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Maisner, Matthias; Myles, Bernard

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Possible Culpability of Filter Geotextile in the Failure of a Sea Wall

M. Maisner, Bundesanstalt fuer Wasserbau, Karlsruhe, Germany
B. Myles, Consultant, BMGeo Limited, Reigate, Great Britain

ABSTRACT
The paper analyzes the possible culpability of filter geotextile in the failure of a reinforced soil, concrete panel sea wall. The geotextile was used to retain dredged sand at the panel joints. The filter design and choice of geotextile was based on an internal company interpretation of the French Nation geotextile filter design for unidirectional water flow. The test method "Determining the soil passing through a geotextile when exposed to turbulent water flow conditions" is now an EN-ISO work item and has been used to assess the ability of a nearly identical geotextile to retain a similar grading of dredged sand and contrasts this with the German Federal Waterway Engineering and Research Institute (BAW) recommendations for geotextile properties and characteristics necessary to retain dredged sand in a sea wall application.

1. INTRODUCTION

Due to the rise of air traffic, in 1992 the operator of the airport in Sydney, Australia, concluded a contract for the design and construction of a third runway which extended into offshore, as reported by Lee (1994). The geotextiles were used to retain dredged sand at the panel joints. The construction works took two years, as reported by Walker (2006). After construction it became apparent that the sea wall, Mill Stream Channel Diversion and Seawall Section, of the third runway, shown in Figure 1, was loosing sand between the joints in the concrete facing panels in reinforced walls.

Figure 1. The runways of Sydney's Kingsford Smith International Airport with Millstream Diversion and Seawall.

This sand loss generated voids, sink holes and settlements behind the concrete panels. Furthermore these defects caused the corrosion of the steel traps behind the walls. The failure of the sea wall and the demands of the principal led to the insurance claim of the contractor and the case went to court after the insurers refused to pay, as reported by CIN (2006). A fundamental issue in the proceeding was the cause of the sand loss. As possible reasons for the sand loss design effects, failures in the construction works or both can be considered. Several experts were heard by the Supreme Court of New South Wales concerning the issue of what had caused the sand loss from behind the walls as reported by

Lee (1994). Finally the court preferred the evidence from an insurer expert. According to this expert evidence showed the sand loss directly as a result of flawed construction of the walls.
The possible culpability of the chosen geotextile product in combination with a possible failure design in context of a test method for turbulence conditions was no particular case during the hearing. This paper analyzed the possible influence of the geotextiles in the failure of the sea wall by using a test method which exposed turbulent water flow conditions to gextextiles.

2. DESCRIPTION OF THE TURBULENT FLOW TEST METHOD

This test method was first mentioned in List (1977) and over the years a great range of filter products have been examined so far at the German Federal Waterways Engineering and Research Institute (BAW). Furthermore it must be mentioned that the turbulent flow test method which is completely described in the Guideline for Testing Geotextiles for Navigable Waterways RPG (1994) of the BAW has helped to develop specifications with requirements for turbulent conditions like the Technical Supply Conditions TLG (2003).

Meanwhile the test method is on the ISO TC 221 and CEN TC 189 work program for preparing a draft. A key feature of the turbulent water flow test method is a four bladed propeller which produces turbulent water flow from 70-90 cm/s to geotextile specimens under specified conditions. The pulsation is 17 Hz. The test facility comprises a load bearing steel frame with a flange mounted-electric motor (the drive), an electric control system, a v-belt drive, drive shafts with turbulence producing propellers, test containers, specimen holders and vessels for the water collection. A single test container with a vessel for the water collection after the testing is shown in Figure 2.

(a) test container and vessel for the water collection (b) filtering to receive the past soil

Figure 2. Test procedure

The geotextile specimens are placed in test containers and fixed in specimen holders beneath the test soil of 1500 g and above a steel mesh. This steel mesh is the open side for the turbulent water flow. Inside the specimen holder is also a brass disc with a mass of 2130 g which produces in combination with the test soil a surface pressure of 2 kPa. Before testing the specimen holders are stored under water. During the testing the specimens are covered with water in the test container. After each test phase of 30 min the outlets are to be opened for the water discharging. The quantity of soil passing through the specimens is determined for a total of 5 test phases from the filtrated water after drying at 105 °C and weighing. A cumulated curve can be obtained by plotting the quantity of passed soil for each test phase against the testing time. According to the RPG (1994) 5 test phases should be carried out as index tests with the test soil ST4 whose particle size distribution is shown in Figure 3.

