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Stressing of geosynthetics during installation and construction on site: Installation of geosynthetics in waterways

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ABSTRACT: Very often the placing of a geosynthetic product and the construction steps which immediately follow incorporate the strongest load this product will meet during its lifetime. In hydraulic and waterway engineering, heavy machinery and large construction elements are normally used, so extraordinary loads are nearly inevitable, even when all work is done with great care. Examples of possible loading states during installation are presented and some advice is given on how to avoid or reduce them.

1 INTRODUCTION

Geosythetic products in inland and coastal waterway engineering are used predominantly as filters or as reinforcement for dams and dikes, bank and bottom protection, groynes and training walls. During installation, the products may have to sustain loads which won't reappear during their lifetime. A geotextile filter, for example, will not have to bear large tensile forces when installed, but when placed below the water table, it has to sustain a certain amount of tensile stress.

Very often in waterway engineering very heavy machinery is used, either to be able to carry out the work in deep and turbulent water, or because large quantities of material are to be moved, or because heavy elements have to be placed. Coastal protection works, for example, may need elements weighing many tons to withstand the wave energy of the sea during a storm surge. These elements are placed on geotextile filter layers which show only millimeters of thickness. Even if they are protected by a cushion layer the placing of such elements means a high impact on the geotextile.

So it is not surprising that a geosynthetic fabric might undergo the most severe load as to material strength (tensile stength, resistance to puncture loads and abrasive forces) during the process of installation and/or covering. These loads cannot be avoided and proper installation has to be guaranteed. Usually, certain properties of the geotextile are asked for when calling for tenders, and very often these "extra loads" are forgotten. Depending on the construction, certain requirements should be included that take into account the loads during installation (e.g. tensile strength, impact resistance etc.). Since the material properties necessary for the installation should not be cost decisive, the contractor has to choose an appropriate construction procedure and care has to be taken concerning which materials will come in close contact to each other and which machinery is to be used during the sensitive parts of the placing procedure.

In the following, critical situations during installation and construction processes are discussed with the aim of minimizing the impact on the geosynthetic product. This presentation can't be complete, but it is intended to initiate fruitful discussions on product specific construction procedures and on quality assurance demands. And it wants to help in recognizing possible mistakes or adverse situations in advance, thus providing the possibility of undertaking appropriate countermeasures.

2 GEOTEXTILE FILTERS

2.1 *Preparation of the subgrade*

Experience has shown that it may turn out quite unfavourable not to prepare carefully the subgrade, upon which the geosynthetic product will be placed. No matter what will be on top of the fabric, in most cases it can be assumed that during further construction and under working conditions the fabric has to sustain loads from moving cover or deforming subsoil.

Any sharp edge (e.g. from rock fragments or roots) in or on the subsoil will cause minor or major faults in the fabric, reducing its reliability and maybe even the lifetime of the structure. The same aspect holds for any preparation platform or any edge the fabric has to pass during the installation process: smooth surfaces and rounded edges help to avoid damage already in an early stage of construction.

As one can imagine, any fabric in between two stones feels like a grain being grinded in a mill and won't sustain that load very long. In any case, stones below the geotextile have to be avoided, even if the material dumped on the geotextile is chosen with care. So it is advantageous to prepare the subgrade in the dry conditions as far as possible.

2.2 *Placement*

Only at first sight, placement by hand seems to be a very delicate installation method. It must be taken into consideration that it is impossible to spread out a geosynthetic cloth by hand without pleats, so it is inevitable to apply strong tension to flatten the cloth and to tear off the plies. It is mostly also necessary to step on the cloth which is not considered favourable, even if it might be a "light load" compared with other impacts.

One of the simple tools to help in placing a geotextile is the spreader bar. The amount of undesired straining depends on the mechanism used. Generally the loads result from improper handling, e.g. high tensioning of one side of the fabric when rolling off is not done perpendicular to the roll. Any turning and swinging means unilateral tension and should be avoided. The same holds for placing from pontoons into the water. The pontoon has to be positioned carefully, not drifting and thus pulling the cloth, misusing it as an "anchor".

