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Lab scale tests of erosion control on slopes with rainfall simulator according to FprCEN/TS 17445:2019

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ABSTRACT
One of the multiple uses of geosynthetics materials is to prevent the surface erosion of soil particles. In order to evaluate the ability of Erosion Control Products to protect the surface of a slope, some full-scale testing procedures were developed. A new test was developed under CEN TC189 lead in order to provide a reproducible method in laboratory with controlled specifications, like the rainfall, the soil used, the slope, etc… This paper explains the different elements of the method and the reason why some choices were made.

1. INTRODUCTION

One of the multiple uses of geosynthetics materials is to prevent the surface erosion of soil particles.In order to evaluate their ability of Erosion Control Products to protect the surface of a slope, some full-scale testing procedures were developed. Among them, ASTM D 6459 – 99 aimed at determining the ability of geosynthetics blankets to protect hillslopes from rainfall-induced erosion.As any standardized test, repeatability is a critical requirement. Therefore, a new Work Item was created within the CEN TC 189 Geosynthetics methods in April 2015 to analyze and to fulfill this requirement. A new method was then established and analyzed at the Working Group 4 level, leading to a final draft in October 2019. After a succinct reminder about erosion and which role geosynthetics provide in preventing those particles movements, this 4-year development will be presented, and will be then shortly discussed.

2. GEOSYNTHETICS AND EROSION CONTROL

2.1 Erosion Control

Erosion is a phenomenon that can be resumed in the movement of soil or other particles at its surface.In our case, we will specifically focus on thesurface of a slope. Particles are detached and are transported, causing the destructuration of the surface and the erosion of the considered soil. Different kinds of external erosion can be identified, such as:

- Rain erosion
- Wind erosion
- Fluvial erosion
- Maritime erosion
- Human or animal-induced erosion

In the specific case of rain erosion, it can be summarized first by the impact of the raindrops which creates the initial detachment of the soil particles (splash and rainsplash-creep), and then the aggregates disruption and theirejection of downsized or single parts outwards from the drop impact. Once particles are mobile, they can be transported by run-off. If the water concentrates in flows, rilling and gully erosion can occur. Other effects that can be observed on the surface are sealing, crusting and compaction.

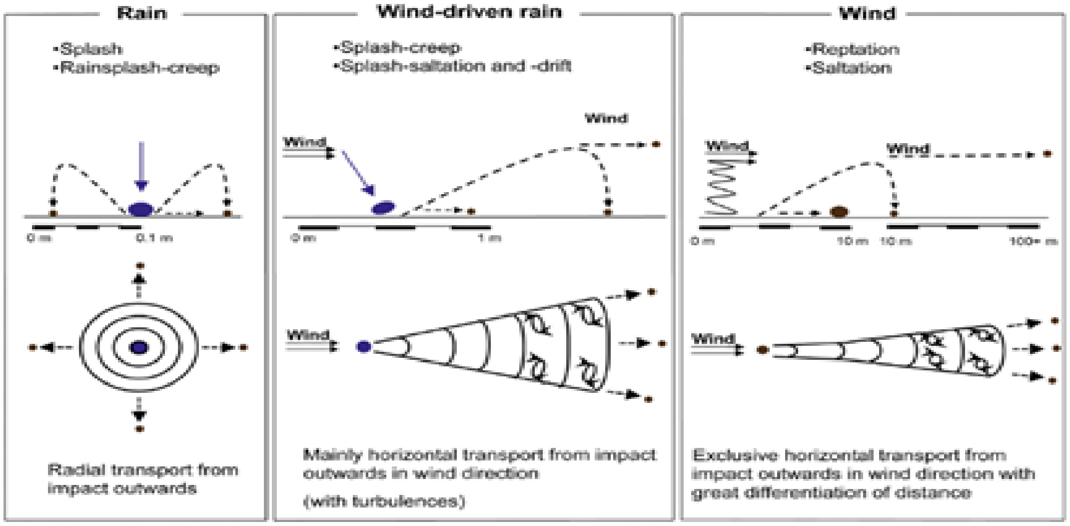


Figure 1: sketches of initial soil erosion processed by rain, wind-driven rain and wind (Marzen et al.)