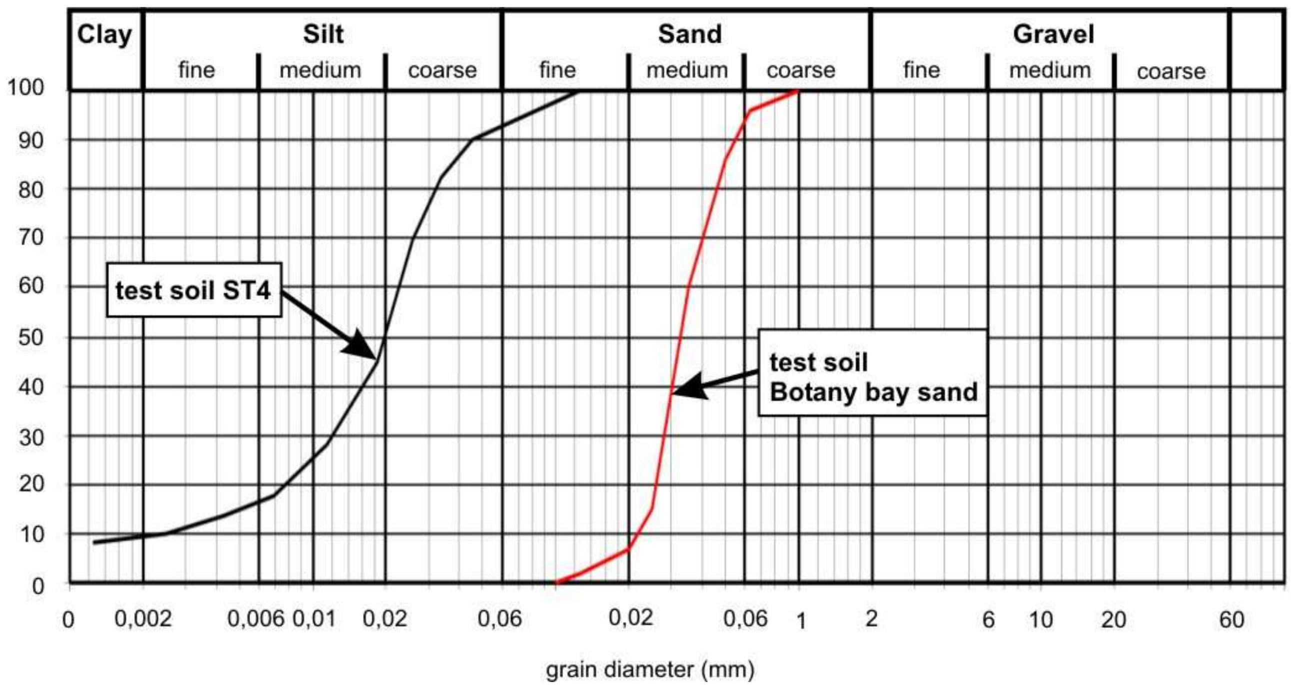

Figure 3. Particle size distribution of the test soil ST4 and the sea wall soil "Botany bay sand".

3. ANALYZING POSSIBLE INFLUENCES UNDER TURBULENT CONDITIONS

According to the New South Wales Supreme Court judgment of 2006-04-12 (NSWSC 223) geotextile strips were placed between the prefabricated concrete panels. These strips were made of continuous filament non woven needled punched polyester and should serve as filter for allowing water flow through the geotextile while retaining soil particles. The geotextile filters were placed in tidal zone with wave exposure. In this environment the exposure of turbulent water flow is a concomitant feature. Due to this fact the turbulent water flow method as described in RPG (1994) is an appropriate test method for analyzing possible influences and causes in the soil loss of the sea wall.

The geotextile selection and the geotextile filter design for the sea wall were based then on index values of a test method for unidirectional water flow (NSWSC 223). A presently valid index test method for unidirectional water flow by using a wet sieving is the standard ISO 12956 for determination of the characteristic opening size (O90 value) of geotextiles. Table 1 shows the O90 values for a small range of mechanically bonded non woven materials. The soil passing results for the last test phase and the total mass of soil passing under turbulent water flow conditions are also shown in Table 1. These results were determined in the framework of Federal navigable waterways applications in accordance with the turbulent flow method and the test soil ST4 as shown in Figure 3. On the basis of Table 1 it appears that there is no relation concerning the O90 value and the soil passing.