Now and then there is some rumour about large tensile forces acting on a geotextile when hanging from the pontoon down into the water, increasing considerably whenever a ship passes. We actually did measurements and we did not find any confirmation of that assumption (Abromeit 1996). The geotextile can be handled gently with this method and will be placed quite stress-free and ply-free.

To keep the geotextile in place, it is often just pinned on the slope, on the pontoon or elsewhere. The result is not difficult to imagine: with an increase in load, e.g. by dumping a cover layer on the geotextile, either the pin is gone or the cloth is torn apart. There is also a long-term aspect: When any layer is dumped upon the geotextile, it will be pulled downslope. The geotextile further up the slope will be stretched and is in this part unable to follow an uneven soil surface. There will remain voids between soil and cloth, which might cause trouble concerning the filtration behaviour. If it is

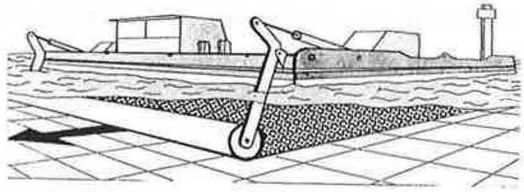

Fig. 1: : Unrolling a geotextile filter (Möbius)

necessary for any reason to fix the geotextile at the upper edge, an elastic clamp should be used for temporary purposes or the geotextile should be buried in a ditch (which might also be necessary to avoid water flowing from the top of the slope behind the cloth). It is worthwhile mentioning that a nonwoven product has some more straining capacity and thus will be able to follow deformations of the subsoil more easily than a woven product.

A very "soft" method of placing a geotextile is to wind it up on a core tube above the water and then unwinding the cloth on the bed or bank of the waterway (Fig.1). The pontoon has to be well controlled as with the other placing methods, but even if there is some extra stress, it will be quite evenly distributed over the width of the cloth.

2.3 *Covering the geotextile*

It goes without saying that rounded elements are more "gentle" to the geotextile than sharp-edged elements and that large elements dumped on a geotextile cause a greater impact than small ones. But there also are some additional points to be mentioned:

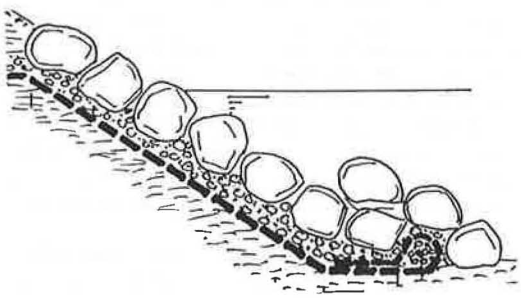

Fig. 2: : Geotextile protected by a cushion layer (SVG 1992)

It is basically a good idea to cover a geotextile by a cushion layer before dumping large blocks upon (Fig.2). But this cushion layer must not lead to careless procedures: The elements of any cover layer will rock and/or move in the immediate period after installation due to dynamic hydraulic loads and

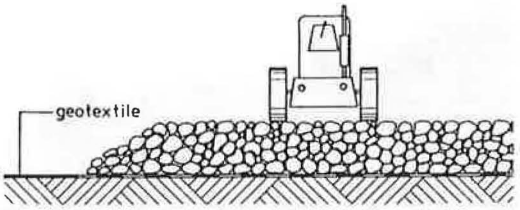

Fig. 3: Protection layer on a geotextile (Santvoort 1994)

due to deformations of the subsoil caused by the new load. Then the grains of the cushion layer may cause abrasive and puncture loads on the geotextile. Thin and very light geotextiles may not sustain this load, so the material has to be chosen properly. In our experience, nonwovens cope better with this load than wovens.

A cushion layer should be as thin as possible but as thick as necessary. In cases of doubt, add some thickness! Dumping the material always leads to irregularities in layer thickness and a single large element falling on the layer will create a "crater". By the way: falling through the air causes a much greater impact than falling through the water. As a rule of thumb, the impact energy is a mere 15% when falling through water (of sufficient depth) compared to the same falling height in the dry.

