COST EFFECTIVE CONSTRUCTION METHODS USING GEOSYNTHETIC CONTAINERS

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ABSTRACT: The term "geosynthetic containers" encompasses all elements that use a geosynthetic fabric as the material to enclose materials such as sand, concrete, waste material, etc. Such elements include bags of all sizes, tubes, mattresses of different shape, gabions and more. Many applications have been developed from traditional construction methods with natural material like rubble mound, wood, natural fibres. The use of construction methods incorporating geosynthetic containers have often resulted either in better structures with increased resistance, extended lifetime or shorter construction time, or in lower costs for structures of the same quality, or even both simultaneously. The paper presents an overview of elements with geosynthetic casing and their possible applications, concentrating on hydraulic structures and coastal protection works. Examples of cost effective applications are given, comparing traditional and alternative construction methods. Examples in coastal protection show that sometimes geosynthetic containers only allow for protection measures at reasonable costs.

1 GENERAL

1.1 *Introduction*

Geosynthetic containers (also called "geosystems"; Pilarczyk 2000) are multi-purpose elements that 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 filled on or near the site. Today most of them are made from woven or nonwoven geosynthetic fabric, but natural material such as jute or coir can also be used in several applications.

The list of the use of containers, primarily in structures involved in soil-water interaction, is very long. The elements may be filled with air, water, sand, mortar, or waste. Often additional functions are provided: for example, the casing may be designed as a filter, or it may be used as reinforcement.

1.2 *Container classes*

To group the large variety of containers, four classes will be introduced: bags, tubes, mattresses and sheets, i.e. voluminous elements, long elements, flat elements and thin elements (Fig.1).

1.2.1 *Voluminous elements / bags*

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

The origin of the development of all geosynthetic containers are sandbags. They have been long known, for example, as immediate scour repair of dikes or as protection against rising water during floods. Big bags up to 1 m³ are used to transport bulk material. At up to 2.5 m³ they are used for hydraulic structures and protection work.

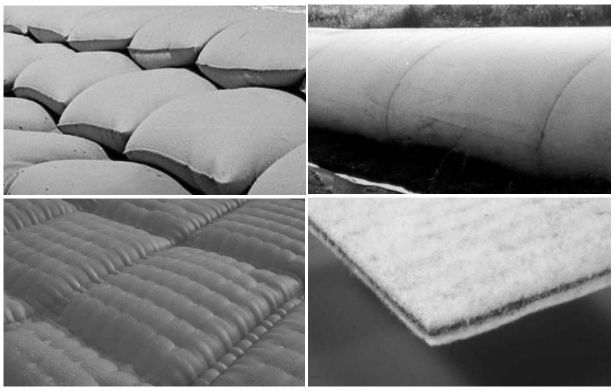

Figure1 Container classes - clockwise: bag (voluminous), tube (long), sandmat (thin), mattress (flat)

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.

For artificial reefs, breakwaters and other special applications in hydraulic engineering or dams for land reclamation, very large containers of 200 m³ fill or more are used.

1.2.2 *Geosynthetic tubes / long elements*

Geosynthetic tubes are long elements installed in bank protection works in rivers and at the coast, as dikes for land reclamation, as the core of groynes and longitudinal dikes, etc. They are also used as casings to be filled with sludge or slurry to dewater those materials for easier final deposit. And with a watertight casing they serve as liquid tanks or flood protection, similar to rubber weirs.

1.2.3 *Mattresses / flat elements*

The many kinds of mattresses form the group of flat elements. With concrete filling, an impervious lining can be achieved, open and grid-like concrete mattresses are installed for erosion protection. Articulated mattresses ("cushion mattresses") provide flexibility. When installed as a protection layer sand fill is also used.

Similar to gabions but with a mattress-like geometry are "stone mattresses" with a casing made of geogrid.

1.2.4 *Thin elements / sheets*

Thin elements like sheets containing a fill material in between two geotextiles also belong to the container family even though they are rather thin. Examples are the sandmat and the geosynthetic clay liner. The sandmat provides immediate protection and hinders floating of a geotextile filter, the geosynthetic clay liner is used as a flexible impervious lining.

1.3 *Reflections on the container material*

1.3.1 *Raw materials*

For a safe placement, for high serviceability and for sufficient long term resistance, the container material has to be chosen such that it will resist all loads to occur. The most often used raw materials are polypropylene and polyester – other material is used when special attributes are required, e.g. very high strength or chemical resistance. Natural material is used if degradation of the casing after some time does no harm or is even desired.

