Geosynthetics - 7th ICG - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

Performance evalution of a BI-component geotextile in accelerated pavement test

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ABSTRACT: Finland has a wide network of low-volume roads, which suffers from frost heave and insufficient drainage. We researched in an accelerated pavement test the performance of a bi-component geotextile to detect, if it dries the pavement more efficiently than traditional solutions. A full-scale test structure was constructed with both traditional and bi-component geotextiles and loaded with the heavy vehicle simulator. Water contents and rutting on the asphalt surface was monitored during these loadings. The bi-component geotextile both accelerated drying after the lowering of water level and also kept the water content in a slightly lower (0.4 - 0.5 weight-%) level than in the reference area. Underneath the bi-component geotextile the water content remained higher than in the reference area. In spite of this, the permanent deformations (rutting) on the pavement surface were smaller in the bi-component geotextile area. So, the life-time of a structure incorporating the bi-component geotextile will increase and maintenance costs will correspondingly decrease.

1 INTRODUCTION

Low-volume roads are a notable part of the Finnish road network.. Finland is relatively large country with a small population. So, the share of public low-volume roads is high. Typical characteristics for low-volume roads are narrow shoulder areas as well as relative steep side slopes. Edge defects, frost heave and insufficient drainage are common reasons for deterioration.

VTT-Building and Traffic at the Technical Research Centre of Finland has carried out accelerated pavement tests on low-volume road structures in Otaniemi during summer and autumn 2001. VTT tested three different pavement structures in a waterproof basin. The tests were part of the 'Low-volume road research' -project, sponsored by the Finnish National Road Administration (Finnra) and carried out in co-operation with the University of Oulu. In one of the tests a new bi-component geotextile type was tested.

2 THE OBJECTIVES OF GEOTEXTILE RESEARCH

The aim of the HVS low-volume road research tests was to study the influence of the road cross section and edge effects to the structural strength of low-volume roads. The testing was carried out in order to verify laboratory test results in a full-scale environment. Furthermore, the objective was to determine suitable modelling parameters for a computer based design system for low-volume pavement structures.

The geotextile research was a separate part of this larger test. The tested material was a bi-component geotextile, and it is assumed that this kind of geotextile would dry the structure more efficiently. The main objective of the geotextiles research was to study its ability to prevent overwetting and capillary water rise. The heavy vehicle simulator (HVS) loading generated cumulative excess pore pressure in the subgrade clay layer by consolidation, which meant risk for higher plastic deformation. If the geotextile had the ability to conduct extra pore water away from the loaded area, plastic deformations would presumably stay at a lower level.

3 TESTED STRUCTURES AND INSTRUMENTATION

3.1 *Test structures and products*

The test structure was built up in a trough-shaped concrete basin. The walls of the concrete basin were thermally insulated and equipped with a groundwater table regulation. The total length of the basin was 36 m. Its depth was 2.5 m and width 4 m at the top and 3 m at the bottom. There is a 3 x 3 m part of the test basin, which in test section 3 is 4.5 m deep (Fig. 1).

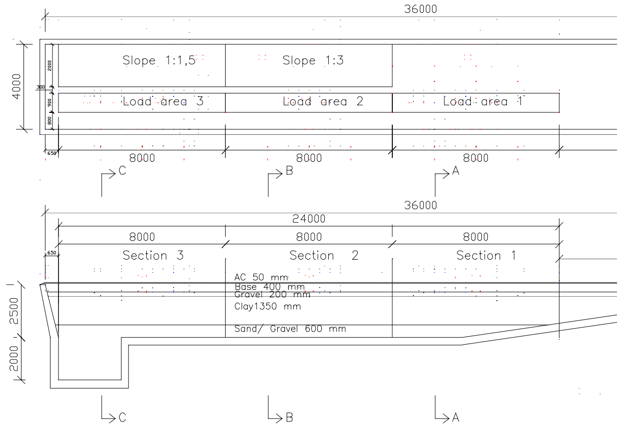

Figure 1. Plan and cross-section of Otaniemi test basin.

All the test sections consist of a thin asphalt surfacing of 50 mm, a 400 mm base layer of crushed rock and a 200 mm subbase layer of gravel. The gravel includes fine-grained particles, so the water capillary rise was evident. The cross-section of this pavement structure is illustrated in Figure 2.

3.2 *Instrumentation*

Instrumentation and measurements were mainly focused on deformations in pavement layers and slope as well as on moisture content in different layers. Pore and earth pressures, were measured. The instrumentation was similar in all sections.