Rain erosion is influenced by many different factors, such as:

- The climate factor: the rain intensity defined by the drop size, their weight, speed and therefre their kinetic energy, the rain frequency (since the behavior of a soil is not the same if it is saturated or not) and the wind that can increase drops speed.
- The soils characteristics: structure, grain distribution, its organic matter, chemical composition, infiltrability and ground surface condition
- The topography: slope, length and shape of the slope
- Vegetative cover: the percentage of vegetation covering the soil and the plants shape

2.2 Action of the geosynthetics on erosion factors

Geosynthetics that are used to prevent or to limit soil or other particles movements atthe surface of a slope, have effects on different characteristics. They do increase the intrinsic resistance of the soil, they modify also the length and the grade of the slope and change the quality of the surface condition. All these actions are temporarily, waiting for vegetation to be established and to partially or fully fulfill this role.

3. STANDARD TEST

3.1 Principle of the lab-test

The principle of this lab-test is first to define a method in order to simulate on the surface of a slope the erosion induced by rain,and then to evaluate the protection provided by geosynthetic erosion control products by measuring the amount of eroded soil. This amount represents an index value of the ability of the geosynthetic product to determine to what extent a slope is protected against a rainfall induced erosion.

When the Working Group began its work, a list of all the questions that the method had to answer to was established. The synthesis of the discussion is provided as below:

- How to test ?
    - Which dimensions of specimen?
    - Which rain?
    - Which soil?
- Apparatus
    - Which size?
    - Which slope?
    - Charactheristics of the collection system
- Soil
    - Which composition?

    - Which compaction?
- How to simulate the rain?
    - Which intensity
    - Which duration?
    - Which drop size?
- What to measure/control?
    - Rain
    - Quantity of eroded soil

3.2 Apparatus

Creating a rain simulator is not a new challenge. Scientific literature does contain many references, the WG4 studied some of them listed below :

- An evaluation of three wood shred blends for post-fire erosion control using indoor simulated rain events on small plots - R.B. Foltz, N.S. Wagenbrenner – 2009
- A method for estimating the interaction depth of surface soil with simulated rain – T. Yang, Q. Wang, D. Xiu, J. Lv – 2014
- Runoff and soil loss from Pinus massoniana forest in southern China after simulated rainfall – L. Cao, Y. Liang, Y. Wang, H. Lu - 2015
- Evaluation of kinetic energy and erositivity potential of simulated rainfall using Laser Precipitation Monitor – D.T. Meshesha, A. Tsunekawa, M. Tsubo, N. Haregeweyn, F. Tegegne – 2015
- The effect of rain, wind-driven rain and wind on particule transport under controlled laboratory conditions – M. Marzen, T. Iserloh, J. L.M.P. de Lima, J. B. Ries – 2016
- Influence of drop size distribution function on simulated ground precipitation for different cloud droplet number concentrations – N. Kovacevic, M. Curic – 2015
- …,

but focused especially on the thesis of S.C. Peixera Carvallho, Rainfall: measurements, variability and laboratory simulations – 2014.

All these developments had to cope with specific constraints. In order to contain the soil and the geosynthetic, it was decided to choose a rigid box, with the following dimensions: 1,0 x 2,0 x 0,10 m minimum. The surface runoff water has to be separated from water filtrating though the soil. The standard slope is 1V / 2H, but can be changed to allow to testing different options.
Direct runoff flow and infiltration oneare separately collected into holding tanks, shielded from the rainfall.

The

Figure 2

Figure 2 shows the different elements and their position.

Key

1	water supply	12	soil
2	constant head tank	13	geosynthetic specimen
3	pump	14	water deflector
4	pressure gauge	15	tank for collection of surface runoff
5	flexible hose	16	tank for collection of infiltration flow
6	frame	17	2,0 m minimum
7	nozzle	18	100 mm minimum
8	pressure gauge	19	26,6°
9	mesh (optional)	20	1,00 m approx
10	rainfall	21	2,50 m minimum
11	rigid box	22	200 mm approx

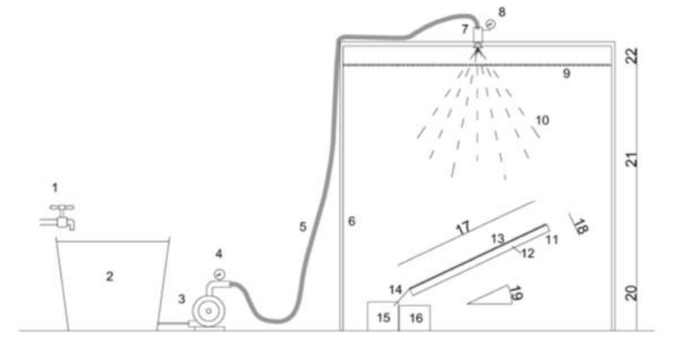


Figure 2: description of the apparatus

3.3 Rainfall simulator

In order to simulate the rain, the apparatus has to provide a rainfall with a controlled intensity R, a mean drop diameter D_{mean}, a mean drop velocity v_{mean} and the kinetic energy KE.

