Experimental study on turbulent flow and wet sieving tests after abrasion load of geotextiles

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Keywords: turbulent water flow, wet sieving, abrasion load, geobags, hydraulic applications, microscope image

ABSTRACT: The abrasion resistance is an important property for the application of geotextiles as geobags (geotextile bags filled with local soil). The abrasion load of geotextiles can be simulated under laboratory conditions by installing geotextile samples in a rotating drum. In the fixed rotating drum test facility the drum is rotating with a defined speed and filled with a mixture of water and crushed stones (2/11 mm). The abrasion load is caused by crushed stones tumbling over the geotextile. For the first assessment of the geotextile abrasion resistance standard index tests methods for thickness and tensile strength are suitable. But for hydraulic applications the filtration behaviour is a more important feature. The filtration behavior after abrasion load is important for the selection of geotextiles. This paper describes comparatively the use of a turbulent flow and wet sieving test method for the assessment of the filtration behavior of geotextiles after abrasion load.

1 INTRODUCTION

Geotextiles are widely used for river embankment or coastal protection projects. A case of geosynthetic application in coastal engineering is the use of geotextile tubes as a shore protection element for dune reinforcement as described in Escalante & Pimentel (2008). An example for geotextiles as geobags for riverbank protection is given in Oberhagemann et al. (2006). On-site abrasion tests of geobags have been specified to assure the stability of the long-term protection. The experience and the first tests led to material specifications for later tenders. While the range for the opening size (O90) in the accompanying documents often is given as ± 20 µm or even more, specifications for a certain application have to ask for much less scatter to fulfil the filter rules. These specifications also involved requirements for the abrasion resistance of geotextiles. Amongst other properties the opening size after abrasion load must be tested by wet sieving. In both applications the geotextiles are exposed to wave action which causes turbulent water flow and abrasion load with sediments.

The filtration behavior under turbulent conditions is important for the selection of geotextiles. Maisner & Myles (2008) analyzed the possible culpability of a geotextile filter in the failure of a sea wall. The geotextile product selection and the filter design were based on the wet sieving method. It was shown that under turbulent water flow conditions the soil passing was increasing over the test time. A turbulent flow test method is closer to on-site embankment behavior than wet sieving method.

This paper analyzed a turbulent flow and the wet sieving test method for the assessment of the abrasion resistance of a commercial geotextile filter fabric.

2 TEST METHODS

2.1 *Abrasion testing*

The test method for the abrasion resistance which is also called “rotating drum test” was first described in List (1977) and originally developed for geotextile filter layers under armourstones. Amourstone layers for slope and bottom protection have some gaps. The space between the amourstones allows for stone movements under hydraulic exposure which may cause abrasion of the geotextile filter. The “rotating drum” test is also appropriate to determine the abrasion resistance of geobags which are loaded by sediment transport. The test facility comprises an octagonal steel drum with eight test sections for the geotextile samples, an adjustable electric motor drive, an electronic control system and the frame. In the rotating drum a mixture of 4 kg crushed stones and 8 l water passes over the geotextile samples for 40000 revolutions in an anti-clockwise direction and 40000 revolutions in a clock wise direction. After every 5000 revolutions the direction of rotation reverses. The rotating drum speed is 16 rpm. Each geotextile specimen must have a dimension of 200 x 300 mm. A high quality basalt chipping is used as abrasive material. The chipping consists of a mixture of three gradings (2 kg of 8/11 mm, 1 kg of 5/8 mm and 1 kg of 2/5 mm). Figure 1 shows the lateral view and figure 2 shows the top view of the test facility.