1.3.2 *Fabric*

As casing for geosynthetic containers, both woven and nonwoven materials can be chosen in all classes. Woven geotextiles have the advantage of high tensile strength, nonwovens the advantage of large straining capacity. If the casing material is damaged, a woven cloth might be more susceptible to crack propagation (the zip effect) than a nonwoven. By allowing large deformations nonwovens will be able to withstand easier the impact load when hitting the ground or when stones are dumped upon them. Wovens need rather high strength to achieve the same resistance. The nonwoven fabric exhibits a higher angle of friction than the woven and should be chosen if stability against sliding of the geocontainer has to be guaranteed.

When a container has to sustain abrasive forces due to rocking armour stones or due to bed load transport, the casing needs appropriate resistance against this type of loading.

Often containers are used in such a way that they are exposed to sunlight at least some of the time. So the fabric has to show sufficient resistance against weathering in general and against UV radiation in particular.

If a permeable system is used, special attention has to be paid to the design of the filter. Even though there are a lot of design proposals for nonwovens, only few are reliable in cases of dynamic hydraulic loading, i.e. pulsating and reversing flow through the geotextile filter. The development of excess pore water pressure in the subsoil due to the fast change in the hydraulic head on the outside complicates the proper filter design (Köhler 1993). The filtration capacity of woven geotextiles is often limited to narrowly-graded grain size distributions. A nonwoven fabric can be designed for nearly any given grain size distribution of the subsoil. Filter rules are given by Holtz, Christopher and Berg (1997), but still there is a lot of discussion about the "best" geotextile filter (Lafleur & Rollin1996). According to Schulz (1993) the geotextile filter may be the more 'open', the lower the coefficient of uniformity. Often tests are considered the best way to find the appropriate filter in cases of turbulent and reversing flow (BAW 1993).

1.3.3 *Seams*

Special care has to be taken concerning the seams of the container. On three sides, the seam is prefabricated at the manufacturer's. Therefore a strength approximately as high as the geotextile itself is guaranteed. The container is usually closed by sewing double chain stitch seams at the top. The reliability of seams is improved, if one seam is straight and the second one is curved to allow for straining of the geotextile if the first seam is broken. A new development is closing nonwoven containers by Velcro. Such seams can only be opened by destroying the fabric.

1.3.4 *Spacers*

When mattresses are used, spacers are needed to keep the upper and the lower cloth parallel to each other. 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 considerable hydraulic pressure inside the mattress at the toe.

Figure 2 Filling geosynthetic containers (courtesy Geofilters Australia)

1.4 *Filling the container*

One of the advantages of building with geosynthetic containers is the possibility of using locally available fill material, thus keeping the costs low. Additionally, it is necessary to develop an effective fill procedure for the intended application that is fast but does not overstress the fabric, especially when large units are used. However, with some skill, such filling plants can be rather simple but very effective.

When filling the container, the bottom of the container should remain on the ground (or in a mould, Fig.2), and it may be appropriate, e.g. when containers with more than 1 m³ of fill are used, to be laterally sustained. Otherwise excessive stressing and straining during the fill process may be the result.

If bags or containers are to be handled with clam shells or similar tools, coarse fill material (e.g. gravel only) will cause damage to the fabric more easily than finer fill. So coarse material should be mixed with finer grains to reduce the stress on the fabric.

Tubes and large containers are often filled hydraulically. Even though this procedure is basically simple, it needs care in any case. So the dewatering openings have to be properly applied (and closed after filling), and in cases of filling on the ground, a situation where the underlying soil material is washed away has to be avoided by, e.g. applying an extra sheet of geotextile underneath.

For special applications, very large containers of 200 m³ fill and more are used. These containers are placed by split barges. Either the ship's hold is lined by one large geotextile sheet, filled with an excavator, closed by sewing and then dumped. Or the container is hydraulically filled.

The latter method has the advantage that no long seams have to be closed on site, but only one small inlet and one small outlet opening.

When using geocontainers as the core of a hydraulic structure that will be protected by an armour layer, the amount of fill should not exceed 80% of the theoretical volume, to allow a proper adjustment to the subsoil, to structures or to the neighbouring geocontainers. When placed without an armour layer, agitation by flow or waves will cause flapping. Permanent flapping may result in fatigue failure of the casing. Therefore geosynthetic containers without an armour and exposed to cyclic loading should be filled completely to avoid flapping of the geotextile.

1.5 *Placement*

The placement procedure is often the hardest mechanical load of a geosynthetic product during its lifetime (Heibaum 1998). When installing containers, it is often not possible to handle them with special care, so it is essential to chose an appropriate casing material that will withstand that impact. On the other hand, the demand of high strength for placemen should not be cost decisive, so the installation procedure has to be chosen carefully.