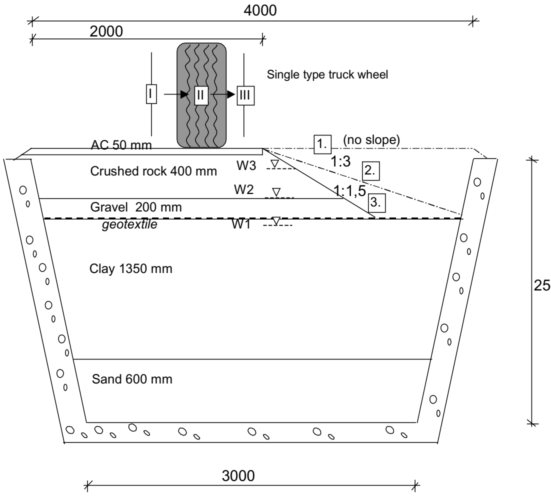

Figure 2. Cross section of low-volume road structures in Otaniemi test basin.

3.3 *The testing procedure*

Before the load testing, the groundwater level was elevated to the gravel surface (W2). The groundwater was kept at this level two weeks in order to monitor the capillarity and moisture content on the top of the clay and the gravel layer. During this period the moisture in the clay surface as well as in the gravel layer was measured with TDR- and radiometric probes. The hypothesis was, that the bi-component geotextile would better prevent capillary rise into the gravel than a traditional geotextile. The traditional geotextile was a non - woven polypropylene geotextile, which weight was about 150 g /m^2. After this, the water level was lowered to the upper part of the clay subgrade (W1) in order to research changes in moisture content of the gravel.

Test parameters and environmental conditions, including the water table regulation, were controlled during the HVS test. All sections were tested identically. At the beginning of test, the water table was 50 mm under the clay surface (W1). At the end of test the water table was elevated to the top of the gravel layer during the test (W2) and to the centre of crushed rock (W3). Static and cumulative pore pressures were monitored with transducers. The time schedule of wheel loads and different levels of water table is illustrated in the figure 3

The pavement response to the moving wheel load with several offsets was measured and finally the pavement performance was evaluated with accelerated testing. .

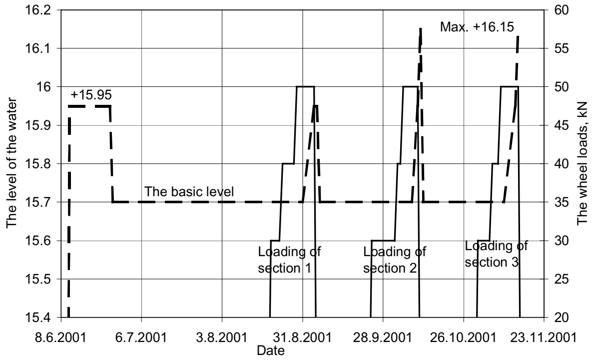

Figure 3. The changes in water levels and wheel loads during the test.

4 CONSTRUCTION OF HVS TEST STRUCTURES

The basin was split into three test sections (1, 2 and 3). Two different slopes were built and as a reference, one section was built without a slope. Side slope inclinations were 1:3 and 1:1,5. Soil materials and top layers were similar in the different sections. The length of each test section was eight meters. Two types of composite fabrics were placed on the top of the clay (Fig. 1). The bi-component geotextiles, which had a length of three meters, were installed at the outside end of test section 1 (without the slope) and 3 (with steeper slope). The traditional geotextile was installed between these bi-component geotextiles. A clay barrier was installed as a vertical hydraulic barrier in the joint area of the geotextiles in the subbase course. During the test the pass of the HVS wheel loaded identically each of the areas.

The test construction proceeded well and no mayor problems appeared. The installation of the bi-component geotextile did not differ from usual procedures. The most challenging part of the construction was the installation of the clay barrier to the gravel layer between the bi-componenent and traditional geotextile.

The grain size of the gravel was moderate and it contained also 4% fines (< 0.074 mm). Table 1 presents the measured densities of the gravel layer (both Troxler and water volumetric).

Table 1. The Troxler and water volumetric measurements of gravel layer.

Measured parameters	Water content, Troxler / water volumetric, w-%	unit weight of soil, Troxler / water volumetric, kN/m^3	unit weight of dry soil Troxler / water volumetric, kN/m^3
Section 1	7.70 / 9.07	21.56 / 21.27	20.02 / 19.49
Section 2	8.37 / 8.05	21.77 / 22.31	20.08 / 20.65
Section 3	7.27 / 7.83	21.53 / 21.22	20.07 / 19.69

5 THE TEST RESULTS

5.1 *Water content measurements with TDR - probes*

The volumetric water content of the soil was followed up with a Trime measurement system, which is based on the time domain reflectometry principle (TDR). The measurement points in the clay layer situated 200 mm under the bi-componenet geotextile, on the geotextile and 150 mm above it. In the reference area, probes rested on the geotextile and 150 mm above it. Totally we had 9 probes installed, five in section 1 and four in section 3.