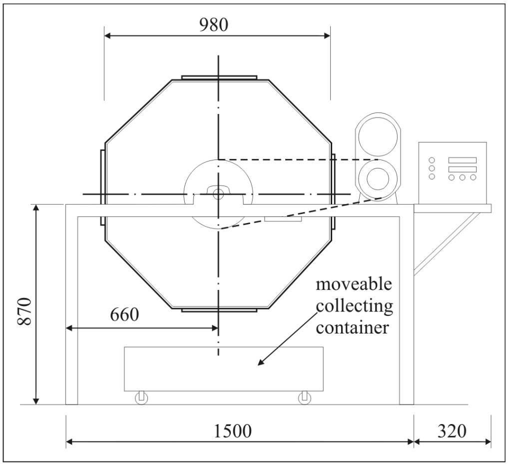

Figure 1. Lateral view of the rotating drum test facility

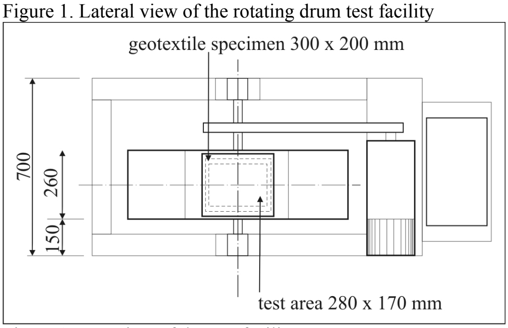

Figure 2. Top view of the test facility

2.2 *Turbulent flow test method*

Details of the test method and the test facility are described in Maisner & Myles (2008). The test facility as shown in figure 3 comprises a load bearing steel frame with a flange-mounted electric motor, an electronic control system, a v-belt drive, drive shafts with turbulence producing propellers, three test containers, specimen holders and vessels for the water collection. Figure 4 shows the lateral and top view of a test container. The geotextile specimen is placed at the bottom of the specimen holder beneath the test soil and above a stainless steel mesh which is the open side for the water flow exposure. A key feature of the test method is the four bladed propeller for the simulation of turbulent and pulsating water flow conditions such as those that occur during the wave action, passage of a ship, etc. The soil passing through the geotextile filter specimens when exposed to turbulent flow conditions are determined in different test phases. After each of the test phases the soil passing is determined from the collected and filtrated water after drying at 105°C. Each of the five test phases is 30 min. In comparison to the previous test phase the test results will also show, whether the rate at which soil passes through the geotextile has stabilized as required by the client. This test method provides an index value for the comparison of geotextile products, if a defined test soil is used. But it could be also used as performance test for the design of erosion protection layers in hydraulic applications, if the local soil is used as test soil.

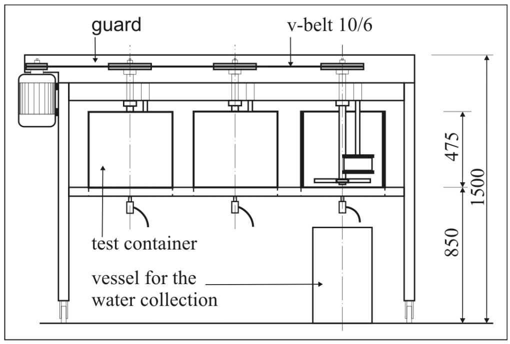

Figure 3. Lateral view of the turbulent flow test facility with three test containers

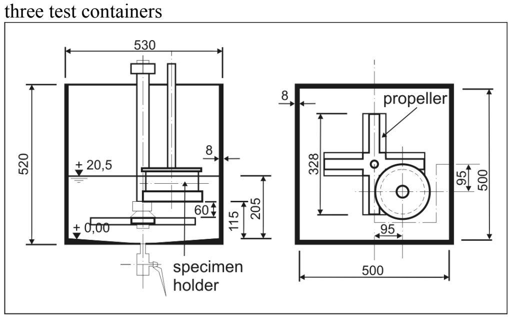

Figure 4. Lateral and top view of a test container

2.3 *Wet sieving method*

The standard EN ISO 12956 was first issued in 1996 and is an important test in Europe for the factory production control and specifies a wet sieving method. This standard describes a method for the determination of the characteristic size of the openings of a single geotextile filter layer by using the wet sieving method. The particle size distribution of the test soil is determined after washing through a single layer of the geotextile specimens used as sieve. This test method can also be considered as an index test for the comparison of geotextile products. In Europe the opening size testing in accordance with EN ISO 12956 is also a requirement for several product standards.