If it is necessary to have a dredge or bulldozer acting on the area covered by a geotextile, a thick protective layer is necessary to provide sufficient shelter for the fabric (Fig.3). Turning with a caterpillar tractor results in rocking and rolling of stones even to a significant depth of the armour layer. Usually a layer thicknes of 0.4 m is sufficient to protect the geotextile when gravel or similar material is used. When using rather hard or sharp-edged material or blocks instead of gravel, the layer thickness should be increased.

The same holds for final profiling to give a cover layer a fine finish: this action might be more troublesome than helpful: Rearranging the stones on the surface with, for example, a grab means a mechanical load also to the geotextile below, while the nice and smooth surface won't last long: It will be changed by the first few (hydraulic) loads which cause transportation or rotation of some top elements until a state of equilibrium is reached.

2.4 *Bad serviceability states*

It was said at the beginning that after the construction process the greatest loads have finished for the geosynthetic element. But if the wrong construction system is used, the stressing remains.

Often a geotextile filter on a slope is not designed to act as a tensile reinforcement, but is forced to: If

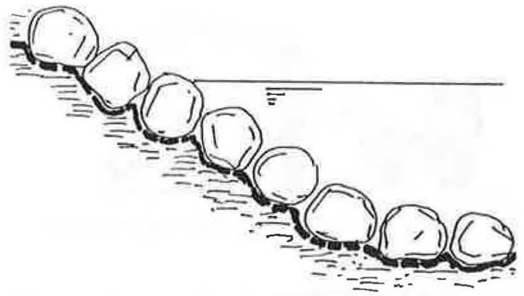

Fig. 4: Geotextile adapting to armour and soil (SVG 1992)

the top edge is fixed, there will always be a large tensile force stressing the fabric due to the deformations below the dumped material the geotextile wants to follow. Usually the geotextile becomes corrugated, which is easy to watch when the filter is not fixed (Fig.4): the top edge will move downslope a considerable amount. When fixed at the top, the geotextile remains (over-)stressed during its lifetime, which may then be shorter than expected.
When large rounded elements are placed directly on the geotextile, there is usually an intimate contact between subsoil and fabric, since the element causes some deformation of the ground which tensions the geotextile. If the ground is very hard, this won't happen. To avoid fluttering of the geotextile in between the contact points of the stones, a cushion or intermediate layer should be dumped first before placing the large elements.

3 GEOSYNTHETIC CONTAINERS

In many cases geosynthetic cloth is used to wrap a fill material. In hydraulic engineering use is made of bags, tubes, mats, summarized as "containers" (Fig.5). Sandbags, for example, are the first and most important help for endangered dams and dikes. It is not possible in all situations to handle such containers with care, so an appropriate material should be chosen. Usually there is a choice of wovens and nonwovens, the first having the advantage of high tensile strength, the second the advantage of large straining capacity. If a wrapping material is damaged, a woven cloth is more susceptible to crack propagation (the zip effect) than a nonwoven.

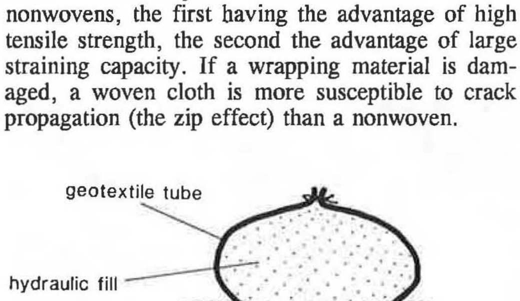

Fig. 5: Geotextile tube dike (John 1987)

Fig. 6: Filling system for large containers (Saathoff 1995)

3.1 *Filling the containers*

To avoid high stress when filling, the container should remain on the ground (Fig.6), and it may even be even necessary for it to be laterally sustained.
When mattress-like containers are used, spacers are needed to keep the upper and the lower cloth parallel to each other (Fig.7). These spacer strings need sufficient tensile strength (as does the warp where they are fixed) to bear the load when the mat is filled. It must not be forgotten that e.g. a concrete fill of a mattress on a slope will produce a considerable hydraulic pressure inside the mattress at the toe.
To avoid such "bags", it might be necessary to fill the length of a slope in more than one step.

3.2 *Transport*

If bags or containers are to be handled with grabs, coarse fill material (e.g. gravel only) will cause damage to the fabric more easily than finer fill. So even when coarse material is necessary or locally available, it should be mixed with finer grains to reduce the stress on the cloth.