According to the judgment of 2006-04-12 on the Millstream wall as shown in Figure 1 was a product with a mass of 260 g/m² used. This product is product sample No. 1 in Table 1 and Figure 4. For the Seawall Section as shown in Figure 1 a 500 g/m² material was used which is product sample No. 2 in Table 1 and Figure 4.

Table1. Opening size O90 and soil passing for a selection of mechanically bonded non woven geotextiles.

Sample No.	Product	O90 (ISO 12956) [µm]	Mass Of Soil Passing ST4 Total [g]	Mass Of Soil Passing ST4 Within The Last Test Phase [g]
1	One layer, continuous filament, 100% polyester	95*	153.76	17,60
2	One layer, continuous filament, 100% polyester	80*	179.91	21,07
3	One layer, continuous filament, 100% polyester	95*	252.33	34.77
4	One layer, continuous filament, 100% polyester	80*	232.3	25.67
5	Two layers, continuous filament, 100 % PP	79	126.6	18.2
6	Two layers, continuous filament, 100 % PP	77	341.5	46.3
7	One layer, continuous filament, 100% polyester	120.2	397,9	30,7
8	One layer, staple fibers, 100% polyester	77.51	48.7	3.68
9	One layer, staple fibers, 100% polypropylene	73.3	110.0	10.80
10	Two layers, staple fibers, PET/PP	116	221.73	20,2
11	One layer, staple fibers, 50% PET/ 50%PP	117	124.14	10,86

* Value as declared by the producer

Figure 4 shows the soil passing diagrams as cumulative curves which were determined as index tests with the test soil ST4 as for the chosen products of Table 1. By comparing Figure 4(a) with Figure 4(b) it can generally be noted that there is no advantage for a particular geotextile product group.

