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THE USE OF GEOTEXTILES IN ROAD CONSTRUCTIONS UNDER INTENSIVE DYNAMIC LOADING

EINSATZ VON GEOTEXTILIEN IM VERKEHRSWEGEBAU BEI INTENSIVER DYNAMISCHER BEANSPRUCHUNG

EMPLOI DE GEOTEXTILE EN CONSTRUCTION DE VOIE A LA CHARGE DYNAMIQUE DE GRANDE INTENSITE

Geotextiles are used in road constructions as separation and filter layers between base courses and soft ground. A research programme inquires the properties of different geotextiles at unpaved or only weakly fixed surfaces with limited thickness by intensive dynamic loading (e. g. builders' road). The researches are done in fullscale (1:1), both in construction traffic and with a special constructed test machine.

The results of the inquiries up to now reveal very different properties of the types and brands of geotextiles. The dividing and filter effect by dynamic loading cannot be judged by systematic rules, but depends on the type of the geotextile, the condition of the subsoil and the construction of the surface.

Geotextilien werden im Verkehrswegebau unter anderem als Trenn- und Filterlage zwischen Tragschichten und weichem Untergrund eingesetzt. Im Rahmen eines Forschungsprogrammes wird das Verhalten verschiedener Geotextilien (Vliese, Gewebe, Verbundstoffe) bei nicht oder nur schwach befestigten, in der Höhe begrenzten Oberbauten unter intensiver dynamischer Beanspruchung (z.B. Baustraßen) untersucht. Die Untersuchungen erfolgen großmaßstäblich (M=1:1) sowohl im praktischen Baustellenverkehr, als auch in einem eigens konstruierten Versuchsstand.

Aus den bisherigen Untersuchungen ergeben sich wesentliche Unterschiede im Verhalten der Geotextiltypen und -fabrikate. Die Filter- und Trennwirkung bei dynamischer Belastung kann nicht nach schematischen Regeln beurteilt werden, sondern hängt vom Geotextiltyp, der Beschaffenheit des Untergrundes und der Konstruktion des Oberbaues (insbesondere der Dicke) ab.

1. Introduction

For several years geotextiles have been successfully used in road constructions. The spectrum of practical use extends from temporary transportation routes or simpler and cheaper kind of production (e.g. builder's roads), over permanent roads with fixed superstructure (concrete, asphalt) to permanent used ways on a coarse gravel bed with particular demands for the upkeep of the railway trackage. In this connection, the way how nonwovens, wovens and composite fabrics work in a dividing and filtering layer among surface and soft subsoil at permanent use in road traffic and at limited strength of the superstructure is of special interest and also the centre of our attention. The reinforcing effect will be observed as a phenomenon within the scope of the complex course of events, however, it will be quantitatively assigned to a basic research of the reinforced two-layer-system which is carried out at the "Lehrstuhl und Pruefamt fuer Grundbau, Bodenmechanik und Felsmechanik" of the Technical University of Munic at the same time.

The filter dimensioning, which is based on experience with static loading, or "dynamic" stress at the hydraulic engineering, cannot give an answer to this problem. That's why a seperate research programme surveys the modes of action of different geotextiles at different kinds of superstructures and at different subsoil conditions. The carrying out takes place by full scale test (M = 1:1) in reality and not by small-scale test in laboratories . Up to now, the tests are limited to unpaved roads and ways (builders' roads, unfixed frost blankets and unfixed base courses). A partly breakdown of particular types of geotextiles, which are used as dividing layers at reduced strengths of the surface, is expected, because of the intensive dynamic stress, which is caused by the common construction of traffic areas, especially during the phase of placement by rolling and mixing action and the effect of pumping.

A large-scale project site, where soil material of approximately 7 million m3 will be replaced with the help of builders' roads, presented itself for the execution of this task. The "Pruefamt" controls the exchange of soil and has at its disposal a completely equipped laboratory at the project site. The available kinds of soil (rock flour, gravel etc.) and the conditions of construction operations (e.g. large equipment pool with different loading vehicles) present a good prerequisite of exact parameter studies at test-routes. By means of the used builders' roads, the conditions and effects of traffic in reality can be studied and compared with the results at the test areas.