3.3 *Placement and service state*

The placement of numerous containers won't be done element by element with a grab. A stone dumping vessel will be appropriate instead, but only a conveyor belt type should be used to minimize the abrasive forces acting on the cloth.

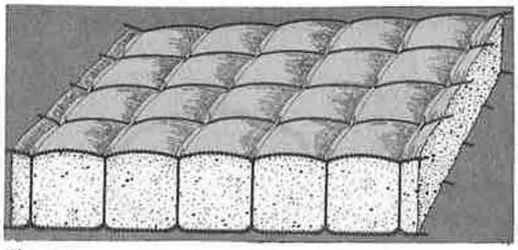

Fig. 7: Mattress-type container (Huesker / Colcrete)

Fig. 8: Fixing the fascines on the geotextile (Huesker)

Sometimes containers are not covered by a protection layer on purpose (or it is removed due to large deformations). When deeper than 1 m below the water table, the durability of the structure is not threatened by weathering. But the question arises as to what happens when the geotextile is destroyed by a ship's propeller or an anchor. To the knowledge of the authors, no great harm has been created to date, but it would be great discussion amongst the lawyers over who is to pay for the damage a floating geotextile may cause when caught by a propeller. To avoid this, a protective layer should always be placed on top of any geosynthetic cloth. Usually, 0.6 m of riprap has proved to be sufficient.

4 FASCINE MATTRESSES

4.1 *Preparation*

Usually mattresses are prepared on the ground, on a pontoon or some other platform (Fig.8). To ease the dragging into the water, it is essential to have a smooth surface below (often an extra woven fabric). The fabric is usually pierced by pins that are used to keep up the strings for the fascine bundles to be fixed on the geotextile. The piercing itself normally does no harm to the fabric, but how often it is forgotten to remove all the pins before dragging the mattress towards the water!

Since the strength of seams is usually lower than the strength of the fabric, all seams perpendicular to the dragging direction are to be avoided.

4.2 *"Parking"*

Once finished, it is often necessary to keep the mattress one or more days on site before dragging it to the spot where to be sunk. This "parking" might not be without problems: Often the mattress is spread in such a position that at high water it is covered partly with water and loaded by waves! Two effects have to be considered:

- Sand is transported onto and into the mattress by the current and the waves, so it has some extra load to be dragged away afterwards.
- Waves move the fascine bundles, the strings that hold the bundles move, too, rubbing the warp. In the worst case, the warp might break and the bundles fall off the cloth.

Mattresses are also parked floating. This should not take too long, since on one hand the wood is soaking up water and on the other hand suspended material is caught by the fascines. So the weight increases considerably and it may go so far that the mattress sinks in parking position without any stone being dumped upon it!

Winds may be rather adverse not only when dragging the mattress to the intended location, but also in the parking position: It is reported that a mattress with cloth and fascines on it was lifted some 30m vertically by the wind.

4.3 *Transport of the mattress*

Dragging the mattress has to be done with great care:

The first chance of the mattress being damaged is when it is moved from the preparation site, since pins, sharp edges, may damage the fabric (Fig.9). Asymetric tension may exceed the tensile force of fabric and/or strings. Jerky movements cause stress peaks and are to be avoided.

The fabric may allow larger strain than the fascines, thus demanding high strength of fabric and strings at point of attachment.

Once on the way, any corners that have to be passed around may be an obstacle to the rather long drag unit of tug boat, mattress, pontoon etc. (length up to 200m). So it might happen that the mattress won't pass the corner but "override" it which is not tender at all to the fabric.

Any flat or shallow water might be a danger because once stuck, it is very hard to get away again. It is easy to imagine that the mattress is not designed for such forces as are necessary to get it afloat again.

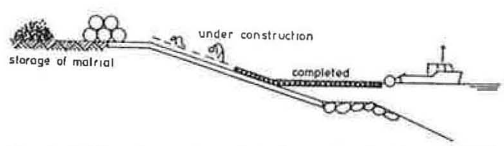

Fig. 9: Pulling the mattress into the water (Santvoort 1994)

High stress acts also on the material, when the floating mattress has to be turned against the current to get it in final sinking position. The same holds for any propeller jet which is directed toward a floating mattress and for high waves. Turning means tension on the outer side and pressure on the inner side. If the pressure is too high, a kind of buckling may occur that folds the mattress upwards or downwards.

