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GEOSYNTHETIC BARRIER-SWELLING NONWOVEN (GBR-S): AN ALTERNATIVE TO GEOCOMPOSITE CLAY LINERS (GCL)

Peter Mohr[1]**, Birgit Widlarz**[2]

[1] *Geotex Ingenieur GmbH. (e-mail: pmohr@ib-geotex.de)*
[2] *Geotex Ingenieur GmbH. (e-mail: bwidlarz@ib-geotex.de)*

Abstract: GCL are often used as an alternative for geomembrane sealing systems in earthwork or hydraulic engineering, as well as sealing of landfills or buildings, which are built in groundwater. Due to their weight GCLs can not be used in tunnelling. For this reason a certain need has been identified to develop a new product, which can be installed with the same simplicity as GCLs, but having only the weight of a geomembrane.

The GBR-S is produced as a single-layer, needle-punched nonwoven, made from synthetic fibres. Afterwards the nonwoven is impregnated with a polymeric emulsion. So every fibre is coated with a layer of a hydrophilic swelling material. In contact with water, the swelling material absorbs water immediately, swells and fills the pores between the fibres. Without ballast a remarkable increase in thickness and size can be noticed.

The development of GBR-S was attended by the TU München, Zentrum Geotechnik over a number of the years. They recognized that many test procedures used for GCL-testing can also be used for GBR-S. But specific advantages of GBR-S made it necessary to develop additional tests, such as the spread-out test. GBR-S has some marked advantages compared to GCL, but the synthetic swelling materials set also limits as well as bentonite. Current testing limits applications. Site reports show different fields of applications. Combinations of GBR-S with synthetic foam, coatings or granular material or even geomembrane are examples of how multifunctional GBR-S can be used in a range of projects.

Keywords: sealing, swelling, non-woven geotextiles, groundwater-protection

INTRODUCTION

One of the major functions of geosynthetics is the sealing of structures against water or groundwater or to protect the environment or the groundwater against pollution. Ponds or rivulets built for landscaping must often be sealed as is also necessary for reservoirs. Geomembranes (GMB) or Geocomposite clay liners (GCL) are common for such purposes. But both types of sealing have some shortcomings (Floss & Heyer, 2002). Many tunnels in Europe, sealed with geomembranes are not water tight. Larger ponds, sealed with GCL need a water supply by rivulets to stabilize the waterlevel. Nevertheless, producers or engineers are apparently satisfied with the state of the art.

For these reasons development of an improved alternative to bentonite mats was commenced by the Authors at an early date, basing development of ideas on a single-layer nonwoven. Unknown to the Authors, thin nonwovens incorporating Superabsorber (SAP) were already in use in the production of telephone cables at this time. Knowing this fact, would have reduced developement work to answer the question, how can I increase weight of such a nonwoven from 50 to 500 g/m²?

An opportunity for such development work presented itself at the beginning of the 90s in textile factories of the old GDR. Using the Malimo technology available there, allows sewing granular Superabsorber into the pile of the fibres. Since Superabsorber has a much higher swelling potential than bentonite, the SAP content had to be reduced to a level at which uniform distribution of the swelling medium could not be guaranteed after transport and placing of the nonwoven, and further tests were therefore discontinued. Discussions held in different working groups convinced the Authors to re-start development work in the mid-90s. An additional criterion was the filling of the nonwoven, or the encasing of the fibres with a swelling agent, while at the same time minimising loss of material.

First samples, using a thickening means for waterbased printing colors, were ready in 1997, and were subjected to a 4-month-long cycle of swelling/sealing, freezing and drying out. After this continuous test, further development of the swelling agent started, which had originated in a completely different application area. Numerous test variants, including paste-like Superabsorber, or SAP fixed chemically to the fibres or between two nonwoven layers, were investigated and rejected because they were either too expensive, or unlikely to succeed.

Two different types of swelling nonwoven were in production within a few years. One type of nonwoven, named fibre-based nonwoven (FB) uses fibres equiped with the swelling material to produce the swelling nonwoven. The other type needs an immersion bath to impregnate a needle-punched nonwoven with a polymeric emulsion (emulsion based = EB).