3 SAMPLE MATERIAL

A commercial nonwoven geobag product was chosen as sample material for the abrasion load in the rotating drum. The geotextile is a non-woven needle punched material. The fibres are made of polypropylene and polyester. Figure 5 shows a stereo microscope extended focal image of the virgin fibres. The diameters of the fibres are roughly 30 µm.

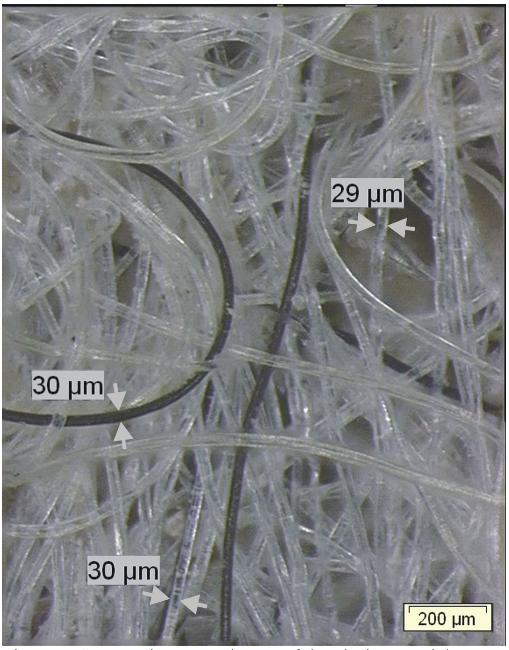

Figure 5. Stereo microscope image of the virgin material

Table 1 shows a selection of general properties of the chosen geotextile.

Table 1. General properties of the chosen geotextile

Mass per unit area (ISO 9864)	396 ± 32 g/m²
Thickness (ISO 9863-1)	3.2 ± 0.3 mm
Tensile strength (DIN 53857) MD CMD	 29.0 ± 0.9 kN/m 29.6 ± 2.2 kN/m

4 TEST RESULTS AND DISCUSSION

After 80000 revolutions of the abrasion drum the specimens for the further testing were taken from the centre of the abraded surfaces. Before further testing the specimens were prepared by washing and air drying. But several particles of the crushed stones in contact with the fibres can be identified after this preparation by the stereo microscope investigation.

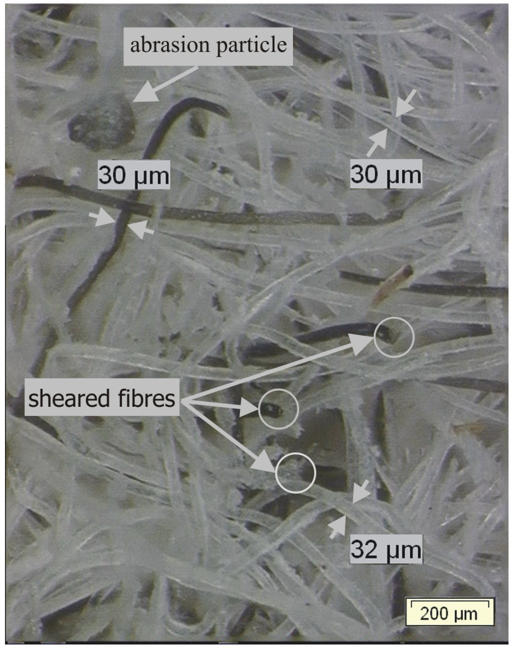

Figure 6. Stereo microscope image of the fibres after abrasion.

Figure 6 shows the top view of the abraded side of the fabric. Some fibres are sheared off. It can be noticed that several fibres perpendicular to the direction of the abrasion load are damaged. But the diameter of the fibres is roughly the same as the virgin material. Abrasion particles of the crushed stones occur among individual fibres. By comparing the general properties before and after abrasion load, as shown in tables 1 and 2, it is obvious that the abrasion load caused a significant decline of thickness and tensile strength.

