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Geosynthetic containers – a new field of application with nearly no limits

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ABSTRACT: “Geosynthetic containers” represent a rather young and developing field of application of geosynthetics in geotechnical and hydraulic engineering. Starting from the classical sandbags, today this term encompasses all elements that use a geosynthetic fabric as the material to enclose materials such as sand, concrete, waste material, etc. Often additional functions are provided, including filtration and reinforcement. The list of possible application is very long, with examples including: small elements filled with concrete; large bags; tubes; mattresses as impervious or protective linings; open and web-like structures in combination with plants; pillow mats; gabions or large containers for breakwaters or artificial reefs.

1 INTRODUCTION

Geosynthetics in the beginning – i.e. when the application of synthetic cloth in geotechnical structures began - were used predominantly as a sheet to separate two soil layers or as a filter replacing the traditional granular filter layer. After many years of extensive discussion, today a number of reliable design approaches are available and it is accepted that geotextiles perform well as separation or filter layer. If there are no analytical approaches for the design of a filter, there are several established tests to prove the ability of geotextile filters in difficult applications.

After establishing the feasibility and efficiency of geotextiles as filters, it was only a small step towards the application of geosynthetics as drains. Geomembranes were installed as impervious lining and special fabric was used as protection layers. For some years now, geosynthetic clay liners have also been used as an impervious lining. These applications were closely connected to landfill technology and geosynthetic clay liners have also in the meantime been applied as the lining in canals.

Later geosynthetics were found to perform very well as reinforcement. Many earth structures could be realised by taking advantage of the perfect interaction of geosynthetics and soil. Many systems are available today and the materials and structures of geosynthetic reinforcement are further developing.

In the packaging industry, synthetic fabric has also been used for a long time. So the idea of combining the two applications and introducing packaging or geosynthetic casing also for geotechnical use did not take long to be realised. Actually, this was being done already when taking synthetic cloth as the material for sandbags that are used in the field of flood protection at rivers or at the coast. Sandbags can be called the first geosynthetic containers.

Geosynthetic containers (also called "geosystems"; Pilarczyk 2000) are really multi-purpose elements. They can be manufactured according to any demand. All forms, all sizes, all materials are used to meet the specific requirements of the individual task. The containers are prefabricated, thus providing a constant quality, and mostly filled on site. Today most of them are made from woven or nonwoven geosynthetic cloth as it is used for filters in geotechnical applications or for soil reinforcement, but natural material such as jute or coir can also be used. The number of applications is permanently growing. In the following, an overview over applications of today will be given, going from thin to large. But by no means can it be complete.

2 THIN ELEMENTS

The placement of geosynthetic filters under water usually needs special devices to keep the cloth spread out without wrinkling and to sink it on the ground. The sheet will float, due either to the material itself that is used, e.g. polypropylene with a unit weight less than water, or to air bubbles trapped within the fabric. The traditional coastal installation of filters is done with fascine mattresses. Willow bundles are tied upon the fabric to keep it spread out. Stones are dumped upon it to sink it and keep it in place under water. In rivers, lakes and canals it is placed without willow bundles by special devices and again kept in place by dumping stones upon it. Besides the problem of floating, currents and waves will hinder the proper placement of a geotextile filter (as is the case when a grain filter is used).

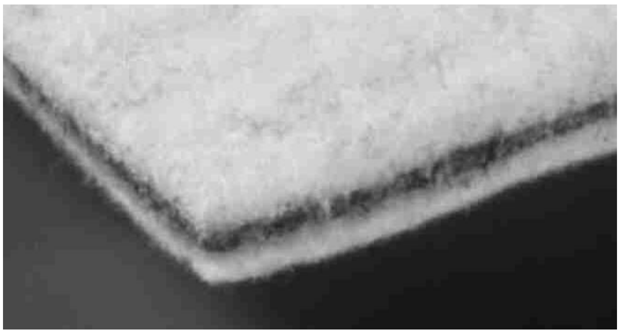

Figure 1. Geocomposite "Sandmat" (Photo: NAUE)

To overcome the difficulties mentioned, a "sandmat" was invented that might be called a thin geotextile container (Fig.1). Sand or another mineral fill, e.g. granulated metal slag with a high specific weight, is kept in between two geosynthetic sheets. The two geosynthetic sheets are either needle-punched or sewn together to keep the fill in place. Such sandmats filled with 5 kg/m² sand have proved in tests to remain in place when loaded by currents up to 0.6 m/s. The maximum fill weight available today is 9 kg/m² increasing the resistance of the filter against currents up to 1 m/s.

Similar in structure but manufactured for a completely different application are the geosynthetic clay liners (GCL), now called clay geosynthetic barriers (CGB). Again a mineral fill, mostly bentonite, is contained between two geosynthetic sheets, forming an impermeable liner for landfill, groundwater protection, canals etc.

Figure 2. Geocomposite "Clay Geosynthetic Barrier"

3 FLAT ELEMENTS

The many kinds of mattresses form another group of geosynthetic containers. They confine a greater volume than the thin elements mentioned above, but like these they cover a large area. They can be filled with sand, concrete or mortar. And they can also be placed "endlessly": the base and top sheet of two prefabricated mattresses are sewn together as needed and only then is the assembled mattress filled.