Rainfall simulator typically includes a suspension system, pipes, sprinkler nozzles and pressurised systems giving a range of raindrop sizes, replicating as closely as possible natural rainfall with valves and pressure gauges for control. The use of one or several meshes can provide a better distribution of the drops, and can also increase their size and kinetic energy (Peixera Carvalho, 2014). The

Figure 3 shows an example of a rainfall simulator with nozzle spraying water on the mesh.

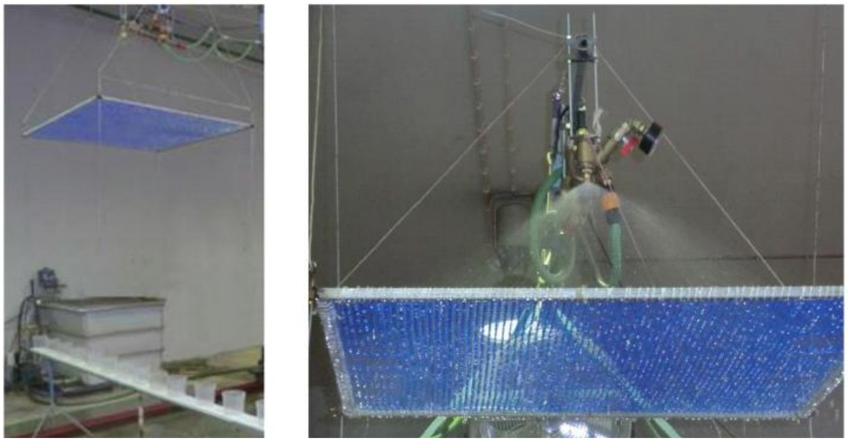


Figure 3: example of a rainfall simulator with nozzle spraying water on the mesh

3.4 Disdrometer

In order to check the rainfall parameters, a disdrometer provided statistical data(distribution, mean value, variance, etc…) of the raindrops, their characteristics in terms of size andvelocity) and the calculation of the rainfall intensity and of its kinetic energy, an example of representation is given in

Figure 4.

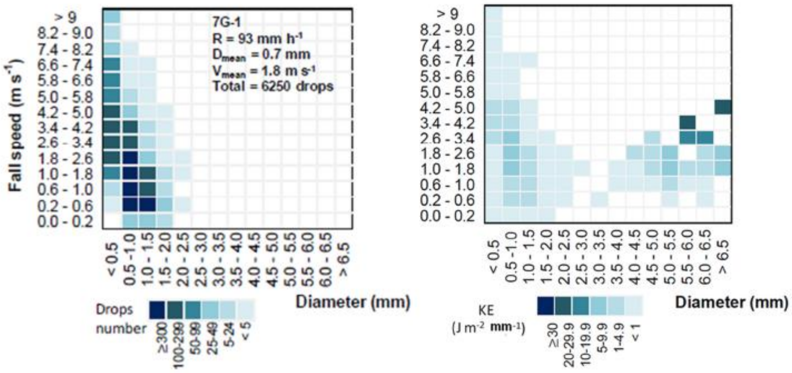


Figure 4: example of D – v-N_i plot and of D – KE – N_i plot

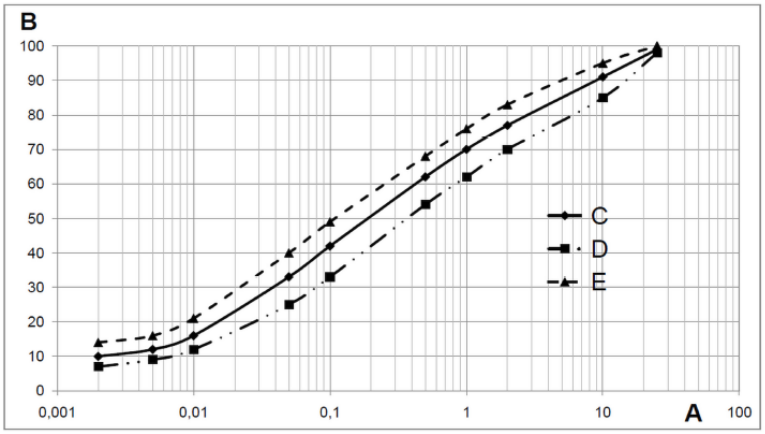
3.5 Soil

The soil was chosen in order to be a very erodible one. The size distribution of the grains is one of the physical characteristic linked to the erodibilty factor. The distribution chosen is defined as below and on the