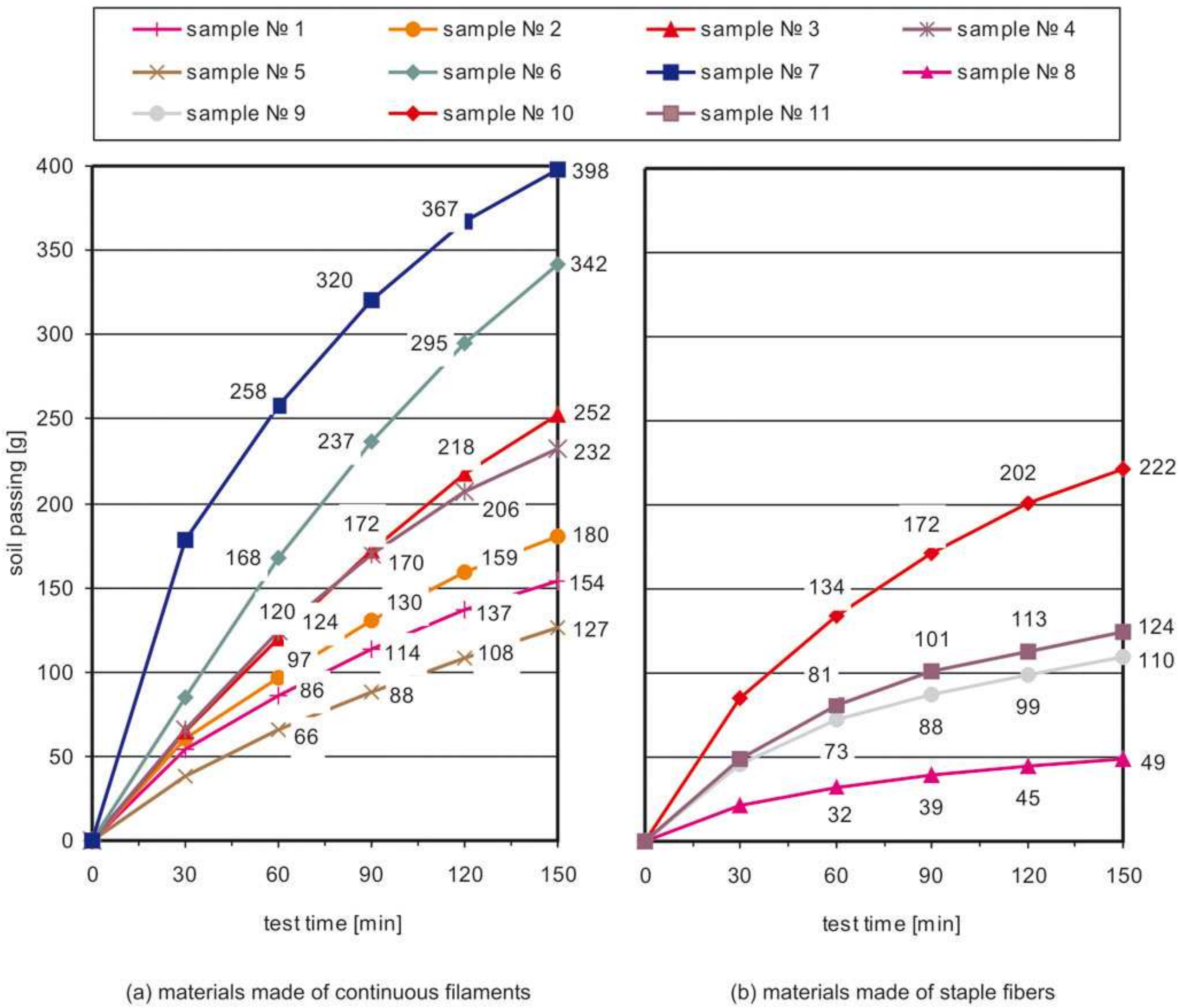

Figure 4. Soil passing diagrams with test soil ST4 for a selection of several non woven geotextiles.

On the basis of Table 1 and Figure 4 it is obvious that the geotextile filters samples No. 1 and No. 2 which were used in the Mill Stream Channel Diversion and Seawall Section have moderate rates of soil passing with soil type ST4 under turbulent conditions within the whole range of shown products. These materials met the requirements of the TLG (2003). But it is to observe that the soil passing within the last test phase for the samples No. 1 and No. 2 is still increasing.

By comparison of the products of Table 1 it can be seen how important is due to the rates of soil passing the selection of an appropriate geotextile filter for a construction project.

For the sake of completeness the mean of general properties for the products which were mentioned in Table 1 are shown in Table 2. On closer inspection of the soil passing results in Table 1 and the thickness or mass per unit of Table 2 it is to note that it is possible to receive appropriate soil passing results with thin materials like sample No. 1.

Table 2. Further properties of the tested geotextiles.

Sample No.	Product	Mass Per Unit Area (ISO 9864) [g/m²]	Thickness (ISO 9863-1) [mm]	Velocity Index V_{H50} (ISO 11058) [mm/s]
1	One layer, continuous filament, 100% polyester	253	2,45	*
2	One layer, continuous filament, 100% polyester	486	4,39	*
3	One layer, continuous filament, 100% polyester	252	2.47	93
4	One layer, continuous filament, 100% polyester	505	4.00	47
5	Non woven material, continuous filament, two layers, 100 % PP	842	6.21	34.1
6	Non woven material, continuous filament, two layers, 100 % PP	659	4.89	51
7	One layer, continuous filament, 100% polyester	371	4.30	*
8	One layer, staple fibers, 100% polyester	1053	8.14	16.38
9	One layer, staple fibers, 100% polypropylene	2088	10.92	16.67
10	Two layers, staple fibers, PET/PP	803	6.63	32,01
11	One layer, staple fibers, 50% PET/50%PP	643	5.63	67,63

*Not tested

According to the TLG (2003) the turbulent flow method is normally used for medium to coarse silt. As test soil for this grading band the soil type ST4 is used, which meets a plasticity index of Ip ≤ 0.1 and a cohesion of undrained soil of u ≤ 1.5 kN/m². The particle size distribution of the soil type ST4 which was used for the testing as shown in Table 1 is apparent in Figure 3. The particle size distribution of the "Botany bay sand" (BBS) which was used as the material for the sea wall section is also shown in Figure 3. A test soil with the particle size distribution of the BBS was assembled by removing particles greater than 2 mm. Due to the O 90 values of the samples No. 1 and No. 2 it is assumed that the particles greater than 2 mm have no influence on the soil passing.

To point out the possible influence of the local soil in the soil passing behavior of the sea wall geotextiles further tests were carried out with the samples No. 1 and No. 2. The BBS was used instead of the normal test soil ST4 and the results are shown in Figure 5. For both geotextile products the total mass of soil passing is low within the limited test time.

For the comparison of the influence of the normal test load in accordance to RPG and an additional load above the BBS test soil Figure shows 5 the cumulative curves of the soil passing. It can be observed that the influence of the additional load is marginal.