Figure 3. Impervious concrete mattress (Photo: HUESKER)

When filled with concrete, an impervious lining can be achieved (Fig. 3). The fabric is not only the envelope but also a certain reinforcement. While the outer cloth may be weakened by weathering, the inner cloth is well protected. Mattresses filled with sand are used as a protection layer, e.g. to protect the geosynthetic membrane of a landfill.

Open and grid-like concrete mattresses are found in erosion protection (Fig. 4). The openings allow for vegetation to be planted, while the grid provides the shelter against erosion. After a short time these mattresses are overgrown completely.

If a certain flexibility and permeability of a concrete mattress is needed, mattresses consisting of columns and rows of "pillows" are used. The seams between the concrete-filled pillows provide the necessary permeability of the layer and the desired flexibility. These mattresses are often used for scour protection measures, since due to their flexibility they are able to follow the deformation of the subsoil.

Figure 4. Erosion protection by grid mattress (Photo: HUESKER)

Since all such mattresses are first placed and then filled, the problem of the fabric floating, as mentioned previously with the geosynthetic filter, has to be considered when placing the mattress under water. Up to a certain size, mattress elements can be prefabricated, but then the advantage of the "endless" mattress, i. e. no overlaps or open joints, is lost.

4 LONG ELEMENTS

Other elements that can be manufactured and placed "endlessly" are geosynthetic tubes. They are found in bank protection in rivers and at the coast, as dikes in tidal mark for land reclamation, as the core of groynes and longitudinal dikes, and in many other predominantly hydraulic structures. For these applications, the geosynthetic tubes are filled hydraulically with sand. Often the kind of applications allows for local unclassified material that helps keep the costs low.

Figure 5. Geosynthetic tube as liquid tank (Photo: BRADLEY)

Geotextile tubes and large containers as described in the next paragraph are also used with success as casings to be filled with sludges or slurries. Dredged material, sewage sludge or other liquefied soil material to be deposited is pumped into a geosynthetic tube. This method saves disposal area, usually large containment areas confined by dikes. Permeable but soiltight geotextiles of sufficient strength have to be used to allow the fill to dewater and to withstand the inner pressure of the fill. To guarantee a sufficient dewatering, special attention has to be paid to the filter design, since simple rules do not apply (Gaffney 2002). Tubes made of strong impermeable material are used as storage tanks for liquids (Fig. 5). Such tubes filled with water are applied as barriers like a rubber weir in rivers to protect roads and buildings from being flooded (Fig.6).

A very new application are vertical geosynthetic tubes filled with sand as "sand piles" in soft ground (Fig. 7). A closed steel tube is driven or vibrated into the soil down to a stratum with sufficient bearing capacity. Then the geosynthetic tube is dropped into the steel tube, filled with sand and then the steel tube is opened at its lower end and pulled out with vibration, thus compacting the sand in the geosynthetic tube. In this way, an economic non-rigid pile foundation is built. Such sand piles act simultaneously as a vertical drain, but the main purpose is to transport the load of a superstructure to a deeper bearing stratum. To bear the strong circumferential tensile stress, these tubes are manufactured seamlessly, which is also very innovative for geosynthetics, since the seam had proved to be the weakest point.

Figure 6. Geosynthetic tube for flood protection

Figure 7. Vertical geosynthetic tubes, "Sandpiles"

5 VOLUMINOUS ELEMENTS

Voluminous elements are those geosynthetic casings that might be best associated with the word "container", i.e. cuboidal elements of limited length, limited width and limited height but of a wide range of sizes from very small (decimeter) to very big (decameter).

One of the best known applications of geosynthetic elements filled with a soil material and the origin of the development of all geosynthetic containers are sandbags. They have been long known, for example, as immediate scour repair of dikes during storm surges, as protection against rising water during floods, as protection or confinement of sand boils at the landside of dams and dikes, or as a toe filter. In some cases the bag and the fill should be permeable, in other cases impermeable. The traditional use of sand bags as an immediate protection measure has been further developed to well designed structures using geosynthetic bags or containers. Today, all sizes of "bags" are available up to very large ones with a volume of 200 m³ and more.

Small elements filled with concrete, for example, are used to repair pitched revetments or walls when an irregularly shaped stone has to be replaced with minimum joints. The bag filled with concrete that is not set yet, will still fit perfectly in the void space and adapt to the neighbouring stones.

Gabions are a very open type of containers, filled with larger stones to provide stability to steep slopes or to protect bank and bottom of a river or coastal banks from erosion. Originally wire meshes were used, but today synthetic material is available with high strength and high resistance against weathering and mechanical impact like abrasion. Special pre-planted elements are available for bank protection (Fig. 8). A strong geosynthetic mesh forms the outer envelop of the element. Inside, large stones provide the stability against the hydraulic load and porous slag retains moisture when the water level is low. Plants that can live in water alone are planted in between and a filter holds back the slag and the plants. This way, the revetment is integrated in nature from the very beginning.

