Performance of Geotextiles in Railroad Laboratory Testing

T. Eichenauer
Polyfelt Ges.m.b.H, Linz, Austria

C. Gobel & K. Lieberenz
University of Dresden, Germany

ABSTRACT: The main functions of geotextiles in a railroad subbase are separation and filtration, but in addition also drainage and reinforcement can be of relevance. In order to quantify the influence of geotextile layers, fatigue loading tests were carried out at the University of Dresden / Germany.

In a big test box (1,4 x 1,1 x 1,0 m) a multilayer system of rubber plate, subgrade, geotextile, sand, ballast stone bed and sleeper was built in, and a cyclic load of maximum 76 kN was applied on top. This device enables almost realistic conditions in a scale of 1:1. The amount of 5 mio. load cycles between 7 and 12 Hz, which simulates 160 km/h speed, corresponds to the annual load of a heavily trafficked railroad track.

As a result the surprisingly high increasing of the Ev2 parameter (= soil stiffness) with time was obtained. Also the strong reduction of settlement showed the positive influence of geotextiles. In summary it is to say, that geotextiles used at fine grained subsoils lead to a strong improvement of the whole railroad system.

1 INTRODUCTION

Worldwide old railroad tracks are improved to higher speeds and new tracks are built over soft subsoils. Decisive for those projects is the long term bearing capacity and further the limited and balanced settlement of the track.

In order for cost-conscious realization geotextiles are used since more than 20 years under railroad subbases. Separation, filtration, drainage and reinforcement are the main functions which geotextiles have to fullfill permanently, so a carefully design of their mechanical and hydraulic properties is essential.

To quantify the long-term improvement of the railway subbase through the use of geotextiles fatique loading tests on a scale of 1:1 were carried out in the laboratories of the University of Dresden.

2 TEST CONFIGURATION

In a test box with the dimensions 1,1 x 1,4 x 1,0 m (Fig. 1) a multilayer system as normally used in a german railroad subbase was established in original size. First a 6 cm rubber plate was laid on the stone floor, and together with a 12 cm layer of fine and highly frost susceptible soil, load bearing values between 10,9 and 17,5 MN/m² (Ev2) of the natural soil could be realized.

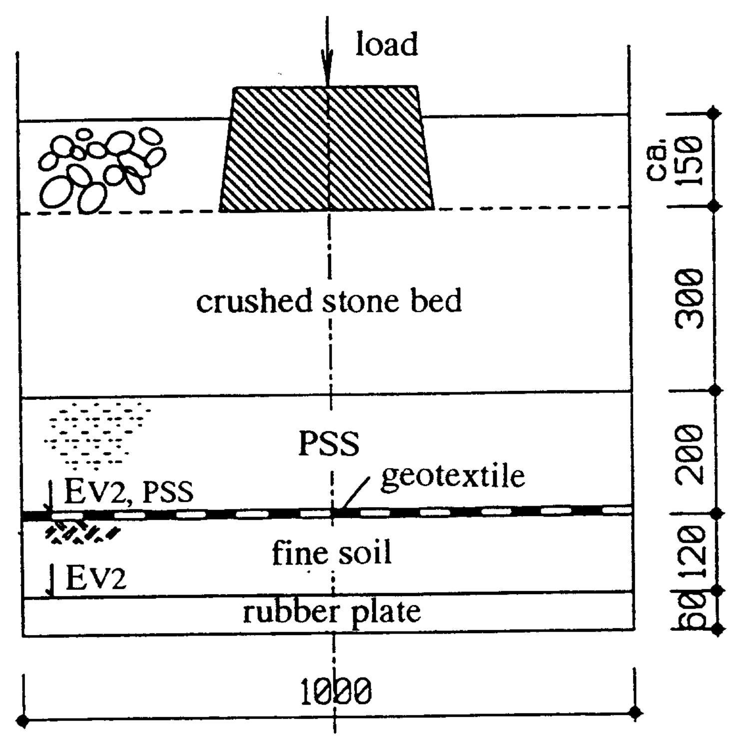


Fig.1: Test device

Over the fine soil different kinds of geotextiles and a 20 cm sand-gravel mixture were placed. On top of this so-called subgrade protection layer (PSS) the bearing capacity was measured at the beginning and at the end of the tests. Each result (Tab. 1) was then compared with the original bearing capacity of the natural subsoil (Fig. 2, 3).

On top of the PSS 30 cm of crushed stone bed with an embedded sleeper were installed. The load transfer into the whole system then was realized with a hydraulic test cylinder on a S 49 rail and a BS 66 sleeper into the stone bed. To prevent friction forces, moveable spacers were placed between horizontal U-steel-frames which itself built the test box.

