Filtration behaviour of sand mats

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ABSTRACT: Sand mats are composite materials for hydraulic applications. They consist of a geotextile top and base layer with a fill of natural sand or aggregates to increase the mass per unit area. The two geotextile sheets are needle punched or sewn together to hold the fill in place and to provide shear strength in the plane of the mat. An advantage is the easier installation under water. Concerning the application as a filter layer, two types of sand mats must be distinguished. Type A are sand mats where only the top layer must be considered for the filtration behaviour. Type B are products where the entire composite is relevant for the hydraulic properties. Concerning the functions filtration and separation EN 13253 requires only the characteristic opening size and water permeability under laminar conditions. For the present study samples were selected, which are representative for the product types and have been currently installed to a great extent at navigable waterways. The paper shows hydraulic properties of the single layers and of the entire sand mats. An important design criteria for use in erosion control works, coastal protection or bank revetments can be the water permeability of the geotextile filter after testing the amount of soil passing (ISO 10772). Sand mats in erosion control works are often exposed to turbulent external water flow conditions. Therefore the paper shows also the determination of the filtration behaviour under turbulent water flow conditions and the hydraulic filtration stability of the single layers as well as the entire sand mats.

Keywords: sand mats, geotextile, navigable waterways, hydraulic properties, erosion control works

1 INTRODUCTION

Hydraulic applications of sand mats have meanwhile undergone an impressive development. Well known for example is the stabilizing function of a dam construction for the Rees floodway at the river Rhine in Germany. In terms of DIN EN ISO 10318-1sand mats are sand filled geocomposites (GCO). They are manufactured by assembling natural sand as ballast material between at least two geotextile layers. Geotextiles made of polypropylene (PP) fibres cannot sink under water due to the low bulk density (density < 1,0 kg/dm³). But also geotextiles with fibres of higher density will float due to the air entrapped between the fibres. The ballast material of the sand mats produced a considerable increase of the mass per unit area. For the installation of geotextile filter layers at navigable waterways often quick sinking is desired. Relevant characteristics of geotextiles and geotextile related products for the use in erosion control works are specified in DIN EN 13253. For the installation beneath armour stone top layers at navigable waterways further characteristics are relevant. As a supplement to DIN EN 13253 there are special requirements for geotextiles or geotextile-related products which are used in bank protection structures defined in the German technical delivery conditions for geotextiles and geotextile-related products on waterways (TDC 2008). In particular cost-effective and time-saving extensive installation at navigable waterways demands specific criteria (Heibaum 2010). These specific installation aspects are not considered in DIN EN 13253. The experience on erosion control works and research on geosynthetics led to the material specifications of TDC. Concerning the application of a sand mat as a filter layer and the required hydraulic filtration efficiency, two types of sand mats must be distinguished. Type A are sand mats where only the top layer must be considered for the filtration behaviour. Type B are products where the entire composite is relevant for the hydraulic properties. For the present study samples were selected, which are representative for both types and have been currently installed to a greater extent at navigable waterways.

2 INTENDED USE OF SAND MATS FOR BANK AND BOTTOM PROTECTION

2.1 *Specific features and advantages*

Figure 1(left) shows a placement unit for geotextiles and armour stones for the widening of a navigable waterway. The geotextile layer must be placed directly on the bed or bank and secured against floating by suitable measures. One possibility is the immediate covering with armour stones after placement as shown in figure 1 (right). Elsewise during the passage of vessels the lightweight filter layer can move. The second step after the installation of the geotextile is the complete drop of armour stones or other bulk material.

Figure 1: Placement unit for geotextiles and armour stone installation (left) and dropping of armourstones (right)

To improve the position stability of geotextiles, sand mats were developed. A geotextile filter layer is the base layer in the composite. The ballast core must be covered with another geotextile layer on the top. It must also be mentioned that in canals, where the slopes are commonly built with a steepness of 1V:3H to save ground, the position stability of sand mats is important. The connection (joints) of the individual sand mat sheets can be made by stitching or overlapping. Seams and overlaps should be placed in the direction of the embankment. When an overlap is required to be perpendicular to the embankment in exceptional cases, the lower sheet shall be applied over the upper one. The overlapping width must be at least 0,5 m when applying the surface course in dry conditions; when applying under water, it must be at least 1 m. The requirements of the TDC 2008 shall apply mutatis mutandis for on-site stitching.