Figure 8. Preplanted geosynthetic revetment elements

Sand bags can be used as a temporary cover layer, for instance for bank protection. The lifetime is limited due to weathering. Under water, weathering is not much of a problem, so they can be used, for example, for scour protection at bridge piers. In 1997 in Germany, geosynthetic containers of 1 m³ volume were used this way in an estuary to protect bridge piers and dolphins (Fig. 9). Placement was successfully done even with a maximum flow velocity of 2 m/s. Around the bridge piers, the geocontainers were covered by an armoured layer, but around the dolphins near the bridge, the geocontainers were left without armour. Even here, no erosion or degradation of the geosynthetic casing has been detected to date.

Traditional, large, single elements for scour protection and repair are fascines, usually large willow bundles that have a core of rubble or riprap, to provide a sufficient resistance against the current. The great advantage of fascines is the fact that they are made of willow, which is a regenerative raw material. With a long tradition, there are many procedures for fabricating and placing fascines. But there remains always the problem of guaranteeing a constant quality of material and fabric. Especially the requirement of acting as a filter cannot always be fulfilled in the desired manner. So elements are needed that combine the required filter capacity with sufficient weight to resist the hydraulic load:

geosynthetic containers can meet these requirements. By choosing an appropriate fill material and a well designed geotextile for the casing, these elements can resist the hydraulic load and protect the subsoil by acting as a filter.

Figure 9. 1 m³ nonwoven geotextile container

Geosynthetic containers can also be installed to form a filter layer when it is impossible to place a granular filter or geotextile filter. Neither a grain filter nor a geotextile filter can be placed when the flow velocity is too high. Often the current is too strong even for placing fascine mattresses or sandmats as described above. With an appropriate size and fill, geosynthetic containers may be placed even with high flow velocities. Model tests in a flume with stacked geocontainers (3 layers to a height of 1.8 m) proved stability up to an overtopping flow velocity of approximately 4 m/s and a mean velocity of 1.5 to 2 m/s (Pilarczyk & Zeidler 1996).

The possibilities of geosynthetic containers to build a filter layer when loaded by waves and currents can be judged from the stabilisation of probably the largest scour ever at the German coast (Heibaum 1999). 1m³ geocontainers were used to build up the filter layer on the slopes of a scour hole as deep as 25 m below the sea bottom. In the upper part the slope was as steep as 1:1, so it was impossible to place a fascine mattress. During the works, the flow velocity of the tidal currents was as high as 2.5 m/s, and the final revetment had to sustain flow velocities of up to 5 m/s.

To provide a flawless filter layer, it is essential that there are no gaps between the elements, so usually two layers are required. Furthermore, the amount of fill should not exceed 80% of the theoretical volume, since tightly filled geocontainers will not adjust themselves to the subsoil, to structures, or to the neighbouring geocontainers. With nonwoven geocontainers even rather steep slopes may be covered due to the high friction angle of the fabric (Fig. 10).

Figure 10. Coastal protection with geotextile containers (Foto: WWF)

The choice of a nonwoven geotextile for geocontainers will also minimise the risk of damage during placement due to its high strain capacity. By allowing large deformations it will be able to withstand the impact load when hitting the ground as well as when stones are dumped upon it. For sufficient robustness during installation and service, a minimum mass per unit area of 500 g/m² and a minimum tensile strength of 25 kN/m are recommended. To obtain a double line of defence concerning the filter effect, the fill of a geocontainer should be graded according to grain filter rules. Such a grain filter in a geosynthetic container may even be of a widely graded grain size distribution, since no segregation will take place when the granular material is dumped in a container.

The size of a geosynthetic container has to be chosen such that the expected hydraulic load will not remove or transport the container. For special applications, very large containers - as large as a split barge – are used (Fig. 11). The ship's hold is lined by one geotextile, the hold is filled, then the geotextile is sewn and dumped on the sea or river bottom. In this way, artificial reefs can be built, or longitudinal dikes or other forms of an active scour protection, or dams for land reclamation, etc.

Figure 11. Geotextile container in a split barge (Foto: NAUE)

6 SUMMARY

The term "geosynthetic containers" encompasses all elements that use geosynthetic cloth as casing. Geosynthetic containers can be manufactured thin but covering a large area like sandmats or clay geosynthetic barriers with a fill of sand or bentonite respectively. Similar to these, but with a thickness of up to 80 cm, are mattresses which are employed as protection layers against mechanical impact, as impermeable linings or as erosion protection. (Horizontal) tubes are used as storage tanks for liquids, barriers filled with water or sand, deposition facilities for slurries, cores of dunes and dikes that can be filled with sand or unclassified material. Vertical tubes are installed as soil improvement and vertical drains. The largest variety of application is with bags. They are applied as armour, ballast, filter, storage, core for hydraulic structures as mentioned with tubes, flood protection, scour repair and protection, improvement of earth dams, and there are many more applications. Since the geosynthetic material can be manufactured precisely according to the planned application, great reliability of the structures built with geosynthetic containers can be achieved. Further development can be expected, since geosynthetics allow for applications with nearly no limits.

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