Geosynthetics, J. Kuwano & J. Koseki (eds)

GBR-S geosynthetic barrier – swelling nonwoven

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

ABSTRACT: Geomembranes or Geocomposite clay liners (GCL) are common as sealing for buildings, tunnels or to protect the environment. Both types have some shortcomings, which sometimes cause problems to the owners of sealed objects. So it was obvious to develop a new product, that we call Geosynthetic Barrier swelling nonwoven or GBR-S. 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 in an immersion bath. After excess material is squeezed off, the nonwoven is dried. So every fibre is coated with a layer of a polymeric swelling material. In contact with water, the swelling material absorbs the water, swells and fills the pores between the fibres. So the nonwoven becomes a sealing layer.

1 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 it is necessary for reservoirs too.

Geomembranes (GMB) or Geocomposite clay liners (GCL) are common for such purposes. But both types of sealing have some shortcomings. Most tunnels in Europe, sealed with Geomembranes are not tight. Larger ponds, sealed with Geocomposite clay liners need a water supply by rivulets to stabilize the waterlevel. Nevertheless producers or engineers are apparently satisfied with the state of the art.

Geomembranes are characterized as watertight. Joints between single layers are welded together and can be tested. Problems occur in edges or corners, where hand-welding must be done. Lifetime of Geomembranes will be shortened by stress or strain, which increase tensions in the polymeric structure.

Geocomposite clay liners are characterized as nearly watertight. GCLs consist of two geotextile layers with bentonite as a swelling agent in between. Joints between layers are made by overlapping, but problems may arise with the geootextiles covering the clay layer. The sealing capacity of the Geocomposite clay liner can be interfered permanently because of weather changes or ion exchange. Arising cracks in the Bentonit due to desiccation will not close by re-swelling.

For these reasons I commenced the development of an improved alternative to bentonite mats at an early date, basing my ideas on a single-layer nonwoven. 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, it was possible to sew granular Superabsorber into the pile of the fibres. At this time, thin nonwovens incorporating Superabsorber were already in use in the production of telephone cables.

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 the tests were therefore discontinued.

Discussions held in different working groups convinced me 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 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 variants, including paste-like Superabsorber, or SAP fixed chemically to the fibres, were investigated and rejected because they were either too expensive, or unlikely to succeed.

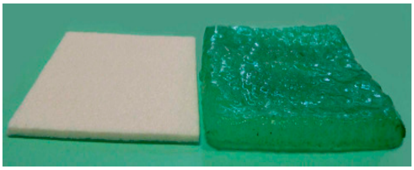

fig. 1: Dry and swollen swelling nonwoven

Since 2002, two different types of swelling nonwoven have been in production, differing in the properties of the swelling agent, ***fig. 1***. Since the drying of the impregnated nonwoven produced environmentally unacceptable fumes, development work was carried out on the swelling agent to alleviate this problem.

2 PRODUCTION

In its different forms, the swelling nonwoven is now a real alternative to welded geomembranes and GCLs. Their ability to swell and seal in salt water or under alkaline conditions enables swelling nonwovens to be used in applications where GCLs are unsuitable.

The nonwovens used a 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, as a certain minimum quantity of superabsorber is necessary to ensure watertightness.

The nonwoven passes through a bath containing a hydrophilic, polymer-based swelling agent. The innovation is recently developed by a large international chemical company. The agent is based on a novel type of polymere, made from well proved monomeric elements, whose long-term performance and ageing behaviour are well documented.

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. For example, one product type permits swelling to occur only within the nonwoven itself, whereas another allows swelling agent to remain on the surface of the product, enabling hair cracks to be filled or surfaces to be sealed. The propoperty can be also used in self-repairing sealing systems.

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. If area weights over 600 g/m² are required, the swelling nonwoven is produced in multiple layers.

3 PRODUCT VARIANTS

The nature of the production process results in a product with a less open surface than that of a conventional needle-punched nonwoven. Since the fabric has already shrunk in the drying process, no additional shrinkage problems occur during any subsequent laminating, or the sprinkling and hot-calandering of polymer particles.

The swelling nonwoven can therefore easily be laminated to films or geomembranes from any of the typical polymers, and in many applications, the resulting product can be sealed without welding the geomembrane. It is sufficient to place a granular protective layer on the membrane to act as a counterweight to the pressure generated during the swelling / sealing process, ***fig. 2***.

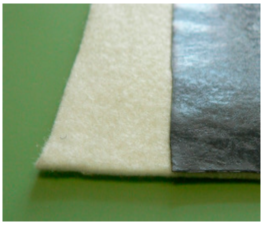

fig.2: Swelling nonwoven with polymer layer

Foams sprayed on one or both faces retard the swelling process in humid conditions, or in contact with fresh concrete, enabling the swelling nonwoven to be laid when it is raining. And placing concrete against a suitably treated swelling nonwoven poses no problems, since the treatment ensures that the moisture required during concrete curing is not absorbed by the nonwoven.

A rubber coating on one side reduces the risk of accidents on sloping surfaces. Swell treating both components of composites made from high-tenacity multifilament wovens and nonwovens enables higher tensile forces to be accommodated without the development of a water-transporting layer.

For tunnel construction, two layers of nonwoven can be needled together in such a way as to form insertion channels between the layers. Water fed into grouting tubes inserted into such channels activates the swelling nonwoven from within, and, if required, cement slurry or a gel can later be fed through the tubes, further increasing the confining pressure.