Figure 2: Connection of sand mats by overlapping (left) and detail (right)

A specific feature and advantage of sand mats is the heavyweight core of fill of natural sand or aggregates. The sand layer improves also the resistances to dynamic perforation loads due to damping the stone drop impact. They have to fulfill the filter rules after installation.

2.2 *Requirements for navigable waterways*

For the intended use in external erosion control work systems the European harmonized standard DIN EN 13253 specifies function related characteristics. But there are no classes or thresholds specified. Concerning the resistance to damage during installation requirements are also missing. Especially the installation methods for hydraulic engineering require specific characteristics with levels or classes. For navigable waterways in Germany this gap is closed by the TDC 2008. An example for an installation related characteristic is the resistance to dynamic perforation loads during the drop of armour stones. According to TDC 2008 the drop energy of 1200 Nm complies with armour stone grading $LMB_{5/40}$ and 1800 Nm to the grading $LMB_{10/60}$ under the terms of DIN EN 13383-1 (Armour stone - Part 1: Specification). The TDC 2008 requires basic tests for specific hydraulic properties and installation related characteristics in addition to DIN EN 13253 certified products. The Directives on geotextile testing in navigable waterway constructions (RPG 1994) specifies the performance of basic tests. RPG specifies also the test facility as shown in figure 3 and the performance of the testing. Turbulent currents can cause erosion of the bottoms or banks of a canal or river in dependence on the particle size of the material present in the banks and beds. Highly turbulent currents occur for example in the tail water of weirs and the return flows due to shipping. The TDC 2008 specifies therefore also the permissible soil passage (mechanical filtration efficiency) for the testing with the turbulent flow method of DIN EN ISO 10772 for fine grained but non cohesive soils. For specific soils the testing with the flow-through method as described in the RPG 1994 is further required.

Figure 3: Drop test facility (left), deformation in the sand bed (top right) and a punctured sand mat (below right)

According to Kunz (2015) concerning the filtration behaviour two types of sand mats must be distinguished in general:

- Type A, only one layer of the geocomposite is filter-effective
- Type B, the complete geocomposite is filter-effective.

Type A is a geocomposite where the base layer is dominant for the filtration behaviour. The base layer has to pass the basic test in terms of RPG 1994. Either in turbulence tests or through flow tests the hydraulic filtration stability must fulfill TDL 2008. The top layer may be damaged during installation and the sand fill may get lost. If the sand is only an additive for the placement, it is possible to allow at the margins of the sheet some centimetres without sand for easier seaming.

Type B can be further distinguished into type B1, products without marking the installation direction, and type B2, where the top layer must be marked for installation with “top” due to the abrasion or drop resistance. The sand has also an effect on the filtration behaviour.

The ballast material for both types shall be in accordance with DIN EN 12620 (aggregates for concrete), DIN EN 13139 (aggregates for mortar) and DIN EN 13242 (aggregates for unbound and hydraulically bound materials).

3 TESTING OF SANDMATS, EXAMPLES FOR TYPE A AND TYPE B

3.1 *Description of the samples*

To point out the room for improvement by assembling geotextiles and sand to a geocomposite a sample of type A and B were assembled and tested. In both cases the top layer is a nonwoven material with 300 g/m² mass per unit area and the same thickness. The mass of the sand and the mass per unit area of the nonwoven base layer are different. Sample type A comprises a base layer which has met the basic test of RPG 1994. The thickness of the base layers differs slightly. Both samples fulfil the requirements of the TDC 2008 for the application in bank protection constructions as a filter beneath a permeable layer of armour stones. They have also met the TDC 2008 requirement for the abrasion resistance. Details of the abrasion testing are described in Maisner & Heibaum (2010). The drop resistance of the samples is different. Table 1 shows selected properties