2. Procedure

During the execution of the research work , two test-series were done at the same time:
- Field test under the conditions at a project site
- Field test under a roof with a special constructed mobile loading device

At the field tests parts of the builders' roads are equipped with different geotextiles and then permanentely controlled. In several sections instruments for measurement of ground vibration and earth pressure are installed. All existing routes can be examined as a whole and opened at interesting parts because almost any of the builders' roads were equipped with textiles. First the registration of all external influences, such as weather, loading, amount of passes etc., is important for all tests. Several of these parameters can only be registered qualitatively at the used builders' roads.

Because of this, a loading device was constructed, which simulates the construction traffic. Tests were made with the help of this machine, which is installed under a roof, where the boundary conditions could be well controlled.

The homogenization of the materials which are to be built-in, could be done with great care. Likewise the amount of passes, the position of the wheelers and the affecting loadings are exactly known.

Up to now the influencing parameters have been varied as follows:
- material of the surface
- thickness and compaction of the surface
- geotextile
- condition of the subsoil

3. Loading Devices

At the project site dump truck (loaded: 60t; unloaded 30t; wheel load: 3 - 10t), dumpers (loaded: 30t; unloaded 25t; wheel load: 2 - 9t), and various trucks were used as hauling equipment and thus served as loading devices on the field test's sections. They cause a large rolling and mixing action and cyclic loading of the "surface/geotextile/subsoil"-system. Vibratory plate compactors and vibratory rollers (10t) were used which stressed the roads in a vibratory way, for the placement of the surface on the builders' roads.

The loading device of the test-section under the roof is a guiding and pulling construction with a continuous adjustment to different levels, onto which a ballast frame with a travelling gear below for the permanent moving of the machine is fixed. Dual wheels are used as travelling gear (d = 95cm; b = 2x15cm; tyre pressure = 6 - 9bar). Their axle is mounted on laminated springs. Also constructions as single wheels with different sizes were used. A loading up to 8t is possible. The previous tests were mostly done with 3t of loading.