The surface of the swelling nonwoven can be made electrically conductive to enable high-voltage inspection of the membrane.

In a further product variant, one face of the fabric is coated with a polymer powder which is activated by contact with hydrocarboncontaining liquids such as gasoline or diesel, ***fig. 3***.

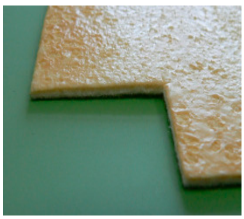

fig. 3: Swelling nonwoven with polymer powder

As a result of these different types of swelling nonwoven, there are solutions for almost every requirement.

4 CHARACTERISTIC PROPERTIES OF THE GEOSYNTHETIC BARRIER SWELLING NONWOVEN

The properties of the swelling nonwoven have been determined by laboratory tests at the Technical University of Munich (TUM) on the basis of basic principles for GCL's. The results of this suitability test are summarised in a test report that certifies the utilisability. In addition to general tests with geotextiles, also specific ones were carried out to simulate particular situations.

mass per unit area in g/m² according to DIN EN 965: dry / swelled / re-dried	*460 / 8300 / 410*
thickness in mm according to DIN EN 964 at surcharge: 2 kN/m³ – dry / swelled / re-dried 20 kN/m³ – dry 200 kN/m³ – dry	*2,2 / 7,5 / 4,5 1,9 1,3*
plunger force in kN according to DIN EN ISO 12236-1996: dry / swelled / re-dried	*1,8 / 1,1 / 1,7*

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 pressure in kN/m²	*approx. 200*

This value 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.

The swelling nonwoven accomplishes the requirements for sealings used in earth-moving, road construction and civil engineering with its low permittivity $< 5{,}0 \cdot 10^{-9}$ 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 completely swelling after re-contact with water, 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. The following table shows that the different atmospheric changes has no influence on the sealing properties of the swelling nonwoven.

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	$< 3{,}9 \times 10^{-9}$

5 PENETRATION TEST

To test the effectivity of 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 the swelling nonwoven is installed. The case of damage "punctiform damaged spot in the Geomembranes" 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.

In the following table, the deciding testing results are summarized according to the testing report composed by TUM. The manufacture of the nonwoven, the equipping with the swelling material and their accepting can be influenced by variations of manufacture. Therefore statistical spreads of the results are possible up to 10 %.

Liquid	*Testing time in [h]*	*Diameter of the face dispersion in [cm]*
deionised water	*1,5*	*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*

According to lab experiments each tested sample of the swelling nonwoven was activated within seconds by all used liquids. The maximum radial dispersion of the penetrated liquid amounts to approx. 2.5 cm (5 cm diameter), ***fig.4.***

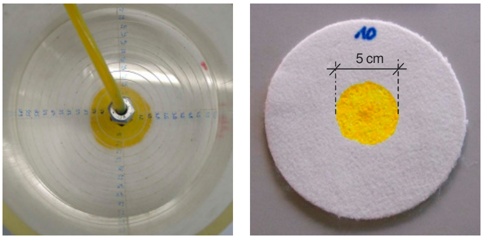

fig. 4: Sample during and after the penetration test

Thus neither salt water (up to 3 % sodium chloride) nor alkaline water with pH = 13, concrete 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.

A smaller dispersion is given if the pressure of the penetrated liquid increases slowly. This simulates a construction with drainage. After removing the drainage, the water penetrates with a slowly increasing pressure. The swelling material will be activated by the first water contact whereby the damage spot will be sealed. The slowly increasing pressure will not enlarge the dispersion, because the impinging water will be blocked by the just activated swelling material.

Tests over a 90-day period showed no increase over the short-term dispersion.

6 ADVANTAGES OF THE GEOSYNTHETIC BARRIER SWELLING NONWOVEN FOR THE CONTRACTOR

The low weight/unit area and the resultant low thickness of the swelling nonwoven reduce transport requirement 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. An overlap of 200 mm is sufficient on subgrades of good bearing capacity; the overlap must be increased on subgrades prone to deformation. Because it is light, the swelling nonwoven needs to be secured against wind by weighting it down.

Inclement weather such as light rain or snow do not impair the placing of the nonwoven, as surface activation delays the complete uptake of water in the product. A product treated to resist rain can be laid even in extremely wet conditions.

Additionally, the swelling nonwoven can be laid during frost periods. Ice does not activate the swelling agent, but sealing takes effect as soon as the ice melts.

If the swelling nonwoven dries out, a thin film-like layer forms on its surface. This layer exhibited a certain degree of impermeability in air-permeability tests, and it activates immediately on contact with water. The nonwoven then continues to swell gradually to its full extent.

7 CONCLUSION

Almost every construction project is confronted with sealing problems. A secure sealing makes the basis of serviceability and load capacity of constructions in civil and underground engineering. The Geosynthetic Barrier swelling nonwoven offers not only sealing solutions for standard situations, but also for any construction in which problems with unfavourable strains are encountered which may lead to failure.

The swelling nonwoven is not a standard product. Consequently several special products with special details can be manufactured specifically with the swelling nonwoven according to the requirements of the customer. Using the Geosynthetic Barrier swelling nonwoven, sealing problems in civil and in underground constructions belong to the past.

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