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Damage of geosynthetics during installation – Experience from real sites and research works

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ABSTRACT: Geosynthetics mostly are designed for the final state. To fulfil the requirements at that time they have to survive the installation process first. The mechanical stresses during this period often cause damages and loss in strength, separation and filtration possibilities.

This paper shows some fundamental stresses during installation found at real sites, full-scale tests and laboratory research works.

The consequences for the applications in road constructions, waterway and environmental applications are demonstrated in the following articles of this session of the German IGS-Chapter.

1 INTRODUCTION

The usage of geosynthetics meanwhile has a long tradition. Many problems of earthworks have been solved with those products. The main tasks are the separation, filtration and reinforcement, which can only be fulfilled if the product survives the installation process. The geotextiles often are very thin and filigree elements which people and machines at earthwork site are not accustomed to. They require special techniques for the installation phase that comprises transportation and handling of the geotextile, preparing of subsoil, spreading out of the geotextile, covering with material, compaction and the necessary construction traffic. To make the usage as easy and safe as possible, in most cases it is easier to "strengthen" the geotextile than to change the site process.

It has been observed that the main stresses of geotextiles appear during the installation phase which results in loss of strength, abrasion effects, thinned spots, cutting of fibres, holes and in the worst case total disintegration along a greater area. Since 1984 several research works have been carried out in Germany [1, 2, 3, 4, 7] that take these facts into account. Meanwhile also international research works are published dealing with this theme [5, 6, 8, 9, 10].

The aim of this paper is not an oversight of all the test results in a scientific manner, but to show some points that should be considered while choosing a geotextile.

2 FULL-SCALE TRAFFICABILITY TESTS

In a research work sponsored by the German government a full-scale testing rig with a twin-wheel loaded with about 30 kN (i. e. axle-load 60 kN) was used to simulate construction traffic over unbounded geotextile-soil-systems. Lots of tests were carried out and the main results are shown in [1, 2, 4]. The subsoil was a soft, silty clay and the base-course material was either rounded, sandy gravel or sharpe edged, crushed-stone dolomitic material.

It was found, that geotextiles were not able to withstand the trafficking stresses in many cases. A minimum base-course thickness of about 30 cm was necessary to prevent the system from breaking and the geotextiles from perforation. This thickness is also the minimum height that standard earthwork machines can handle. Increasing the base-course height to 50 cm led mostly to a larger amount of wheel passes than the use of "stronger" geotextiles at lower heights. Among others this induces that the reinforcing effect is not the main aspect in this application.

Great differences were found between the geotextile groups: needle-punched nonwovens, thermally bonded nonwovens and wovens. The function as a separation layer could be fulfilled by flexible, low strength nonwovens as well as by rigid, high-strength wovens. The "damaging" stress of stones trying to puncture the geotextile can be covered by great deformations (low modulous nonwovens) or by high tensile forces (high modulous wovens) in the local area around the stone as well.

Further on the construction traffic is no static stress for the geotextile-soil-system. At low base-course heights a continuous movement of stones along the surface of the geotextile during every pass could happen as well as the widening of holes, when stones already have punctured the geotextile. The separation and filtration effect of the geotextile could not be guaranteed for the further run.

The dynamic influence of the passing wheel leads also to a "pumping" effect not covered by the filtration rules known from waterway constructions. The tests showed the migration of fine material through geotextiles well designed according to those rules. A smaller amount of material transport should be possible to allow the building of a stable geotextile/soil-filtersystem and not to prevent the consolidation of the subbase. But it should not lead to a slurry of the base-course materials. Special notice should be given to intensive vibratory compaction at low base-course heights leading to "blocking" effects under the geotextile.

The research work was accompanied by the working group (chaired by Dr. Wilmers) of the German Road and Transportation Research Association (FGSV) which used the experience for their regulations published already in 1987 [11].

3 FIELD TESTS FOR DAMAGE DURING INSTALLATION

It was found that the experiences of the above mentioned research work were not only suitable for site roads but for all applications where geotextiles must be installed and covered by soil. The only difference is to be seen in the length of the period these stresses can occur.

3.1 Compaction on rigid subbase

During the construction of a steep slope reinforced with geotextiles the soil transportation and its compaction must be done over each layer for a short period. But this period may be enough to reduce the considered strength in a relevant manner. The subbase here is a rigid soil. This topic was considered in two test series.