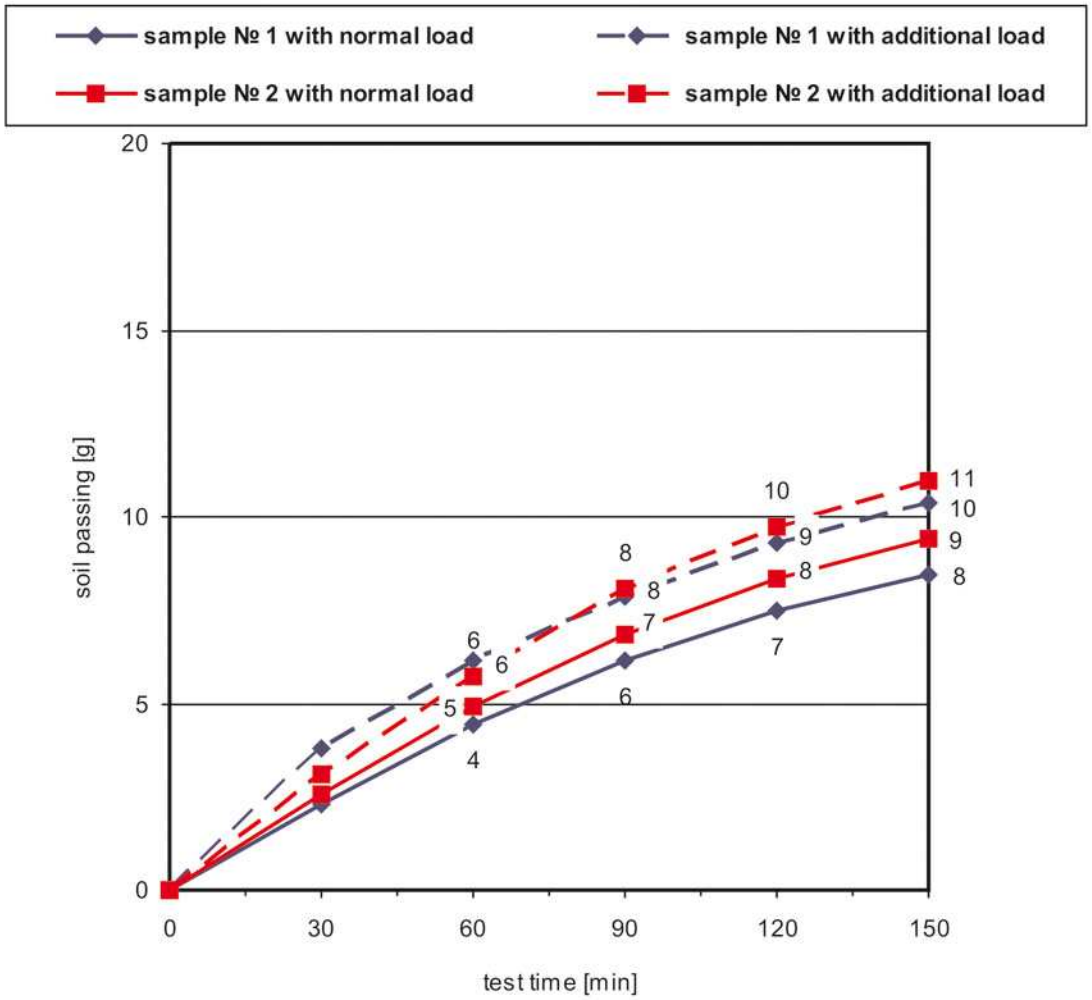

Figure 5. Soil passing diagram to show the influence of the load for the test soil “Botany bay sand”.

According to NSWSC 223 the compaction and the grading of the sand were arguments during the experts hearing. Due to this fact Figure 6 shows for the test soil ST4 comparison of normal load and an additional load of 1.1 kg which means an addition of 52%. The soil passing with the additional load of 52 % is almost the double value. An important influence for the soil passing behavior of geotextile could be the compacting of a fine grading soil. Table 3 shows also the results with the normal load in accordance to the RPG and an additional load of 1.1 kg which means a supplemental of 52 %.