Table 1. Selected properties of the sand mat samples type A and B

Product Sample	Thickness (mm) At			Mass Per Unit Area (g/m²)	Tensile Strength At Failure (kN/m)		Drop Resistance (Nm)
	2 kPa	20 kPA	200 kPa		md	cmd	
Type A							
Entire composite	≥ 11	≥ 10	≥ 7	≥ 5900	≥ 30	≥ 40	1800
Base layer 1	≥ 6	≥ 5	≥ 3				
Layer 2	≥ 3	≥ 2	≥ 1				
Type B							
Entire composite	≥12	≥ 10	≥ 6	≥ 5500	≥ 30	≥ 40	1200
Base layer 1	≥ 8	≥ 5	≥ 2				
Layer 2	≥ 3	≥ 2	≥ 1				

3.2 *Hydraulic Testing of the samples type A and B*

Sand mats in erosion control works are exposed to turbulent inflow or through flow conditions. Concerning the functions filtration and separation DIN EN 13253 requires also the testing of the characteristic opening size O_{90}. This wet sieving test method was originally issued in 1996 as DIN EN ISO 12956. This standard describes a method where the particle size distribution of the test soil is determined after washing through a single geotextile layer or a geotextile related product. The test procedure describes no details for testing sand mats. For the wet sieving testing of the geocomposite samples type A and B the edges of the specimens were sealed with a polyurethane (PUR) sealing compound to prevent the loss of particles of the sand core. The results of the O_{90} testing of the composites and the single layers are shown in table 2.

Table 2. Results of the characteristic opening size O_{90} based on ISO 12956

	O_{90} (µm)	
	Type A	Type B
Composite with sand core	81	110
Composite without sand core	73	104
Layer 1 (thick base layer)	77	126
Layer 2 (thin top layer)	75	125

By comparing the results of the composites with their single layers it is obvious that there is no significant alteration of the O_{90} values by assembling the single parts with a sand layer. This observation relates to both types A and B.

Table 3 shows test results for the water permeability in accordance with DIN EN ISO 11058. When comparing the results of the composites with their single layers it is obvious that there is significant alteration of the V_{H50} values by assembling the single parts with a sand layer. This observation relates to both types A and B.

Table 3. Water permeability normal to the plane without load according to DIN EN ISO 11058

	V_{H50} (mm/s)	
	Type A	Type B
Composite with sand core	12 ± 0,2	12 ± 1,3
Composite without sand core	33 ± 2,2	57 ± 3,0
Layer 1 (thick base layer)	41 ± 4,0	92 ± 1,8
Layer 2 (thin top layer)	134 ± 4,8	155 ± 6,8

A better method to assess the filtration behaviour as described in Maisner & Heibaum (2010) can be the turbulent flow test method of DIN EN ISO 10772. Details of the test facility are given in RPG (1994). Table 4 shows the results of the testing in accordance to DIN EN ISO 10772 for the single components and the geocomposites of the samples type A and B. During the testing each specimen undergoes five loading phases. Each phase is 30 minutes long. The permissible soil passage of the TDC 2008 is 300 g for the complete test time of 150 min and 30 g in the final test phase of 30 min. Both values can be found in table 4.

Table 4. Mechanical filtration stability (turbulent flow method, ISO 10772) with test soil type BT4

	Sample Type A (g/m²)		Sample Type B (g/m²)	
	g/ 150 min	g/ last test phase	g/ 150 min	g/ last test phase
Composite with sand core	93	8	290	29
Composite without sand core	117	14	639	98
Layer 1 (thick base layer)	285	20	827	149
Layer 2 (thin top layer)	345	28	653	58

By comparing the results of the composites with their single layers it is obvious that there is significant alteration of the soil passing values by assembling the single parts with a sand layer. This observation relates to both types A and B. Figures 4 show the soil passing diagram obtained by the turbulent flow method for the sand mat sample type A with their single components.