TECHNICAL DATA:

- Testbox: Area 1,40 x 1,10 m, height 1,0 m. Built from 10 cm high U-steel-frames with elastic spacers.

- Hydraulic cylinder: Max. static load 48 kN, max. 76 kN at the 5 mio. load cycles. Medium frequency 10 Hz.

- Load transfer: Over a prestressed concrete sleeper BS 66 with a S 49 rail.

- Stone bed: 30 cm of common crushed stone. Grain size between 35 and 56 mm, compacted to a density of 1,48 g/cm³.

- Subgrade protection layer (PSS): 20 cm sand-gravel with a uniformity coefficient of 6, compacted to a density of 100 % Proctor (1,84 g/cm³). Classification SW (DIN 18196), optimal water content 9 %.

- Geotextiles:
  - ° Needled staplefibre nonwoven — Stf
  - ° Needled endlessfibre nonwoven — Ef
  - ° Woven — W
  - ° Geogrid — Gg
  - ° Composite (stitchbonded Ef) — C

- Subbase: 12 cm of extremly frostsusceptible fine material. Classification TL (DIN 18196), Proctor density 1,80 g/cm³, optimal water content 16,5 %, Ip = 12,7 %, installed load bearing capacity (Ev2 over subbase and rubber plate, according to the plate loading test in DIN 18134) 10,9 - 17,5 MN/m².

- Rubber plate: Thickness 6 cm.

3 TEST REALIZATION

In different test series (Göbel et al, 1993; 1994) different kinds of geotextiles (Tab.1) have been installed over the subsoil. The test results were compared to the test device without geotextile. The used load of about 5 mio. cycles with 10 Hz and a maximum of 76 kN corresponds to 48.063 trains with a speed of 160 km/h and a maximum wheelload of 125 kN or to a one year heavily trafficked (133 trains / day) track.

Test	Geotextile	Soil	Inst./Excav.
		(MN/m²)	(MN/m²)
0	without geotextile	13,4	20,9
			26,9
1	staplefibre needlepunched	17,5	17,1
	450 g/m²		37,4
2	woven, 20 x 20 mm	16,2	22,4
	strip tensile 80 kN/m		35,6
3	geogrid, 28 x 40 mm	12,1	18,9
	strip tensile 31,5 kN/m		34,9
4	endlessfibre needlep., 350 g/m²	13,7	22,7
	strip tensile 21 kN/m		35,8
5	stitchbonded endlessf. needlep.	10,9	19,3
	strip tensile 75/25 kN/m		39,7

Tab.1: Different test devices; bearing capacity Ev2

The load bearing capacities at different levels were measured at the beginning, during and at the end of the test and have been used for the evaluation of the system. Also the settlement, the changing of the subsoil-watercontent and the changes in geotextile parameters were investigated.

4 RESULTS

Fig. 2 and 3 show the results of the load bearing measurements on top of the subgrade protection layer. At the installation only the systems with the 350 g/m² endlessfibre needlepunched nonwoven (test 4) and the geocomposite (test 5) are leading to an instant increase of the bearing capacity, if compared to the test without geotextile (test 0).

The staplefibre nonwoven (test 1) showed, probably due to its compressability and the low strip tensile strength (especially at low elongations) significantly poorer behaviour with load bearing capacity values even under the test without geotextile.

The high strength products (test 2, 3) have been in the same or slightly lower region compared to the basic test 0.

B........basic test
Stf......staplefibre nonwoven
W...... woven
Gg..... geogrid
Ef...... endlessfibre nonwoven
C........geocomposit

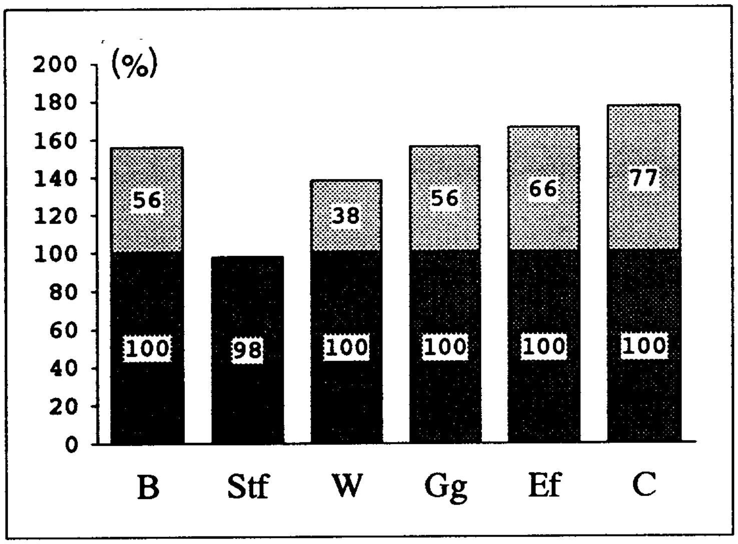


Fig. 2: Relative increase of the PSS bearing capacity at installation, compared to the subsoil (= 100 %)

Even more important are the results after the 5 mio. cycles. It is obvious, that all used geotextiles led to an improved railway subbase system (Fig. 2). The staplefibre product with +114 % and the woven with +120 % only have been slightly better than the test without geotextile (+101 %), but the geogrid and the needled endlessfibre showed with +188 / +162 % significantly higher load bearing capacities. The geocomposite, made of a needled endlessfibre nonwoven reinforced by stitchbonding bi-axial yarns, led even to an increase of +265 %. This is more than 2,5! times higher than the results without geotextile.