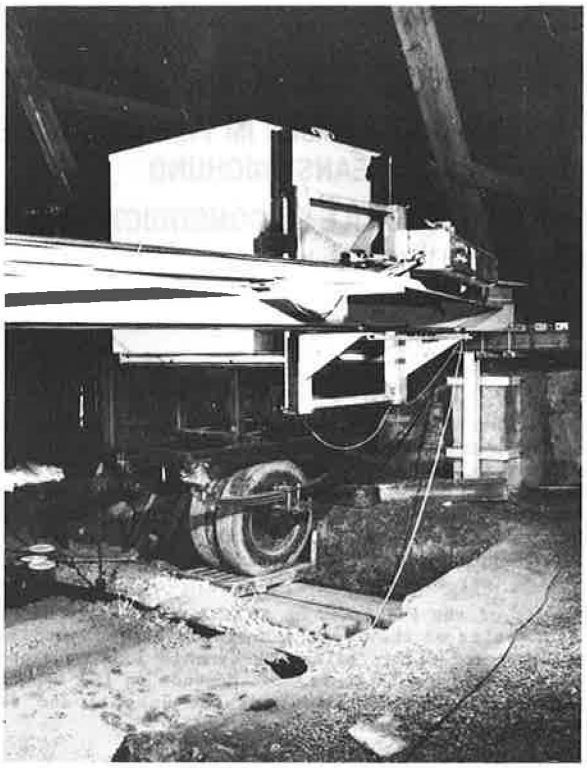

Fig. 1: Loading device; horizontal and vertical guide

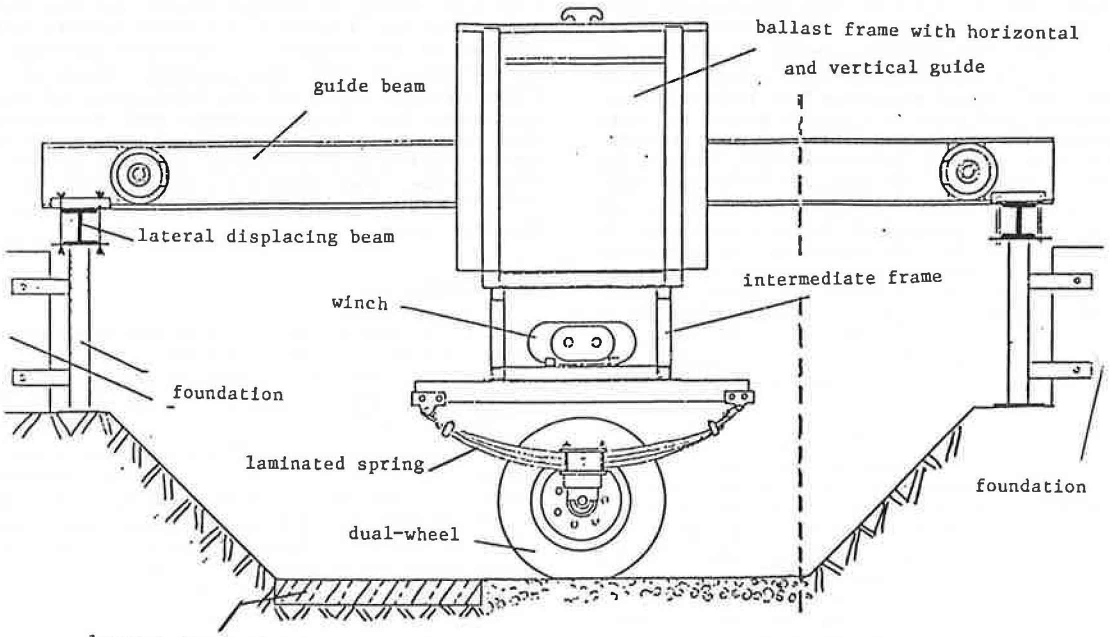

Fig. 2: Draft of the loading device

4. Description of the Test Field in a Hall and the Used Natural Materials

The test field is an area of $8x8m^2$ in a hall. There, the existing soil was excavated to a depth of 2m and replaced by the testing soil. The testing soil is a kind of clayey silt (geological called "Loess") of the group TL (DIN 18196) with known characteristic values as follows:

- liquid limit w_l = 30%
- plastic limit w_p = 20%
- plasticity index I_p = 10
- proctor density ϱ_{pr} = $1.9t/m^3$ at w_{pr} = 13.5%
- density of solid particles = $2.73t/m^3$

Placement water content and density are varied.

Round grained and crushed aggregates are used for the surface´s materials and built-in in different thickness. This round grained material is sandy gravel of old river deposits, which are without any cohesion.

Dolomitic coarse gravel is used as crushed aggregates with the nominal size of 0 - 45mm (mineral concrete).

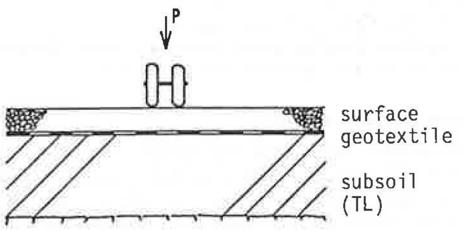

Fig. 3: Schematic test structure

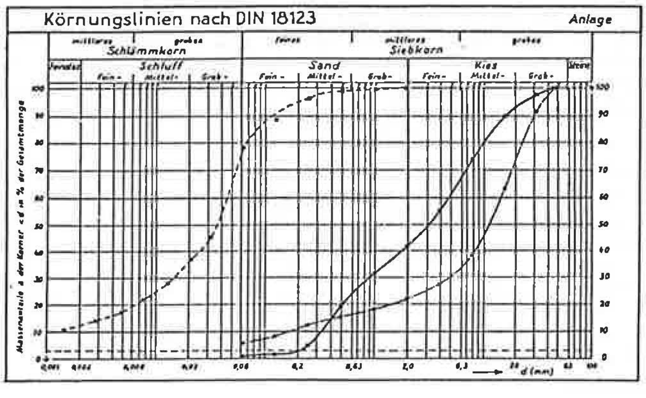

Fig. 4: Grain size distribution of the used natural materials (left to right: "Loess",dolomite, gravel)

5. Used Geotextiles

Geotextiles of different producers were used in a great variety of types for the tests. It was tried to do justice to the fibre raw materials as well, as to the diverse manufacturing methods at the selection of material. The nonwoven needle punched geotextiles produced of the fibre raw material PP and PES were used in a weight of 140 to 600 g/m^2, the thermic bonded geotextiles made of PP and PE in a weight of 100 to 280 g/m^2. Wovens of PP-ribbons and splicing threads of the weight of 95 to $335g/m^2$ were examined. Further composite fabrics resulting of a combination of woven fabrics/grids and nonwoven geotextiles were used.

