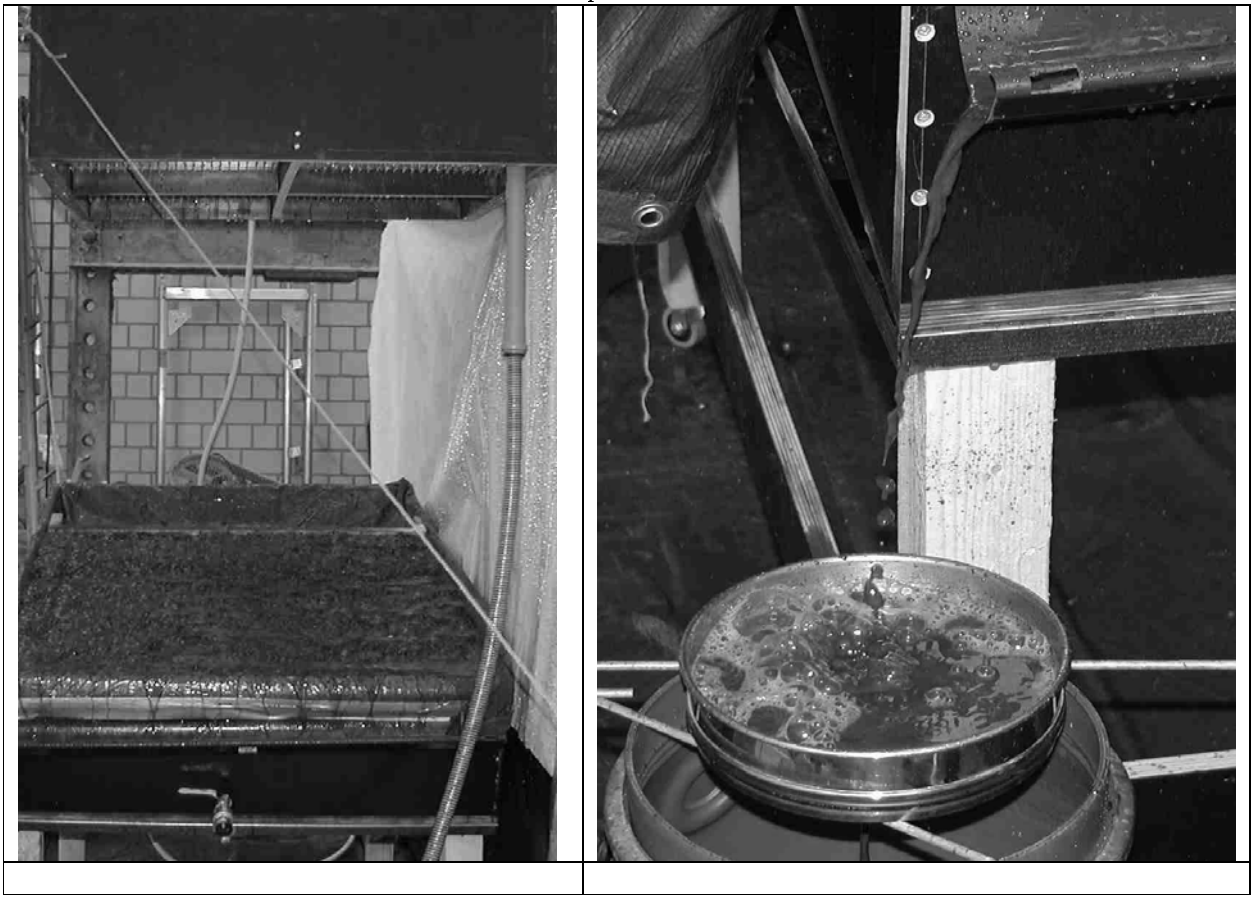

Figure 2. Left: Test Setup During the Rain Testing. Right: Sieve and Tank to Separate the Eroded Soil

TEST RESULTS

After the tests the collected soil has been weighed. The results are given in Figure 3 and Figure 4. In both cases the unprotected slope failed at a slope angle of 1:3 (18.43 °). The protected slopes have had a remarkable smaller soil loss and where stable up to the maximum slope angle of 1:1 (45 °). Because these tests have been initial tests to establish a test method which combines the design of rain drops with a sufficient layer construction to model the bedding of the harmed top layers, some aspects needs to be taken into account for future research. One of these topics is the effect of the filament count of the mattress. An indication for this is the artificial root length compared to the structural roughness of the mattress. The artificial root length for the tested materials is given in Table 1. Compared to the natural root length of a grass seeding with at least 750 m/m², all materials provide a sufficient artificial root length.