The first test [7] had mainly the aim to get comparable criterias for nonwovens and wovens. So the usually used high-strength reinforcing materials are spare represented. It was done with a round sandy gravel used as subbase and base-course with a height of 25 cm. The system was compacted with a 10-t-vibratory roller with one pass (forward and backward). After this the products were excavated and visually inspected. The remaining CBR puncture values were determined (fig. 1).

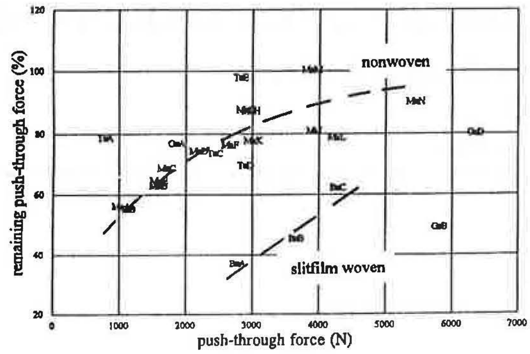

Fig. 1: Remaining CBR puncture test values after compaction of gravel over gravel subbase

It was found that needle punched nonwovens with an initial CBR value of less than 2 kN had a residual strength of about 60 - 70 %, such with CBR values between 2 kN and 3.5 kN about 70 - 80 % and those above 3.5 kN between 80 and 100 %.

Thermally bonded materials had great differences due to two production procedures. One type showed residual CBR puncture values of 80 % and more, which is even higher than comparable needle punched nonwovens. But it was observed that a large amount of holes would decrease eventually necessary filtration and separation functions.

For slitfilm wovens clear higher strength is required to achieve comparable low damaging than nonwovens.

A comparison based on the mass per area showed good correlations and the need of about 300 g/m² to receive 80 % of residual strength.

This test series was (among others) the basis for the new version of the regulations [11] from 1994 with its different boundaries of the robustness classes.

Another field test was carried out for a specific project. From a woven grid several types with different tensile strength were used for reinforcing purpose within a crushed, sharpe-edged material. After usual compaction the materials were excavated and visually inspected. It was found that only a type with a strength 3 to 4 times the value needed for the reinforcing task had reasonable low damages to be used for a safe long-term construction. These factors show the importance of checking the damage during installation, when there is no experience neither with the geotextile, the layer material nor the construction management.

3.2 Compaction and traffic on soft subbase

In another test series geotextiles were used as separation layers between soft, fine-grained subsoil of low bearing capacity and three coarse-grained base course materials [14, 15]. It was taken special care to evaluate separately the influence of placing the subbase material, its compaction and the loading by construction traffic. An additional goal of the investigation was to compare as many different geotextile products and product types as possible under similar boundary conditions. The tests were carried out with a range of products available on the market which are normally used for this type of application, including mechanically bonded nonwovens, heat-bonded nonwovens, slit-film wovens and composite materials, and, as far as possible, different raw materials, unit weights and strength values were investigated. In each test section, as many of the geosynthetics as possible were used, irrespective of their suitability according to current standards or general assessment. It was hoped that the failures thus deliberately provoked would test the validity of the limits laid down in current standards. The field-test series yielded the starting parameters for the subsequent, smaller-scale, simulation tests now to be carried out.

Three types of subbase material were used. A gravel excavated at the site was a very sandy gravel with a maximum grain diameter of 58 mm. The portion of crushed material was negligible. The fine fraction with $d < 0.063$ mm was less than 2%. The test section with this material will be referred to as "SR I". The second material was a crushed-stone base course 0 - 56 mm of granite prepared according to RG MIN StB 83. The crushed grain was sharp edged and resistant to abrasion (referred to as "SR II"). Finally an unsorted rock 45 - 200 mm was used, that was a very heterogeneous, poorly graded material, consisting of angular, crushed granite with a maximum grain size between 250 and 300 mm (referred to as "SR III").

After rolling out the "geotextile area", placing of the base-course material was started. For this, fresh material was laid on the already placed fill by reversing trucks, and then spread by a tracked bulldozer.

Dumping of fill directly on to the geotextile was avoided. This type of installation stress was excluded from the test series and will be part of a future test series.

In all three test sections, a base course with a uncompacted thickness of 50 to 55 cm was applied. The fill was extended over the test area to guarantee adequate anchoring of the geotextiles and to facilitate trafficking by trucks.

After completion, the base course was compacted using a Bomag BW 217 D2. For this, the whole fill area was compacted lane-by-lane with one pass each (1x forward, 1x backward) statically, two passes with low-amplitude and one pass with high-amplitude vibration.