Fig. 5: List of test series

subsoil, consistency		gravel		dolomite				surface
		40	80	20	30	40	50	thickness (cm)
Löß	pasty	-	1	-	1	-	1	no geotextile
		-	4	-	3	-	5	needle punched
		-	1	-	3	-	2	termic bonded
		-	2	-	2	-	4	wovens
		-	-	-	-	-	2	composite
	stiff	1	-	2	-	1	-	no geotextile
		2	-	3	-	1	-	needle punched
		-	-	3	-	1	1	termic bonded
		-	-	3	-	1	2	wovens
		-	-	1	-	-	-	composite

(Tested kinds of geotextiles: needle punched nonwovens, termic bonded nonwovens, wovens, composite fabrics)

6. Testing Procedure

The requested placement condition of the subsoil in each test (consistencies, lasting from pasty to stiff) will be controlled for its uniformity by compaction- and water-content measuring and by measuring with a vane apparatus, before loading. Further the customary field test are carried out (e. g. plate loading tests, static soundings and CBR-tests).

The filling thickness of the surface is coordinated with the used geotextiles and the consistency of the subsoil. The condition of the placement is controlled with a nuclear density-meter and by plate loading tests. Placement level and relative changes are layed down by leveling in such tests, where deformometers are not suitable because of too high deformations. With the help of cross-sections in each field, relating to the condition of placement, the changes at the geotextiles and at the top of the subsoil could be found out and measured. This matter goes for the removal after finishing the test and also for the partial removal at interruptions of the experiments. But the latter one is limited to a few and sporadic actions, because of its inevitable disturbances for the further testing procedure.

During the test the required tensile force of the vehicle (rolling resistance between tyre and road surface) is ascertained by a measuring cell. Arising earth pressures are measured so far as possible by soil pressure cells at different levels in the test construction. Geometric changes of the development of the wheelers are in addition to the levelings measured by the Benkelman beam (fig. 6). After excavation the plastic deformations are documented by the measuring of a raster (10cm), which was drawn on the geotextiles before it was tested. The continuous observation of the course of the elastic and plastic deformations of the geotextiles by the help of elctric strain gauge is only possible, if the product is less extensible, that means if deformations are remaining at a measurable range. Such test constructions are to be used intensively at the parts of the programme lying ahead.

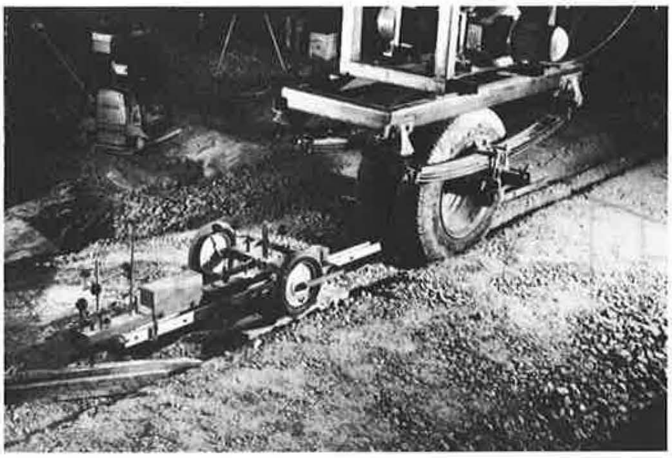

Fig. 6: Observation of the deformation (elastic and plastic) with the help of a Benkelman beam.

The number of the possible passes depends on the testing procedure, the appearing deformations and the conditions of the geotextiles. After the test soil samples are taken from the surface, exactly above the geotextile, they are examined in a laboratory. Besides plate loading tests are made on the base course, but this is only possible at a small depth of the tracking.

After finishing the test, loaded and unloaded areas are distinguished at geotextiles laid open. Representative geotextile samples are examined in the laboratory for changes of the effective opening size, the permeability, the intake of soil material, and the tension-strain characteristics respectively the resulting destructions. The tests are accompanied with microscopic photographs.

The subsoil is examined, regarding to the water content and the changes of density. Further vane apparatus-, soil penetrometer-, plate loading- and CBR-tests are carried out. In the laboratory the grain-size distribution of the surface material is determined after the test. Accumulation of fine particles exactly above the geotextiles, and water content determinations of the surface material should show the changes in the track. The water contents of the subsoil are ascertained by taking of soil samples beneath the geotextile.