TDR-probes were measured from eight to ten times during the whole test. The measurement was quite time-consuming, because it took at least 30 minutes to perform one. The test results were altered from volumetric water contents to water contents in weight percents. The results of TDR-measurements from the test section 1 are in given in Table 2.

Table 2. The water contents in weight percents from test section 1 measured with TDR-probes.

Water, w-%	Clay +15.55	On the geotextile +15.75	Gravel +15.90	Reference geotextile +15.75	Reference gravel +15.90
6.6.	28.43	10.69	8.51	9.03	8.79
25.6.	28.11	10.93	8.84	9.22	10.17
29.6.	28.68	10.46	8.75	8.89	9.93
21.9.	27.98	10.31	9.36	8.89	10.41
2.11.	27.47	10.65	9.93	9.41	10.22
7.11.	27.34	10.60	9.89	9.27	10.12

5.2 *The water content measurements with pore pressure heads*

There were two pore pressure cells in the clay layer in both test sections 1 and 3. One was situated under the bi-component geotextile and the other in the reference area beneath the traditional geotextile. Their heads were on the level +15.64 some 100 mm under the geotextile. The pressures were recorded once an hour. The figure 4 shows the test results. The pore pressure measurements in test section 3 in bi-component geotextile area looked more unsteady than the other pore pressure measurements.

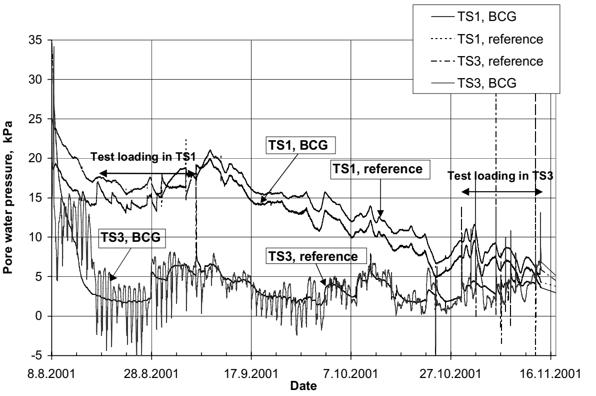

Figure 4. The pore pressure measurements from the clay layer TS = test section and BCG = bi-component geotextile.

5.3 *The water content measurements with radiometric probe*

There were four radiometric tubes, one in each test section and one in bi-component geotextile area of section 3. The radiometric measurements were performed two times: on the 25.6.2001 (water level W2 +15.95) and on the 29.6.2001, when the water level had been lowered to the level + 15.70 (W1). The measurement intervals were 100 mm. Figure 5 illustrates the results of these measurements.

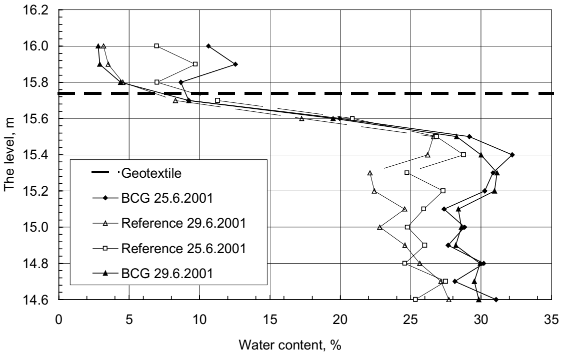

Figure 5. The radiometric measurements in test section 3. (BCG = bi-component geotextile)

5.4 *Rutting*

HVS-profilometer measurements were the method to monitor the deformations of the surface of the asphalt. Rutting was measured after 5 to over 500 passes. The number of passes depended on the stage of test and rutting depth. In each test section there were three measuring points. Point 1 in test section (TS) 1 and point 3 in TS 3 situated in the bi-component geotextile area and the others were reference points. Figure 6 illustrates the rutting in test section 1.

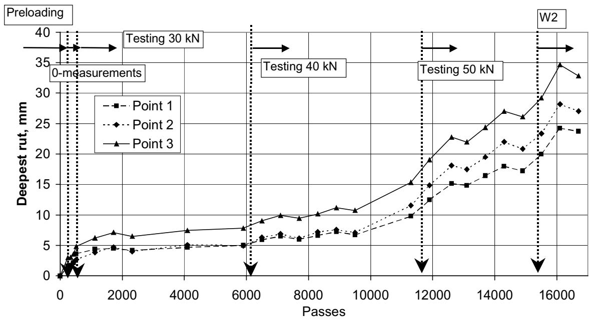

Figure 6. The profilometer measurements in test section 1.