After completion of compaction the sections were trafficked using a loaded Volvo BM A35 truck. This was done so that one wheel track was situated at the quarter point of the investigated geotextile area, and the other wheel track outside the test area. In total, 18 passes were made on test section SR I, and 6 passes each on test sections SR II and SR III.

The removal of the base course material was done as far as possible with an excavator with a special shovel down to a height of 25 cm over the deformed geotextile level. The remaining material was removed carefully by hand. Damage of the geotextiles during excavation can therefore be excluded.

The classification of damage on visual inspection immediately after removal of the sub-base was done due to former test series [2]. Subsequently, the samples were divided into two separate groups with different stresses (vibration compaction only vs. compaction and traffic). The whole area was examined. Damage was documented in terms of location, size and type. Residual strength values were observed with the CBR puncture test.

With the sandy gravel (SR I) nearly no visual damages were found. The residual CBR puncture values were between 60 and 105 %, values from areas with compaction only being slightly higher.

The test series with crushed-stone base course (SR II) however showed visual damages even in the areas with compaction only. Here undamaged were about 90 to 100 % of area, with residual CBR puncture values between 60 and 90 %. In the areas with traffic also, great ruts with puncturing of stones into the geotextiles with lots of damages were observed. The "weaker" products couldn't prevent the break through of the construction. This is astonishing because the boundary conditions (subsoil, base-course height) were the same as in SR I. "Stronger" products had problems also, but could serve for the intended number of passes with great deformations and damages in most cases. The part of undamaged areas were between 30 and 100% with complete damage of some very "weak" products. The residual strength of the CBR puncture values were found between 0 % and 80 %. Products chosen according to the German classification [11, 12] had undamaged areas between 80 and 100% and residual CBR values between 60 and 80 %.

At the test series SR III with the unsorted rock it was found that the material initially punctured the

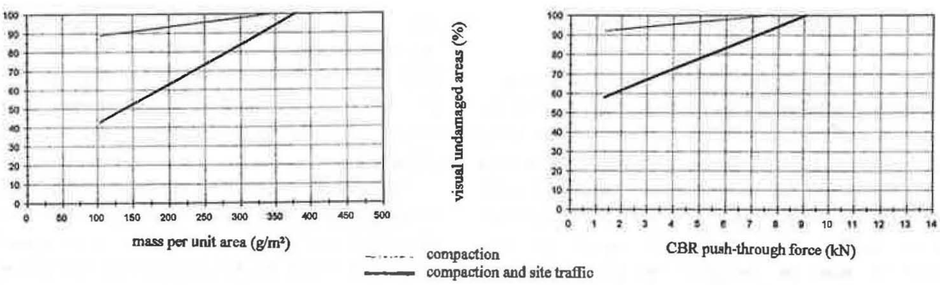

fig. 2 and 3: part of undamaged areas, SR II, base course material: crushed-stone 0-56 mm

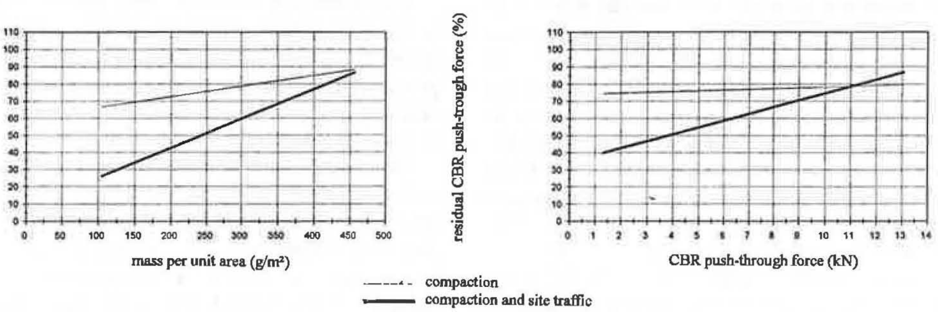

fig. 4 and 5: residual strength, SR II, base course material: crushed-stone 0-56 mm

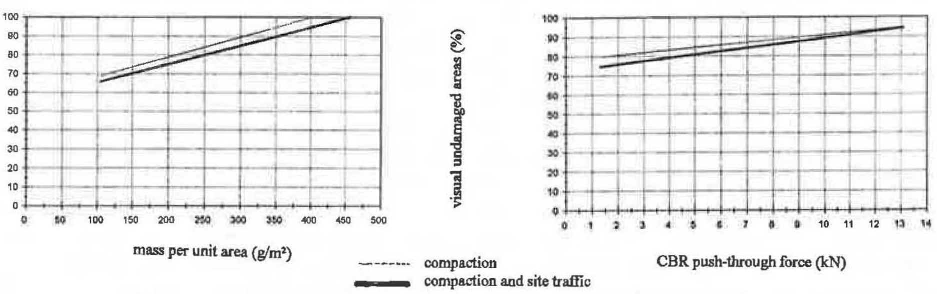

fig. 6 and 7: part of undamaged areas, SR III, base course material: unsorted, crushed-rock