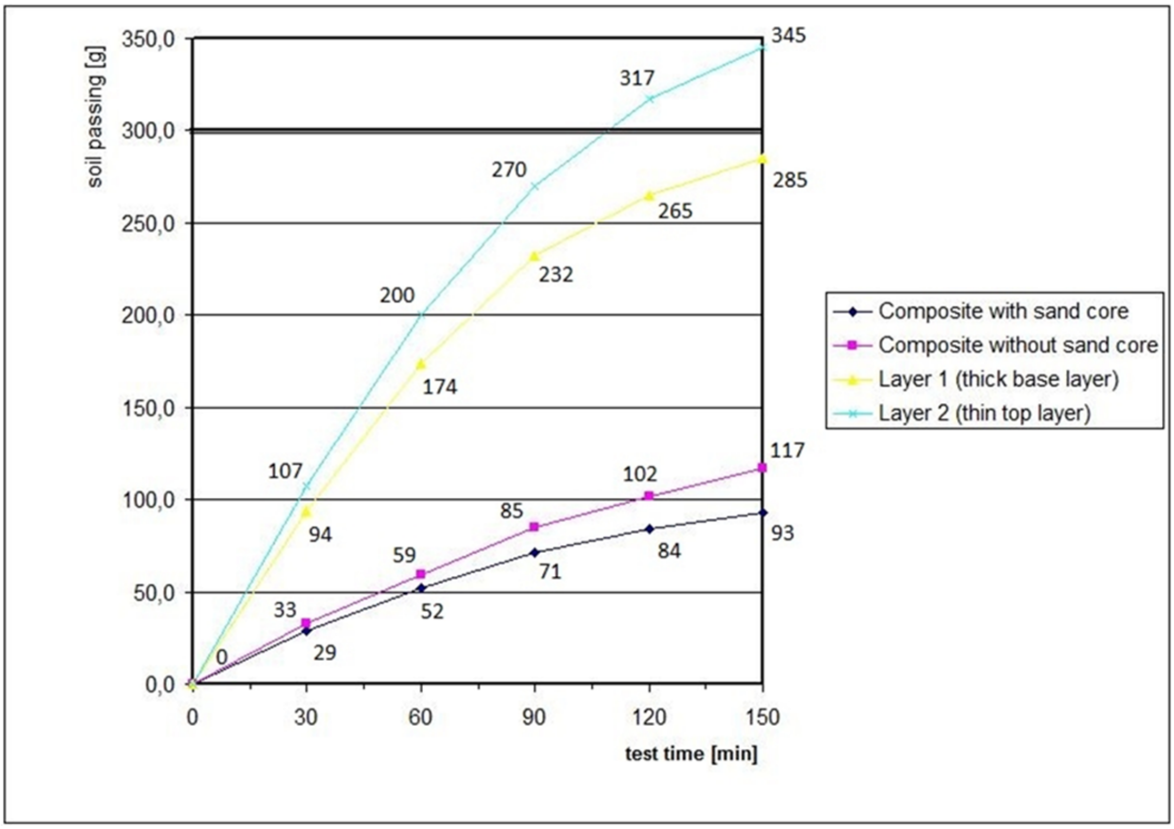

Figure 4: Turbulent flow testing on type A, composite and single layers

For type A, the limits of the TDC 2008, 300 g for the complete test time of 150 min and 30 g for the last test phase, are fulfilled for the composite with sand core, without sand core and the base layer.

In contrast, Figures 5 show the soil passing diagrams obtained by the turbulent flow method for the sand mat sample type B with their single components. Only the composite with sand core fulfilled limits of the TDC 2008