Figure 5:

- Clay: 10 to 14 %
- Silt: 24 to 28 %
- Sand: 58 to 62 %.

The plastic Index has to be as close as possible from 4.5.
The soil is placed in the box in 2 lifts of 50 mm, compacted to 90 % of Standard Proctor Density.



Key

A	grain size (mm)	D	lower gradation limit
B	percent passing	E	upper gradation limit
C	typical gradation		

Figure 5: typical grain size distribution of the test soil

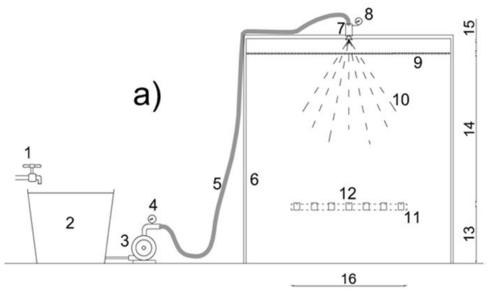
3.6 Geosynthetic specimen

A minimum of 3 specimens has to be tested, one for each rainfall intensity, with minimum dimensions of 1,0 x 2,0 m minimum, conditioned at 20°C and 65% relative humidity.

3.7 Calibration

The calibration consists in different steps:

- setting the rainfall intensity gauges, as shown on
- Figure 6
- calibrating the rainfall intensity
- preparing the disdrometer
- calibrating the rainfall
- Recording of data
- Calculation and expression of results
- Calculating the theoretical values
- Calibration check.



a) cross section

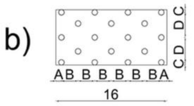


Figure 6: plan view with location of 18 gauges

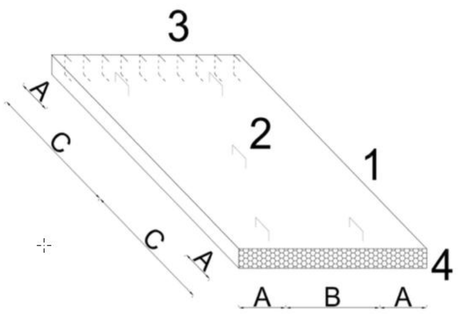
3.8 Procedure

The soilwill be previously air-dried and sieved. It is theninstalled in the box in two layers, and compacted to 90% of standard Proctor density, as explained before.

The geosynthetic is fixed with five staples and also clamped on the top, as shown on

Figure 6

Figure 7.
The box is inclinedwith a grade of 1V/2H
The plot is wetted with low rainfall intensity (5 mm / h) for 20 minutes.
Test operation and data collection for each rain intensity can be executed, once with a bare soil and after with at least one specimen, for 30 minutes and 100 mm/h rainfall intensity as a reference.



Key

1	rigid box	A	250 mm
2	staples (oriented as shown)	B	500 mm
3	clamping system	C	1,0 m
4	grid		

Figure 7: typical scheme for fixing the specimen to the steel box with a clamping system and to the soil with staples

3.9 Evaluation of the C Factor of Rusle (Revised Universal Soil Equation)

For the evaluation of the C Factor of Rusle, a procedure is suggested in annex D of the standard, and consists in performing at least3 tests, with 3 different rainfall intensitiesamong several possible ones (30 mm/h, 60 mm/h, 90 mm/hor 50 mm/h, 75 mm/h, 100 mm/h), performed at the same slopefor 30 minutes. Calculation leads to the determination of the different values :

- the soil loss A
- the R factor
- the K factor
- the LS factor
- the C factor

4. CONCLUSION

This test has been written in order to provide index values, in order to have repeatable measurements. Soil, grade, rainfall, etc…, have been chosen in order to have erosion and are not supposed to be representative of each cases that can be meet in real life, performance test are dedicated to such matters.

5. REFERENCES

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