7. So Far Received Results

Because of the actual intermediate stage of this research programme, it can only be reported about some test results of the roofed test field. In the following the reports only refer to the surface material of mineral concrete (0 - 45 mm) out of crushed dolomitic material, because this was mostly used.

The tests are distinguished into groups, as follows:
a) stiff subsoil, 20 cm surface
b) stiff subsoil, 40 cm surface
c) pasty subsoil, 30 cm surface
d) pasty subsoil, 50 cm surface
(In each case variation of the geotextiles with an additional course without any fabrics)

a) Stiff Subsoil, 20 cm Surface

The tests carried out are to be interpreted in reference to the condition of placement. Also the limits of minimizing the surface thickness should be searched.

Observation during the passes

A large elastic vertical deformation is noticed in the track, partly it decreases until 1.5 m behind the wheel. A quantitative analysis is carried out with the help of video technique.

Mechanical stress

The resistance to mechanical stress is decisive for the mode of action of a geotextile. Some geotextiles endured only a few passes, before they partly are torn along their entire length. This especially happened to light thermic and mechanical bonded nonwovens and to a light composite fabric with a nearly uneffective tensile reinforcement. Of course, in such cases the geotextile has no longer a dividing function. The resulting effect was a great mixing of the subsoil and the surface - soon after a few passes the track is useless.
After the removal some geotextiles were partly perforated in the wheelers. This was especially noticed at medium thermic bonded nonwovens and at light wovens. At the wovens it was remarkable that the holes were created sometimes by displacing of the threads, but sometimes also by tearing of the warp and the woof.
At the thermic bonded nonwovens a large abrasion of the upper layers of the geotextile turned out.

Deformation of the subsoil

It is remarkable that low thickness of the surface of the angular material causes more or less deep trackings after a small amount of passes (fig. 7). These trackings mostly result from the deformation of the subsoil (= deepening into the track and raising of two bulges at both sides). The depth of the wheelers in the subsoil and the steepness of the slopes depend on the used geotextile. For example: Wovens have a more gentle gradient section of the slopes than nonwovens. Before taking up of stress, especially lighter non woven needle-punched and termic bonded nonwovens causes great strain and deep tracks with steep sides. Fig. 8 and 9 show the course of the trackings in the surface (dual tyres) and the formation of the wheelers in the subsoil with a heavy nonwoven, needle punched geotextile (see fig. 10, too).

Deformations of the geotextiles

Plastic deformations were noticed i.e. after 200 passes at heavy nonwoven needle punched geotextiles (10 - 15%), at one product up to 40%.
The depressions in the middle of the track are in the surface and the subsoil in the same order. After the digging out the geotextiles show - as far as they were not destroyed - in many cases retrogressive elastic spring suspension and therby are lying hollow compared with the subsoil.

Dividing effect

A distinct migration of fine particles upwards through the geotextile is noticed at the medium wovens built in. This was especially obvious at the overlapping areas of different geotextiles, where the migrated fine particles had accumulated at the bottom side of the nonwoven lying above. Relatively small embedment in the wovens between the warp and the woof was possible.
One can see an area (ca. 1-2 mm) with embeded fine particles at some nonwovens with especially homogeneous structure and mostly greater thickness in the lower part. Above this, the geotextiles as a rule were eclean. These geotextiles show a distinct sealing effect and the forma-