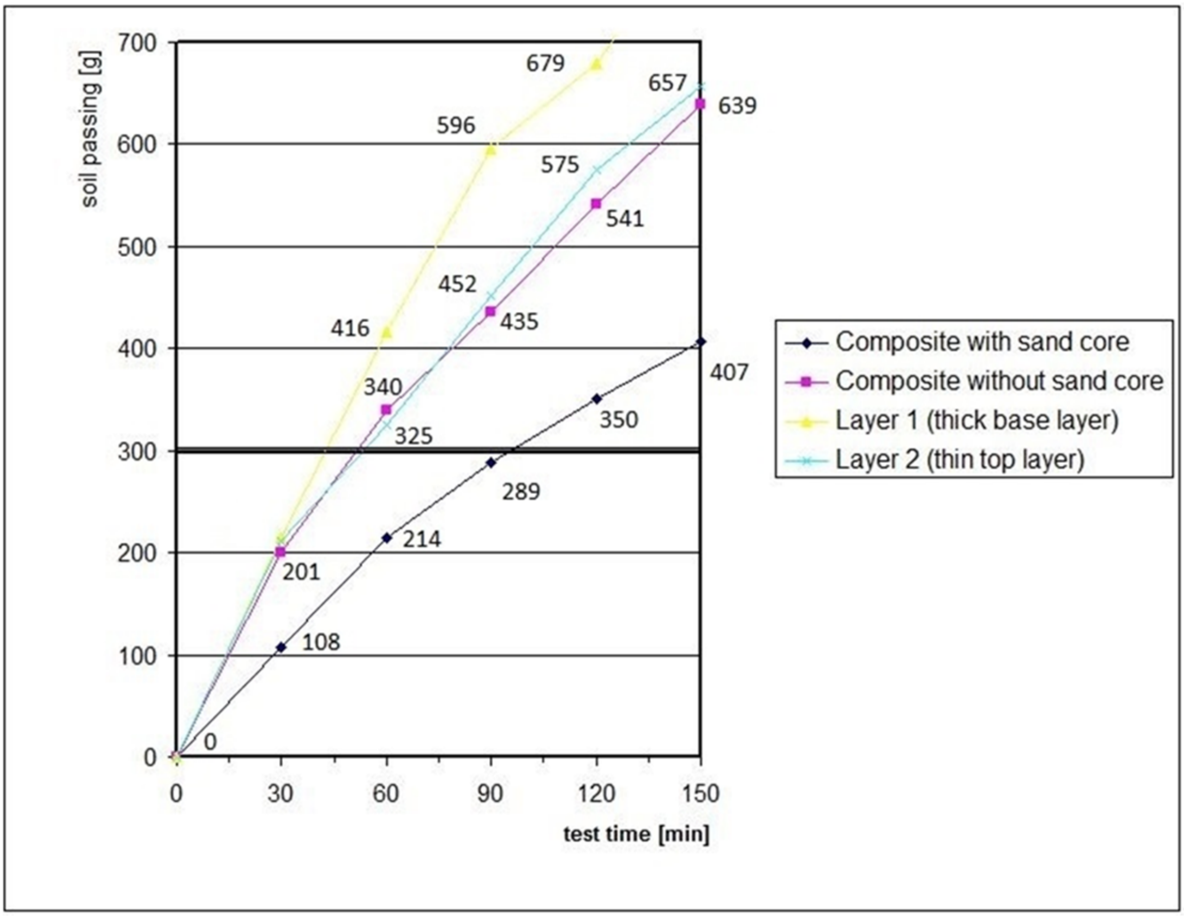

Figure 5: Turbulent flow testing of type B, composite and single layers

For the sake of completeness, Figure 6 shows the grading curves for the test soils BT4, BT3, O_{90} in comparison with the grading curve of the sand mat sample type A. The TDC 2008 and the RPG 1994 specifies soil types for the testing of the mechanical filtration stability. Test soil type BT4 which is chosen for the turbulent flow method has particles of clay.