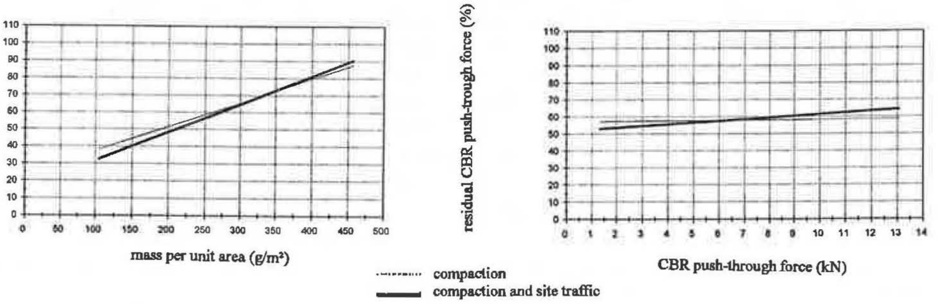

fig. 8 and 9: residual strength, SR III, base course material: unsorted, crushed-rock geotextiles but formed then a very stable construction with a better trafficability than the other two. The rock material built together with the tensile strength of the geotextiles a suitable stone foundation for the short period of surcharging. The part of undamaged areas were between 70 % and 100% (only compaction) and 50 % and 100 % (compaction and traffic). The residual CBR puncture values were between 40% and 80% (only compaction) and 20 % to 90 % (compaction and traffic). The damaging here in the two different loading conditions was very similar.

Each of the different types of geotextiles showed different behaviours in residual strength, visual damaging and deformations at site. It is not possible to present this here. As an example for the group "needlepunched nonwoven" one finds CBR puncture values > 4 kN and a mass per unit area > 350 g/m² as sufficient for a good survivability to the installation stressesof SR III (unsorted rock).

3.3 Dropping of base-course material

The dropping of base-course material was examined in a different test series. It was done with the same stone materials as described above, with different falling heights, subsoils and fixing conditions of the geotextiles. But in all cases the damaging effects were much lower than with compaction or traffic loadings.

4 LABORATORY TESTS FOR SIMULATION OF DAMAGE DURING INSTALLATION

The experience of the numerous field tests showed that there could not be one single test for simulation of damage during installation. The results of the field tests must be used to calibrate laboratory tests, existing test methods must be checked against those results.

The laboratory test procedures have to take into account the different site conditions. I.e. a test that should simulate the passes of a truck on weak soil must allow great relative deformations between geotextile and soil with high local loadings at low frequencies to get realistic. On the other hand a test for simulating compaction on rigid subsoil and subbase must use high frequencies and low relative deformations at area loads. Some possible procedures can be found in the papers named in the references.

Also the different requirements of road, waterway and waste disposal constructions must be determined

5 CONCLUSION

As main installation stresses for geotextiles on site the dropping of stone materials on the geotextile, the compaction and the travelling over the first soil layers were found. The behaviour depends most on the type and condition of the soil above and below the geotextile and of course on the type of the geotextile. The wide span of geotextile types and their different behaviours in the tests cannot be shown in a short article like this. That's the reason why such generalised curves are used like in fig. 2 to 9. More detailed informations will be published in a research report later on. Special informations on certain products can be received from the producers that partly sponsored the tests. The users of the geotextiles are encouraged to ask for such results due to importance of the query.

The results found in the tests are in good accordance with the classification in [11, 12]. More details can be found in [16].

The judgement of the susceptibility of geotextiles to stresses during installation only on residual strength values is of course not the right way. In many cases it is more important to look at the changes of opening sizes or permeability. These changes can be derived in a first step from the part of visually damaged areas. I.e. the determining and dimensioning of geotextiles according to opening sizes with accuracies of 0.01 mm is quite senseless, if holes with several cm arise during installation!

Hopefully the installation phase will soon be looked at as an substantial one with its own criterias as it is done already in all other constructions in civil engineering. In cases with no experience and at lack of regulations suited for the specific site conditions, it is strongly recommended to do full-scale site tests. This can prevent from failures caused by a wrong choice of geotextile products, having in mind that of course products and constructions exist that will fulfil the task.

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