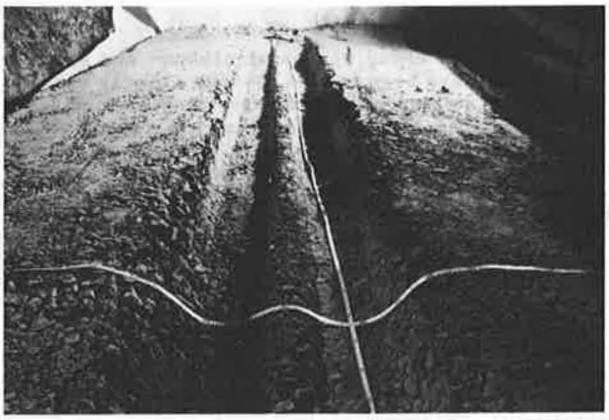

Fig. 7: Tracking after several passes; dolomite surface

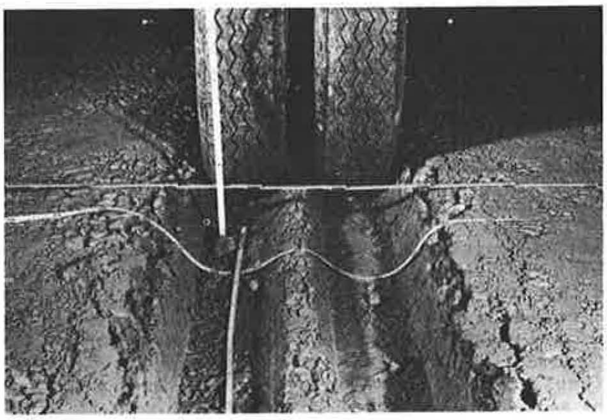

Fig. 8: Example of the tracking in the surface using a needle punched nonwoven

tion of a filter cake. It was remarkable that at thin nonwovens a relatively high movement of fine particles happened, partly also by usaging 3 layers. No accumulation of material was noticed between the layers. Here the building of a filter is only possible in the whole system: subsoil - geotextil - surface.

b. Stiff Subsoil, 40 cm Surface

No decisive deformations at the sections with installed geotextiles are remarkable after 300 passes over stiff subsoil and 40 cm surface. No difference was noticed between wovens, nonwovens and a part without any geotextile.

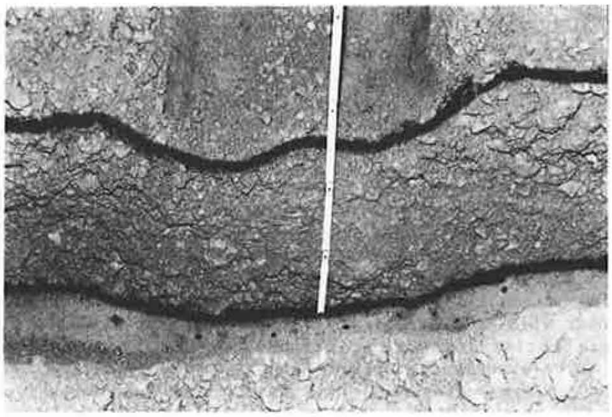

Fig. 9: Trackings in the surface (dual wheels, dolomite surface), wheelers in the subsoil ("Loess" subsoil, needle punched nonwoven)

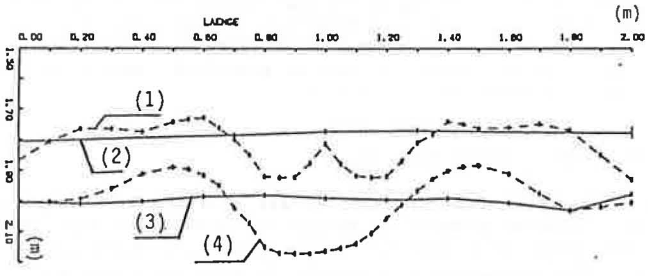

Fig. 10: Example of survey of the cross-section (Geotextile: needle punched nonwoven)
(1) top level dolomite after the test
(2) top level dolomite before the test
(3) top level "Loess" before the test
(4) top level "Loess" after the test

c. Pasty Subsoil, 30 cm Surface

The construction with 30 cm mineral concrete and pasty subsoil has not enough bearing capacity, not even with help of heavy geotextiles. Already after 3-4 passes there appeared a 20 cm deep tracking which got deeper and deeper. The test had to be discontinued.

d. Pasty Subsoil, 50 cm Surface

The construction of mineral concrete of 50 cm thickness resisted the imposed load. After 1000 passes wheelers were formed, where free water gathered above the geotextile, which was squeezed out of the "Loess" by the consolidation process in the track. The geotextiles tested till now (heavy nonwoven needle punched and wovens) resisted the loading without damage - no noticable perforation.
Distinct stone-imprints and some thinner or torn parts were noticed at heavy thermic bonded nonwovens. The surface of these fabrics was partly abraded.