The main difference between the natural and the artificial root length is that the grass penetrates the soil up to 7 cm. Having the layer thickness in mind, it can be stated that the whole layer was reinforced with natural roots. The used erosion mattresses had no negative effect on the germination of the grass seeds. If the effect of an erosion mattress would be attached to the artificial root length the coarseness of the soil is important. The grain size distribution of the used soil has fitted best to MAT 1. This one had the closest structure to hold back the fine pea gravel particles. The experiences from construction sites indicate that the thicker mattresses are more suitable for coarser soil.

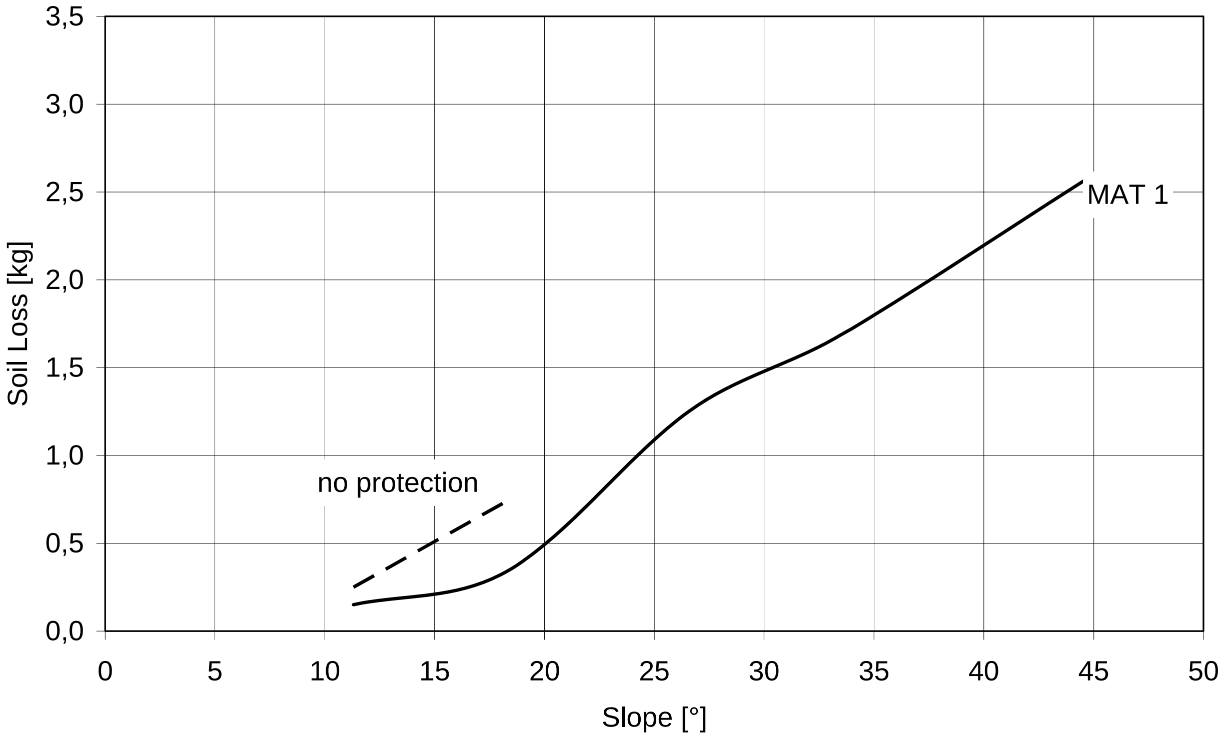

Figure 3. Soil loss after a rain of 60 mm/h for 20 minutes

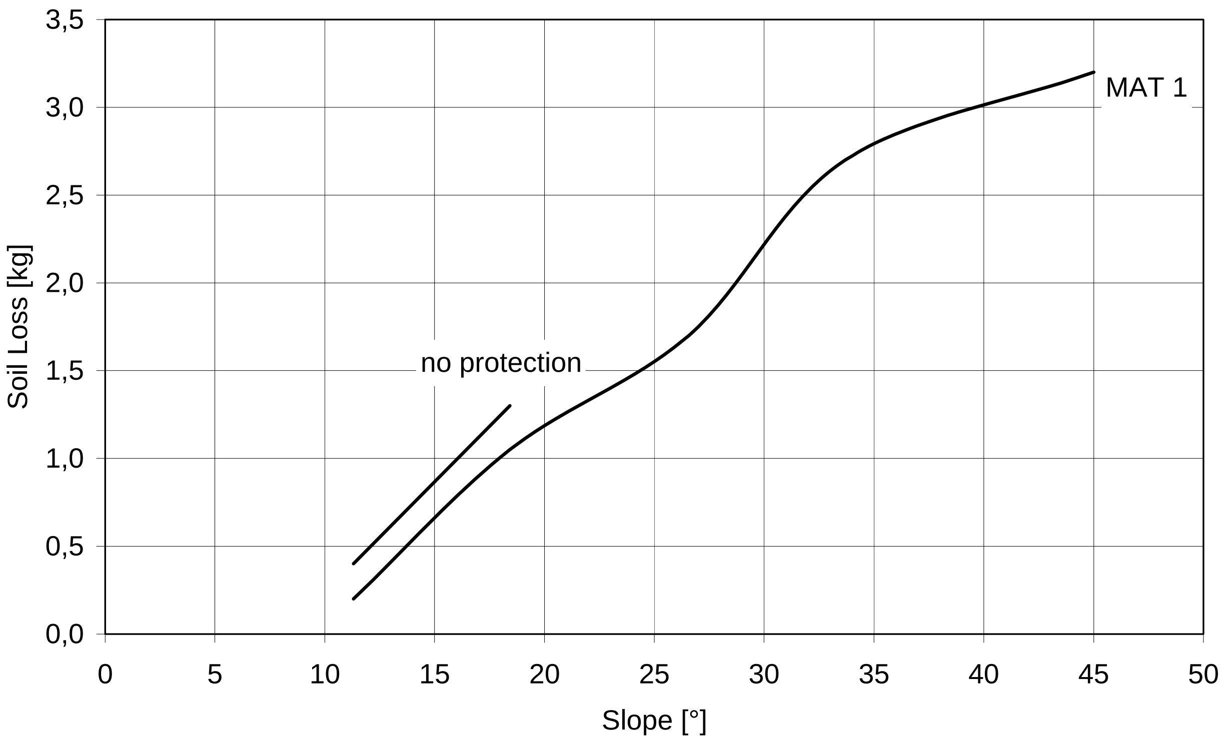

Figure 4. Soil loss after a rain of 120 mm/h for 20 minutes

SUMMARY AND RECOMMENDATIONS

The tests have shown that the use of geosynthetics for the purpose of erosion control should be considered for slopes exceeding an inclination of 1:3 (18.43 °). Any absolute measurement would be helpful to quantify the effect of erosion control mattresses on top of a sensitive slope surface. The test setup and the chosen test procedure are suitable for laboratory tests. The calibration of the rain drops was one of the main goals. Afterwards the modelling of the two rain events was simple to achieve. With its sufficient repeatability, the test procedure is suitable to link the erosion protection effect to special properties of the erosion control mattresses, like artificial root length and/or others. Further investigations have to be done to provide the needed data. The described tests should be seen as a contribution to transfer the erosion control topic from a philosophy based on experiences to an engineering design task.

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