All these dangers diminish, the smaller the mattress. But there is the general question of the optimum solution of either small elements with many overlaps (which are always a critical point) or large elements that are more difficult to handle.

4.4 *Sinking the mattress*

Again the geotextile is heavily loaded when the mattress is sunk. Stressed between two boats or pontoons, loaded by the impact of falling stones (especially in shallow water), the fabric has to bear a lot more than it ever has to during its working lifetime. It is important to cover the mattress completely as soon as possible, since the first stones to sink the element are moved much more on the fabric by currents and waves than the whole body of

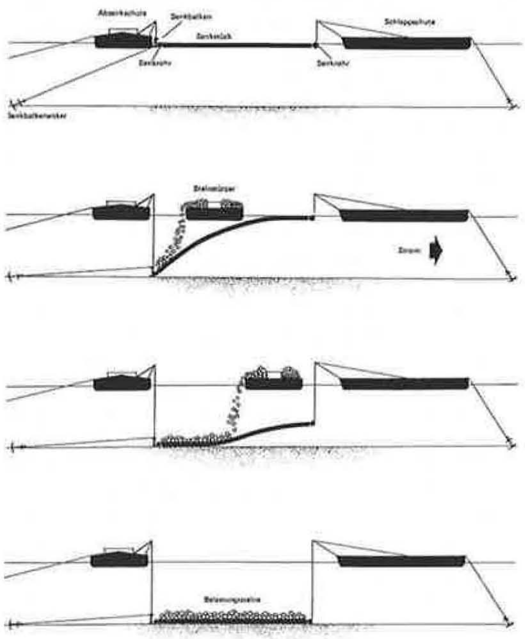

Fig. 10: Sinking scheme of a fascine mattress (Colcrete)

armour layer, thus creating abrasive forces, for which the fabric is not designed.

Placing a mattress looks so easy when explained in schematic drawings but incorporates a lot of critical situations in reality (Fig.10). But nevertheless this construction system has proved quite reliable and will be so in future, provided good quality control accompagies the element from preparation to service state.

5 ACKNOWLEDGEMENT

We have tried to collect as many critical situations in the life of a geosynthetic product before it has been positioned at its final place. This collection would not have been so comprehensive without the help of some colleagues, namely Gerhard Hackmann (Colcrete - von Essen), Janssen-Graalfs (Möbius-Bau), Jan T.Meerkerk (Hirdes) and Jan de Boer (Gouderak), to whom we would like to express our deepest thanks. The pictures are taken from literature or from broshures distributed by firms as citet.

6 A FINAL WORD

Looking for examples to be presented here, we discovered that often the manufacturers of geosynthetic products do not know the loads their product will undergo until it performs the way it is intended in design. Since the manufacturer can't anticipate all possible loads, since they depend on the individual procedure chosen, it is necessary to formulate all required material properties from the side either of the client or the contractor.

So the dialogue between all the institutions involved in such constructions should be intensified insofar as the steps (and the stresses) that are undergone by a geosynthetic product until it is in its final position should be discussed to find the optimal solution. Usually, tests are performed to find out how a product behaves during the installation process. But the question is, which tests are representative. Index tests e.g. like the puncture test, do give some information, but there is no calibration concerning the behaviour under real loads. The BAW (Federal Waterway Engineering and Research Institute), as the consultant part of the German Waterway Authorities, has developed certain performance tests that represent those loads, e.g. concerning abrasion, dumping impact, etc. According to our experience, only such tests give reliable information as to installation loads. Therefore such tests according to the individual use have to be passed by all geotextile products that are considered for the structures of our waterways (TLG 1993).

Since knowledge on installation loads is not yet sufficient we would encourage all kinds of measurements, e.g. concerning the tensile forces of a fascine mattress until it is in its final place or abrasion caused by a caterpillar track moving on a cushion layer. Only then will we know and not only live in faith!

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