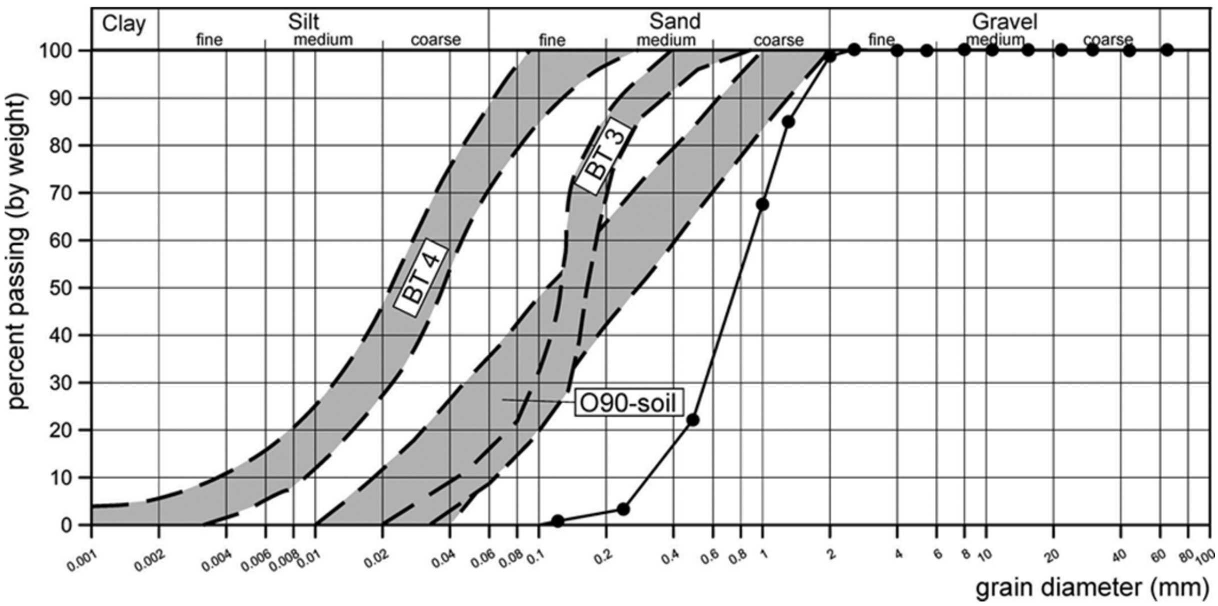

Figure 6. Grading curves for the test soils ST4, ST3 and O_{90} by comparison with the sand core of the sample type A

4 CONCLUSIONS

Sand mats are geocomposites which are assembled by two or more geotextile layers. Beneath the top layer is the sand core for the improvement of the mass per unit area. An advantage of these products is the easier installation under water for intended use as filter layer at navigable waterways for example. Economic aspects lead to the development of a new product type of sand mats. Type A are sand mats, where already one of the geotextile layers have sufficient filter properties. By contrast Type B are products where the entire geocomposite is relevant for the hydraulic properties. The mechanical filtration behaviour of a single geotextile filter layer can be significantly improved by assembling with a sand core and a thin top layer to the composite sand mat. DIN EN 13253 is the European harmonized standard for geotextiles with the intended use in erosion control works. Concerning the function "geotextile filter" the wet sieving method of DIN EN ISO 12956 is required. It was shown that the results of this method don't provide sufficient information for the filter design of sand mats.

The paper shows also hydraulic properties obtained by the turbulent flow method of DIN EN ISO 10772 for the single layers and for the complete products. By comparing the results of the composites with their single layers it is obvious that there is significant alteration of the soil passing values and improvement of the hydraulic properties by assembling the single components with a sand layer.

Sand mats in erosion control works are often exposed to turbulent water flow conditions. The mechanical filtration behaviour of a single geotextile filter layer can be significantly improved by adding a sand core and a thin top layer to the composite sand mat. Economic aspects lead to the development of a new product type of sand mats. In addition to the technical supply conditions for geotextiles at navigable waterways in Germany further requirements for sand mats are appropriate. It would be a technical improvement if in the harmonized product standard DIN EN 13253, for sand mats with the function as filter, the wet sieving test DIN EN ISO 12956 would be replaced by the turbulent flow test method DIN EN ISO 10772. An important design criteria for use in erosion control works, coastal protection or bank revetments, can be the water permeability of the geotextile filter after testing the amount of soil passing (ISO 10772).

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