PRODUCTION

The fibres of the FB-nonwoven are equipped with a certain content of swelling material. Variation of swelling properties needs more or less fiber weight/ unit area. The use of any impregnated fibre for the production of textiles reduces on the one hand technical properties of nonwovens, such as tensile load and plunger force, and on the other hand increases the values of extensions and maximum movements. FB-nonwovens are limited with respect to their minimum weight by the required values of plunger force and tensile load. But there are no restrictions for the production of heavy weight products.

The EB-nonwovens consist mainly of PP, PET and PA fibres, the choice of fibre depending on the application. There are production limitations on the weight/unit area and the thickness of the nonwoven. The EB-nonwoven passes through a bath containing a hydrophilic, polymer-based swelling agent. To avoid breaks during impregnation a minimum tensile strength is necessary. The weight of the wet emulsion is about four times the later dry content. After the bath, excess material is removed by a squeegee. Altering the pressure during this squeezing process allows the properties of the finished product to be varied widely. Finally, the swelling nonwoven is hot-air dried. The drier is designed to cope with only a certain moisture quantity in the nonwoven, and this imposes limitations on the fabric thickness and the saturation level.

The nature of the production process results in a EB-product with a less open surface than that of a conventional needle-punched nonwoven. Since the fibres have already shrunk in the drying process, no additional shrinkage problems occur. The swelling nonwoven can therefore easily be laminated to films or geomembranes from any of the typical polymers (Mohr, 2006).

CHARACTERISTIC PROPERTIES OF THE GEOSYNTHETIC BARRIER SWELLING NONWOVEN

The properties of EB-swelling nonwovens have been determined by laboratory tests at the Technical University of Munich (TUM) on the basis of basic principles for GCL's (Table 1). The results of this suitability test are summarised in test reports that certifies the usability (Prüfamt für Grundbau, Bodenmechanik und Felsmechanik, 2003, 2008). In addition to general tests with geotextiles, also specific ones were carried out to simulate particular situations. Standard tests for geotextiles were made to see the alteration between dry / wet / re-dried conditions.

Table 1. Permittivity of EB-swelling nonwovens

Swelling pressure in kN/m²		approx. 200
Permittivity according to DIN 18130 TX-KP-ST-UO in [1/s]:	Swelling nonwoven without strain	$< 5 \times 10^{-9}$
	after dry-wet-changes	$< 3 \times 10^{-9}$
	after frost-thaw- changes	$< 3.9 \times 10^{-9}$

Swelling properties

The swelling pressure and the swelling enhancement are established similar to the test with geocomposite clay liners. The configuration tested gave the following results: Swelling increases significantly as the amount of swelling agent increases. The swelled area of the swelling nonwoven is limited after water ingress through a punctiform damaged spot in the GMB which is laid on the swelling nonwoven. This small swelling area will not interfere with design calculations and construction elevations respectively. Swelling enhancement will only follow if the swelling nonwoven is almost completely swelled and the load on it is smaller than the swelling pressure.

Sealing properties

The swelling nonwoven accomplishes the requirements for sealings used in earth-moving, road construction and civil engineering with its low permittivity $< 5.0 \times 10^{-9}$ 1/s also attainable in critical weather conditions. Extreme weather variations like dry-wet and frost-thaw-cycles have evidently no influence on the swelling properties of the swelling nonwoven. As a result of the constant drying and the complete swelling after re-contact with water even after 20 test-cycles, no permanent damage spots will persist.

In the lab, dry-wet-cycles as well as frost-thaw-tests were realized. The basis for dry-wet-experiments was the testing recommendation for GCL. The frost-thaw-changes were simulated in a climate chamber where the realistic temperature changes from 20°C down to –10°C were adjusted.

Penetration test

To test the effectiveness as a geosynthetic barrier swelling nonwoven, as a layer between two Geomembranes or between GMB and concrete, the penetration test was developed. Two perspex discs represent these two layers in between which the swelling nonwoven is installed. The case of damage "punctiform damaged spot in the geomembrane" is simulated by a small hole in the upper acrylic layer where the liquid ingresses at a specified pressure. Additionally, an extra adjustable load is applied on the system (Figure 1).