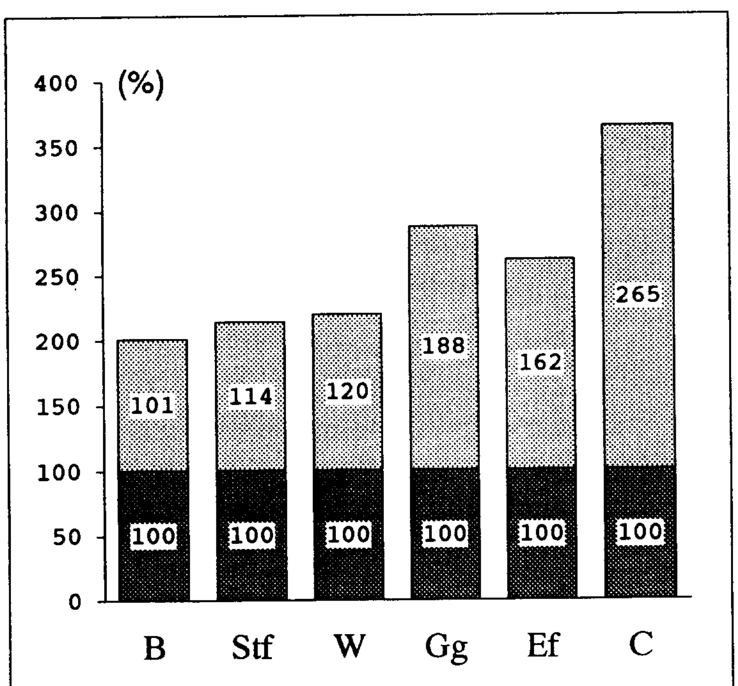


Fig. 3: Relative increase of the PSS bearing capacity at excavation, compared to the subsoil (= 100 %)

These results showed that:

- highstrength geotextiles (grids and wovens) with the main function reinforcement showed nearly the same improvements of the bearing capacity as needled endlessfibre nonwovens with the main functions separation, filtration and drainage. So, for the design they can be seen as equivalent.
- there is a significant difference between staplefibre and endlessfibre nonwovens. The used staple fibre products show due to their compressability and due to their very low strip tensile strength at low elongations only little improvement of the bearing capacity.
- geocomposits made from endlessfibre nonwovens, stitchbonded with bi-axial yarns, which fullfill all 4 main functions as separation, filtration, drainage and reinforcement, showed far the best improvement of the system.

The settlements were measured without geotextile, with the endlessfibre, the composit and a grid (test 0, 4, 5, 3a). The endlessfibre and the composite system showed both 25 mm settlement over the PSS. This is a factor of 2,4 less settlement than without a geotextile (60 mm, Fig. 4). Measured directly on the sleeper, this factor increased even to 3,75! (24 mm compared to 90 mm, Fig. 4). For the highstrength grid, also a factor of 1,4 (43 mm compared to 60 mm, over the PSS) was obtained.