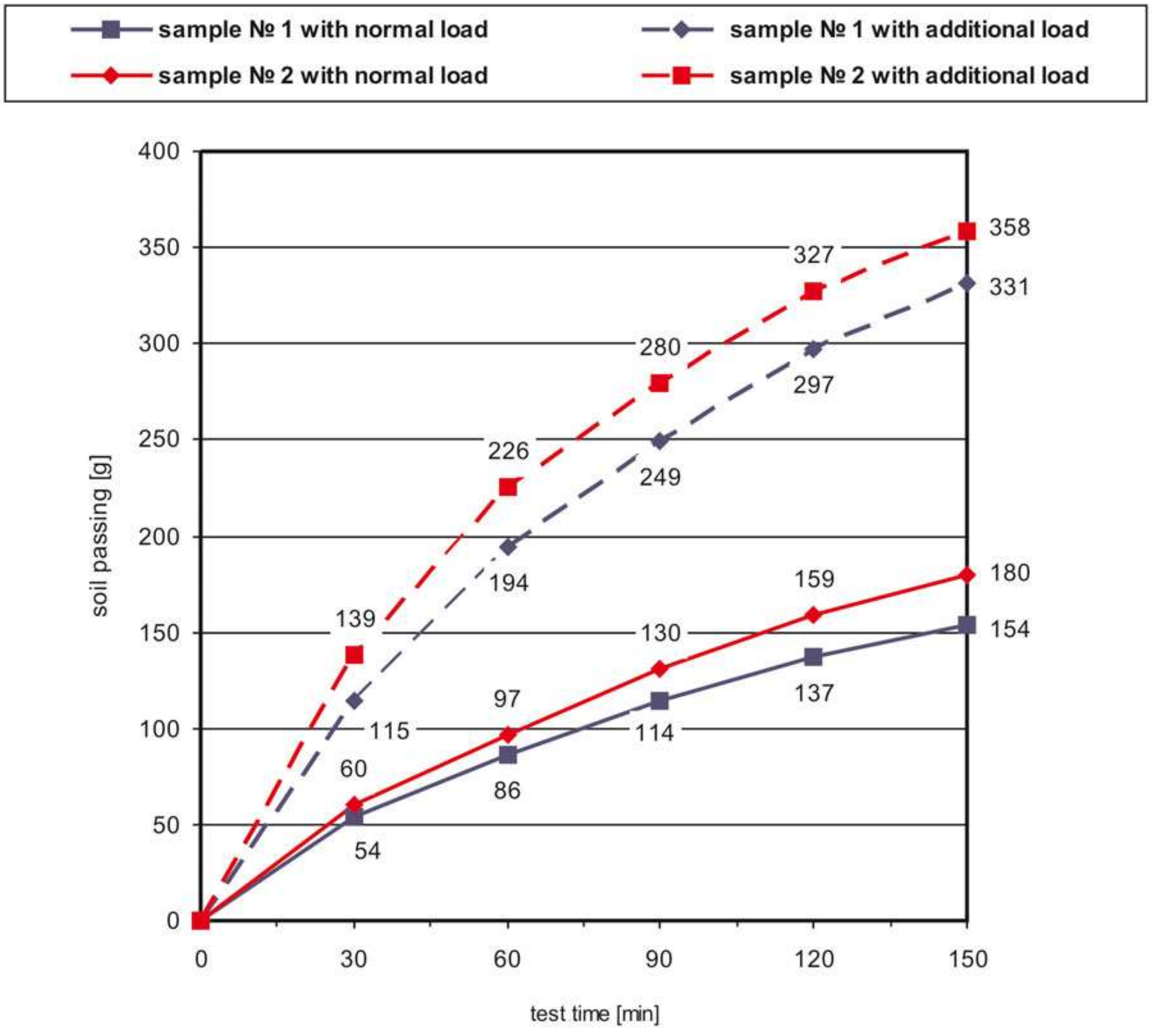

Figure 6. Soil passing diagram to show the influence of the load for the test soil ST4.

4. CONCLUSION

After the construction of the third runway it became apparent that the sea wall was loosing sand. This sand loss caused the failure of the sea wall. Two non woven geotextile products were used under turbulent water flow conditions as filters in the sea wall. The cause of the sand loss and a possible geotextile design error were fundamental issues in the indemnity proceeding of the construction company against the insurer. The geotextile selection was based on an old test method for unidirectional water flow.

A correlation concerning the soil passing rates under turbulent water flow conditions which where determined with standard soil type ST4 and the O90 values, EN ISO 12956, could not be found.
The turbulent water flow tests which were carried out with a test soil which particle size distribution corresponding to the local Botany bay sand shows low soil passing rates. But this assessment relates to the limited test time.
For safety-related construction projects like a sea wall for a runway it is recommend to carry out performance tests under turbulent water flow conditions with the local soil.

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