According to lab experiments, each tested sample of the swelling nonwoven was activated within seconds by all used liquids (Table 2). The maximum radial dispersion of the penetrated liquid amounts to approximately 2.5 cm (5 cm diameter) (Figure 2). Thus neither salt water (up to 3 % sodium chloride) nor alkaline water with pH = 13, leachate of concrete, has an effect on the laminar dispersion as well as the temporal effect. This substantiates the immediate activation of the swelling material, whereby a 5 mm diameter punctiform damaged spot in the geomembrane can be totally closed and completely sealed despite unfavourable strains. Tests over a 280-day period showed no increase over the short-term dispersion.

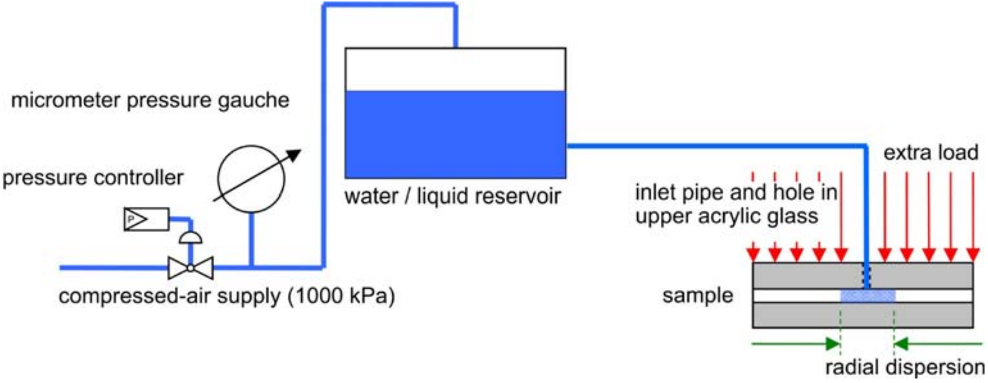

Figure 1. Scheme of penetration test

Table 2. Permittivity of EB-swelling nonwovens

Liquid	Testing time in [h]	Diameter of the face dispersion in [cm]
deionised water	1.5	1.0 - 3.5
0,5 % NaCl-solution	3.4	4.0
	24	4.5
3% NaCl-solution	2.8	5.0
	24	4.0
pH13-solution	1.5	4.2
	24	4.0
	1200	5.0
	2400	5.0
	6720	5.0

Figure 2. Dispersion after trial

Utility tests

Cylinder-test

In cylinder-tests conducted by the Authors, the swelling nonwoven was tested for long times with water load up to 30 centimeters on top of the sample and without abutment below, using different liquids (Mohr, 2003). As the test samples are activated within seconds, normally no liquid passes the nonwoven layer (Figure 3). Sometimes crushed concrete is used as a ballast layer in ponds or basins. Such material can contain rusty steel, which causes problems to GCLs. It was found that many dyad metals (for instance Fe_2O_3) hinder the swelling agent from swelling too (Mohr, 2003) (Figures 4 & 5).

Figure 3. Cylinder test with water load

Figure 4. Failed Cylinder test after rust exposure

Figure 5. Swelling nonwoven with rust damage

Wash-out tests

Flowing or seeping water can wash extended swelling material on the surface away. In unfavorable conditions the bentonite content of GCL can be completely washed away. The test in 4 steps (Figure 7), showed that a certain amount of swelling material, depending on the amount of impregnated agent, is washed away only in the first step. The swelling agent inside the nonwovens structure will not be moved (Figure 6).

That result was confirmed in a test made for a flood protection system at the FH Deggendorf. A mixture of water, sand and silt flowed for 98 hours through a test-canal, lined with an EB-swelling nonwoven. After two days the extended swelling agent was completely washed away from the surface and sedimentation process of mineral material started. The thin silt layer protected the swelling agent inside the nonwoven. After drying, the swelling nonwoven was installed in a cylinder. The sealing function still remained (Zentrum Wasser und Umwelt, 2006).