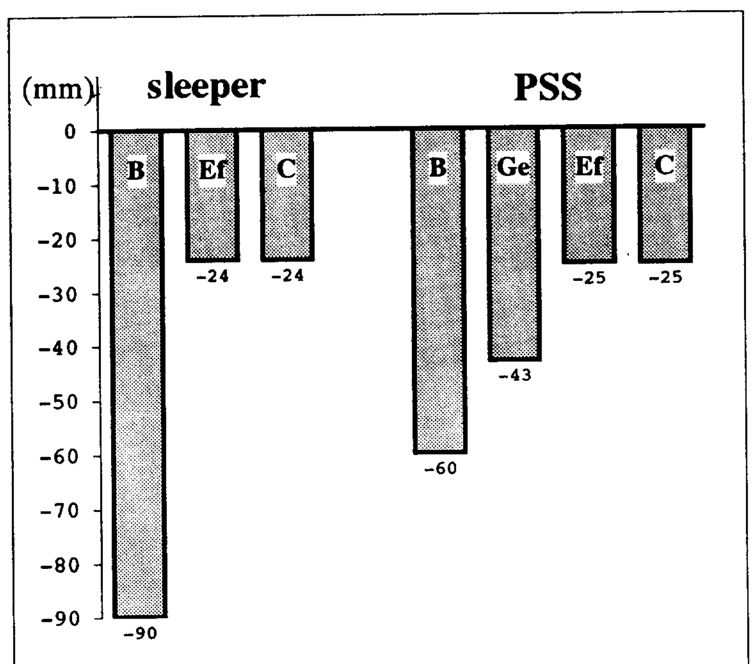


Fig. 4: Settlement over the PSS and the sleeper

The watercontent of the subsoil in test 4 and 5 changed to 15,9 / 15,6 %. This is less than the 17,3 % of the system without geotextile and shows the good drainage function of the needled nonwovens.

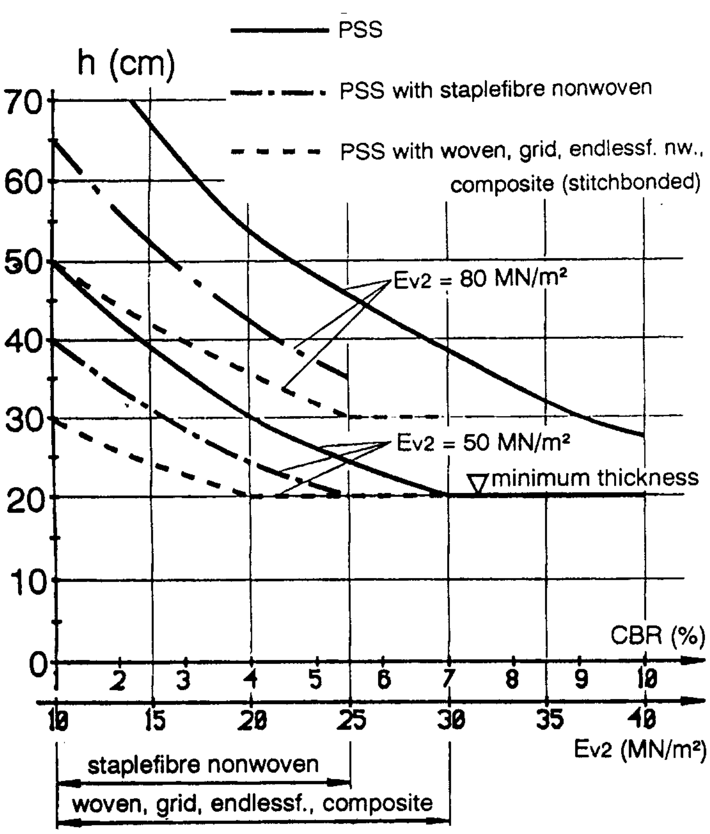
5 DESIGN PROPOSAL

The advantages of geotextiles with respect to the subsoil bearing capacity might result in a reduction of the necessary thickness of the PSS. With regard to the latest test results the design proposal after Lieberenz et. al., 1993 was slightly modified. Following factors were used:

- PSS with needled staplefibre nonwoven: 1,15....1,35
- PSS with needled endlessfibre nonwoven, woven or grid: 1,50....2,00
- PSS with geocomposite (endlessfibre nonwoven stitchbonded with yarns): 2,00

These numbers are equivalent to the improvement of the railroad subbase through the used geotextile. They are valid mainly for weak soils between 10 and 30 MN/m² (Ev2). The design chart for the basic PSS-thickness is according to German DS 836, EzVE 6 (after Lieberenz et al, 1993).

The improving effect of endlessfibre needlepunched nonwovens is essentially higher than with staplefibre nonwovens. Also the geocomposits showed much higher values than wovens or grids, but for a clear design differentiation the results has to be confirmed by full scale site tests.



*) The geocomposits showed significant higher improvements than wovens or grids, but this has to be confirmed by full scale site tests

Fig. 5: Necessary thickness h of the PSS (mod. after Lieberenz et.al.,1993)

6 SUMMARY

From the test results following conclusions can be made:

- after a certain stabilization process all used geotextiles led to improved systems.
- the relative increase of the bearing capacity of the tested geotextiles differ very much between installation and excavation.
- staplefibre nonwovens showed at installation even worse behaviour than the case without geotextile.
- endlessfibre nonwovens are in the same range as wovens and grids, so there is a clear differentiation to staple fibre products (installation and excavation).
- the composite made from endlessfibre nonwoven, stitchbonded with bi-axial yarns showed significant better test results than all other geotextiles. Obviously the summary of all 4 geotextile main functions (separation, filtration, drainage and reinforcement) led to this good result.
- the watercontent of the subsoil decreased more under use of needled nonwovens and composits compared to wovens and grids.

7 REFERENCES

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