6 DISCUSSION

6.1 *Water content*

The TDR measurements showed in average 0.5 w-% acceleration in drying in the BCG area in the upper part of the gravel layer when the water level has been lowered 250 mm in three days. Drying just on the geotextile surface was slightly slower in the BCG area than in reference area with about 0.1 w-%. In the average the upper part of the gravel in bi-component geotextile area was to some extent drier from 0.3 to 0.5 w-% (fig. 7) than in the reference area.

The pore pressure measurements during test loading from test section 1 are shown more detailed in figure 8. The pore pressure reacted clearly to the loadings especially in test section 3. In test section 1 the pore pressure in bi-component area reacted more sensitively to the loadings than in reference area.

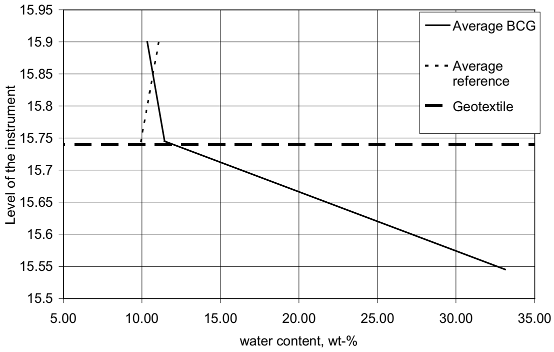

Figure 7. The average TDR-measurements in test section 1.

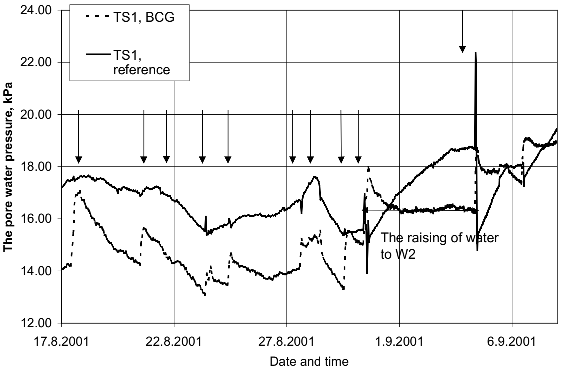

Figure 8. The pore pressure measurements in test section 1 under loading time. Black arrows show the loading impulses.

Changes in water level had little effect to the pore pressure in the bi-component geotextile area and slightly more in the reference area (fig.9). Only after the loading impulse the pore pressure began to rise. This can be due to both the drying effect of the BCG and also a moisture retention effect, as the water level had not risen as quickly in the BCG area as in the reference area.

According to the radiometric measurements the bi-component geotextile speeded up drying in the layer on the upper side of the geotextile (figure 9) with about 3.0 w-%. This figure illustrates the difference between the two measurements made in reference area and in BCG-area after the water level had been lowered 250 mm three days earlier. Under the geotextile the situation was opposite and drying was in fact little slower in BCG-area than in reference area (in average 1.4 w-%).

The radiometric method gave clearly lower water contents to each layer than the TDR-method. The moisture contents of different measurements are compared in table 3. In the gravel layer the water content differed about 6 w-% and in the clay layer 8 w-% depending on the definition method. Radiometric borehole method of these two methods is a more reliable method to measure the water content. Yet, the TDR method shows the differences quite reliably.

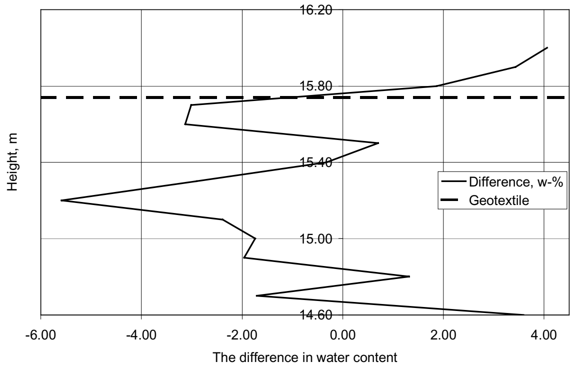

Figure 9. The difference of water content between BCG-area and reference area (w-%) after 250 mm lowering of water level.

Table 3. The average moisture content of BCG / reference structures in different layers in test section 1 and 3, when water level is +15.70 (W1).