Figure 6. Wash-out-test

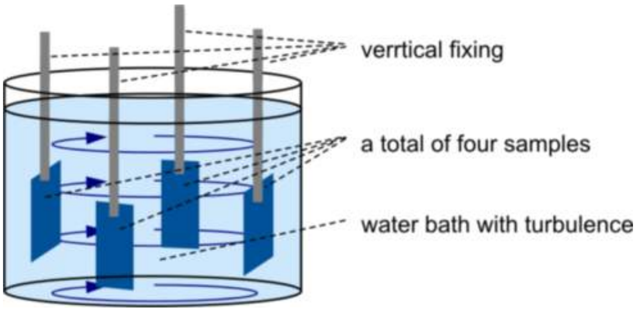

Figure 7. Scheme of wash-out-test

Basin tests

For different tests a metal basin was built in Deggendorf. Pipes above and below the sealing layer allow the in-flow and out-flow of liquids or gases. The swelling nonwoven is embeded between sandlayers. The basin can be covered and sealed. Tests were made to find the required length and ballast load for a tight overlap in joints between two sheets.

In other tests, EB-nonwovens with different content of swelling agent were installed. Both outlet pipes were protected by filter paper. Water seeped for 72 hours above and below through the sand bed (Figure 8). The activated swelling material extended into the sand. A certain amount was washed away by the seeping water and was held back by the filter paper. After 10 days of drying the sand was removed carefully. Both sides of the nowoven were covered with a layer of sand, which was stuck together by the swelling agent. The thickness of the stuck sand depends on the content of swelling agent (Figure 9). The sand in front of the filter paper was also stuck (Zentrum Wasser und Umwelt, 2006). To avoid any wash-away of extended swelling agent one of the surfaces, later in contact with the seeping water, can be laminated with a 0.5mm PE-membrane.

Currently, work is being carried out to perform additional basin tests, especially to test the sealing function with hydrocarbon compounds. In one test diesel is used to fill the upper part above the activated sealing layer. Air is sucked from the lower part of the basins to discover diffusion of gases or a failure of the sealing. In another test, gases are blown into the lower part under light pressure and the airflow through the upper outlet is tested for diffusion of gases.

Figure 8. Swelling nonwoven between two sandlayers with enhancement

Figure 9. Swelling nonwoven with stuck sand after the test

Parts of ammonia fumes or hydrogene sulphid gas are dissolved in the swollen nonwoven. But the effects on the swelling nonwoven are not verified, because tests are not finished yet. The results of current tests will be presented during the meeting in Edinburgh (Prüfamt für Grundbau, Bodenmechanik und Felsmechanik, 2008; Zentrum Wasser und Umwelt, 2006).

Further experience

GBR laminated with extruded geomembranes will be compacted to reduce thickness due to the heat of GMB and pressure of calander. To avoid the reduction of thickness both products can be connected by an adhesive film. Normal or simple galvanized steel corrodes in contact with activated swelling nonwoven, but no problems occur with special galvanisation or high graded steel. Permeability increases with rising temperatures of water or very dry air, like in desert conditions. However, the reasons are unknown. It may be that a high rate of evaporation on the nonwoven surface reduces the water content of the swollen particles. The sealing slime becomes porous and increased vapour diffusion is added to the normal water flow rate passing the swelling nonwoven.

ADVANTAGES OF THE GEOSYNTHETIC BARRIER SWELLING NONWOVEN FOR THE CONTRACTOR

The low weight/unit area and the resultant low thickness of the swelling nonwoven reduces transport requirements to a fifth. On the construction site, no complicated or expensive unloading and placing equipment is needed. Its low weight simplifies the rolling-out and positioning of the swelling nonwoven. Cost for overlap can be cut by stitching the length of nonwovens (Mohr, 2003; 2008).

CONCLUSION

Almost every construction project is confronted with sealing problems. A secure sealing function is key for serviceability and load capacity of constructions in civil and underground engineering. The swelling nonwoven is not a standard product. Consequently, several special products with special details can be easily manufactured according to the requirements of the customer.

Corresponding author: Mr Peter Mohr, Geotex Ingenieur GmbH, Truderinger Str. 265, München, 81825, Germany. Tel: 0049-89-54808949. Email: pmohr@ib-geotex.de.

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