Table 2. General properties after abrasion load

Mass per unit area (ISO 9864) [g/m²]	410 ± 33
Thickness (ISO 9863-1) [mm]	2.8 ± 0.3
Tensile strength (DIN 53857) MD [kN/m] CMD [kN/m]	 20.6 18.6

The increase of the mass per unit area is linked to the inclusion of the abrasion particles of the chippings in the pore space of the geotextile. For the determination of the effect of abrasion on the characteristic values for opening size O_{90} the samples were cut off and installed in the abrasion drum in machine direction and cross machine direction. By comparing the O_{90} results before and after abrasion, as shown in table 3, it is obvious that no significant decline and no influence of the production direction were determinable.

Table 3. Results of characteristic opening size O_{90}

	Opening size (ISO 12956)
Before abrasion	73.6µm
After abrasion MD CMD	 78.7µm 78.1µm

For example, the European standard EN 13253 specifies the relevant characteristic of geotextiles used in erosion control works for preventing the migration of soils. The determination of the O_{90} value in accordance to ISO 12956 is part of the factory production control and statement of compliance. According to EN 13253 the range for the O_{90} values in the accompanying documents is ± 20 µm.

The results for the turbulent water flow method before and after abrasion load are shown in table 4.

Table 4. Turbulent water flow method results

	Before abrasion load	After abrasion load
Soil passing in 150 min [g]	176.2 ± 11.8	213.9 ± 10.4
Soil passing in the last phase of 30 min [g]	18.3 ± 0.9	23.20 ± 1.8

It is notable that the abrasion load caused a significant increase of soil passing in 150 min and in the last test phase of 30 min.

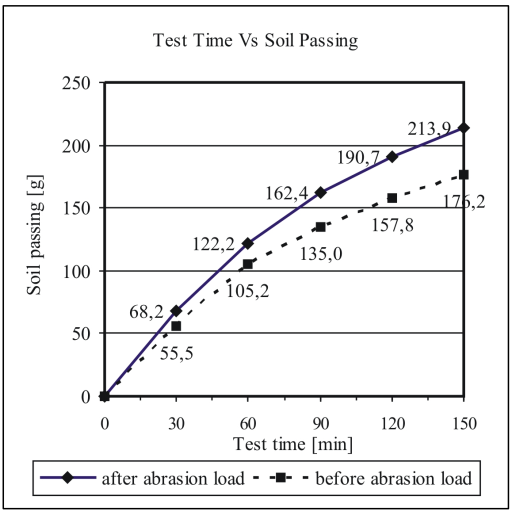

Figure 7. Soil passing diagrams before and after abrasion load

Figure 7 shows cumulative curves as soil passing diagrams which are obtained by plotting the soil passing for each test phase against the complete testing time.

5 CONCLUSION

The present study shows that specifications are needed to limit the range of parameters as e.g. the opening size given in the accompanying documents (CE marking) to fulfil certain requirements as for example filter rules. To check the opening size, usually the test according to ISO 12956 is performed.

By comparing the O_{90} opening size values, which were determined by wet sieving before and after the abrasion load, it became obvious that the wet sieving test might not be sufficiently sensitive to determine deterioration due to abrasion load - the O_{90} index test did not show significant differences.

For the tested geotextile the turbulent flow test method by contrast to the wet sieving method shows significant differences in the soil passing behavior of the tested geotextile. After abrasion load was no decrease of the fibre diameter determinable by stereo microscope. But several fibres are sheared off. Even though the determination of O_{90} did not show a remarkable change of the opening size, it has to be judged individually, if the increase of the soil mass passing in the turbulent flow test can be tolerated or not.

The chosen example highlights the different sensitivity of test methods in a special case. Nevertheless generally determining the opening size by the wet sieving test is considered to give adequate results to check the effect of abrasion on a geotextile.

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