Water, w-%	TDR	Radio-metric	Reference TDR	Reference radiometric
Crushed rock	-	2.8	-	3.2
Gravel	9.73	3.65	10.26	4.03
The surface of geotextile	10.29	9.24	9.11	8.29
Clay	31.64	23.87	-	21.94

6.2 *Rutting*

Rutting on test section 1's point 1 (bi-component geotextile area) has been smaller than on the other points (fig. 6). On the contrary rutting on test section 3's point 3 (bi-component geotextile area) has been larger than on the other points. The main reason for this larger rutting in test section 3's point 3 is the fact that it situated on the deepest part of the basin (figure 1). Hence, it is not dealt more in this study.

Part of this difference in test section 1 was due to the fact that test basin had a slope in BCG area and the pavement there is thinner than in other points. It can be roughly estimated that total rutting would be about 13 % bigger in point 1, if the pavements had equal thicknesses. This estimation bases on the assumption that stress distribution and displacements are nearly linear in the depth of 2.2 meters to 2.6 metres. Even after this addition the BCG area is rutting a bit slower than reference area. Emu-Coil measurements showed that more than 70% of permanent displacements took place in crushed rock and asphalt layers together. Figure 10 illustrates the relative (equal thicknesses) rutting with different water contents in gravel layer.

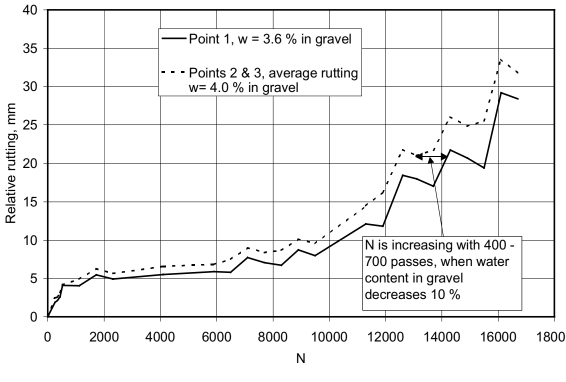

Figure 10. The relative rutting vs. passes with different water contents.

On the base of figure 10 it is possible to say, that rutting reduced in the bi-component geotextile area with about 400 - 700 passes. These passes can be changed to the expanding of life-time of the structure, while the daily traffic is known. This expading concerns this particular structure and can not be generalized.

7 CONCLUSIONS

The test results of this full-scale test indicate the following:

- The construction work with bi-component geotextile did not differ from the construction with traditional geotextile.
- The water content in the layers, which lay over the bi-component geotextile, was from 0.4 to 0.5 w-% lower than in reference area with traditional geotextile.
- The water content in the layers, which lay over the bi-component geotextile, decreased after lowering of water level more quickly (from 0.5 to 3.0 w-%) than in the reference area.
- The water contents just on the bi-component geotextile and underneath it were slightly higher (in average 1.4 w-%) than in the reference area.
- The pore pressures in bi-component geotextile area reacted more sensitively to the loading impulses.
- Rutting on the bi-component geotextile area was to some extent slower than in the reference area.

We started this research project with the basic assumption that the bi-component geotextile performs a capillary barrier between subgrade and pavement. The other assumption was that the bi-component geotextile would prevent overwetting. The test results exhibit that both test assumptions are true concerning the layers above the geotextile. Yet, this drying effect is slight, but noticeable. The capillary barrier both accelerated drying after the water level was lowered and it also kept the water content in a slightly lower level than in the reference area.

On the other hand the water content under the bi-component geotextile was higher than in the reference area. Even though there were both drying and wetting, the rutting of the asphalt reduced and the life-time of the road structure expanded. Permanent deformations (rutting) occured mainly in the upper part of a pavement. So an efficient way to prohibit these is to keep the water content of subbase and base course low.

The laboratory studies of Henry & Holtz (2001) showed that bi-component geotextiles reduced frost heave. Together the frost heave reduction and the lower water content are likely to lenghten the life-time of a low-volume road structure even more efficiently than our test indicates. Although our study concerns only road structures, it is presumable, that this kind of behaviour can be detected in other structures like greens of golf courses, sportfields etc.

The rutting and water content results are not all unambiguous and straightforward. The greatest need for further research is to study the effect of both frost heave and lower water content to the life-time and deterioration of a road or some other structure.

8 ACKNOWLEDGEMENTS

We gratefully acknowledge the Polyfelt GmbH for financial support of this research project especially for manufactoring of the special bi-component geotextile used in this application. We also acknowledge the Finnish National Road Administaration (Finnra) for the sponsoring of the whole of the Low-volume road research project.

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