8. Present State of Knowledge

Final qualitative statements cannot possibly be given now, because of the delay in the decisive phases of the current research work, which was caused by partly surprising realisations with regard to sometimes insufficient resistance of geotextiles to intensive mechanical loading. Nevertheless, clear trends appear in outlines, which let expect, that a starting point of dimensioning will be found for the aimed use of geotextiles and for the optimum in road constructions with respect to the requirement. The spectrum of the possible employments of the geotextiles is very widely spread with regard to the kind of surface, loading or conditions of the subsoil. This can only be put in order with help of differentiated parameter studies.
The respective starting points and required criterions have to be exactly registered. Then the full specification of the temporal development and stresses of the geotextile from the installation to the continuous loading including the appearing changes in the subsoil and the surface is of special interest. Especially the composition is very important in regard to particle-size distribution, particle shape and cohesiveness for the function of the geotextile at road constructions with unpaved soil bases. Therefore the full scale tests should be enlarged to weakly paved soil bases, to take into account an optimum dimensioning of the whole system under economical aspects.
Therefore the setting up of new categories in regard to requirements in road constructions on bad subsoil is necessary. With regard to the suitability of geotextiles at unpaved soil bases, it can be reported, based on the present results, as follows:

8.1 Needle Punched Nonwovens

In principle these geotextiles are suitable depending on their kind of production. Because of their great ductility they cause large depressions on especially soft subsoil with the consequence of repair. In some cases the strict orientation to filter-technical sealing conditions can cause the formation of filter-cake (i. e. also at vibrating compaction in the surface) beyond the geotextiles that results in a reduced transmission of the shearing force. The damageability at angular surface material is harmless as long as its granular skeleton is able to stabilize itself kinematically. But, if this is not the case, in the long run there will be possibilities for the fine particles of the subsoil to force their way through at perforated respectivly overstretched parts, because of permanent enlarging coarse grain-movements. The filter- and dividing-effect is not secured from the first. Different aspects arise in respect to the kind of production. Kind of production, structure and raw material of the needle punched nonwovens influence the selection of the thickness of the geotextile, especially at intensive dynamic loading.

8.2 Termic Bonded Nonwovens

For the general use of thermic bonded nonwovens approximately corresponding aspects as mentioned above (see 8.1) are applicable. Nevertheless the thermic bonded nonwovens have a comparatively higher tensile stiffness, which is very positive until the breaking limit is not reached, because of too large deformation. Certainly, this happens very soon at bad subsoil and to little thickness of the surface. Furthermore the relatively weak and brittle bonding points of the fibres are very susceptible to intensive friction, which can arise at unpaved soil bases of too little thickness. The selection of a thicker quality will avoid this. For filter-technical aspects it is also profitable.

8.3 Wovens

Till now relative cheap wovens of ribbon- and splicing thread-wovens have been tested. Wovens clearly show the advantage of a great reception of tensile stress at little strain and so from the beginning they are favourable for the cooperation in the whole system. Because of the very different products of the wovens one should be careful not to generalize this term in the geotextile sector. Easy displacing wovens have a tendency to give way to penetrating soil particles without formation of tears in warp or woof direction; in many cases damages are limited in kind and size. Therefore the dividing function together with an improvement of the increasing effect of load carrying capacity in comparison with nonwovens is not completely to deny, although one cannot speak of an own filtering effect. Nevertheless at the geotextiles, this depends on the degree of strain and damage. However there soon result limits to the resistance of too light wovens, because of intensive loading. For the engagement one should take at least average qualities into consideration.

8.4 Composite Fabrics

The combination of filter-effective nonwovens with strengthening inserts (wovens, grids) is the best solution at especially high demands for the geotextiles, because of advantages and disadvantages mentioned before. Such materials were used in previous tests partly as special fabrics with very good success (But materials with very weak grids cannot be taken into account). Good filtering effects of needle punched nonwovens at where not too much importance is put to sealing condition and great tensile stiffness of the intermediate woven even under intensive loading take care for an efficient dividing effect as well as for a clear improvement of the load carrying capacity.

9. Summarizing Judgement

The tests, which have been made up to now, show fundamental differences in reactions of the geotextile types and fabrics under intensive traffic load. The filtering and dividing effect cannot generally be judged by schematic rules, but it depends on numerous parameters, which have to be tested in detail in regard to their importance. The usefulness of the road is influenced by the composition and construction of surface, but especially its thickness (particulary at cohesive base courses), besides the type of the geotextile and the condition of the subsoil. A too low thickness of the surface at bad conditions of the subsoil cannot be compensated even by heavy geotextiles. It is expected from further tests, that selection criterions and attempts for dimensioning will be found. In the future above all it will be important that the complex processes in temporal phases of the development of the interaction of subsoil, geotextile and surface, from the establishment to the permanent use of the road could be judged in detail.