Single geosynthetic containers are mostly placed by an hydraulic excavator. For elements up to 1.5 m³ clam shells with soft edges are appropriate while for lager elements special buckets are used. To place such containers precisely in large depth, special equipment is necessary and available.

The placement of numerous containers won't be done element by element. Small containers can be placed using a belt conveyor. In large rivers and in the sea, a stone dumping vessel might be appropriate, but then a conveyor belt type should be used to minimize the abrasive forces acting on the cloth. If only a push-type is available, a sand layer under the containers is necessary to reduce the abrasion impact.

Placing mattresses that are filled on site creates extra problems. The fabric will float before it is filled. But only these mattresses have the advantage of being installed "endlessly", i.e. no overlaps or open joints in the area to be covered, so special equipment is needed.

Up to a limited size, mattresses can be prefabricated or assembled in the dry. Such mattresses are placed by special cranes and need overlaps or special measures to bridge the joint between the mattresses.

2 COMPARING TRADITIONAL AND ALTERNATIVE CONSTRUCTION METHODS

2.1 *Methods of placing a filter under water*

A filter on the sea floor beneath an armour layer could either be a granular or a geosynthetic filter. Placement creates problems in both cases, mostly due to currents and waves. But omitting the filter and only covering the subsoil by an armour layer means wasting money. Without a filter, the armour material will sink into the subsoil due to dynamic hydraulic actions and the missing cover has to be replenished until such an amount of armour material is piled that the hydraulic load at the interface subsoil-armour is so low that no further erosion or liquefaction takes place.

2.1.1 *Granular filters*

As to granular filters, it seems to be easy to place a mineral filter layer by just dumping it on the surface to be protected. But quite often placement proved to be difficult as well. Two significant difficulties have to be considered:

The first one is the gradation of the filter material. Only very narrowly graded material can be dumped through water. When using a broadly graded filter material, the finer fraction takes longer to reach the bottom than the coarser fraction, causing material segregation. Thus a 'reverse filter' will be created: the fine material on top (which is no filter, actually). If a narrowly graded material is used, dumping is possible, but several layers with increasing grain diameter are needed to create a reliable filter between subsoil and armour, increasing the costs significantly.

The second one is the erodability. At least the first filter layer consists of grain sizes not significantly larger than the subsoil, so the material may be eroded nearly as easily as the subsoil. Only in lakes or canals with no (or nearly no) flow can a granular filter be placed reliably.

2.1.2 *Geotextile filter*

A geotextile filter is placed under water either by sliding it from a pontoon, holding it near the bottom by a guide-bar and ballasting it immediately or by rolling it up above the water, submerging the roll and unrolling the sheet under water. Both procedures ask for special equipment. Without this, the geotextile filter will always float, since polypropylene is lighter than water and must float. But even Polyester, a material with a unit weight higher than water, will float due to the air bubbles trapped in the fabric when sinking the sheet.

Another problem can be insufficient friction at the geotextile-subsoil interface on a slope. This has been experienced when using the traditional type of bottom protection in coastal protection works, i.e. the fascine mattress. For such mattresses, usually a woven geotextile is chosen as a base and a filter with fascines tied on it. With increasing steepness, the danger of a mattress sliding increases. For such applications a geocomposite fabric is available: a nonwoven fabric for filtration and friction combined with woven material for tensile strength.

To overcome the problems related to geotextile filters, the stability used to be increased by attaching heavy iron chains at the edges of the filter cloth (Zanke, 1994). But such a measure is rather time and cost intensive. To ease placement, the "sand mat" was invented. This is a geocomposite that might be called a thin geotextile container: Sand or another mineral fill, e.g. granulated metal slag with a high specific weight, is confined between two geosynthetic sheets. The two geosynthetic sheets are either needle-punched or sewn in short-distanced rows to keep the fill in place. Such sand mats filled with 5 kg/m² sand have proved 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 to 1 m/s. The sandmat can be placed with the usual placing equipment for geotextile filters, thus saving costs compared to the extra treatment mentioned above. But the equipment has to be sufficiently strong to carry the higher load.

When both a geotextile filter – even when placed as a sand mat - and a granular filter cannot be installed properly because of being shifted, folded, turned or eroded before it is covered by an armour layer, elements are needed that will be stable against the current, that do not undergo any alteration during the placement process and that provide the filtration capacity needed. Such elements are geotextile containers with a casing designed as a geotextile filter and filled with sufficiently permeable material.

When using geosynthetic filtering containers, reliable and cost effective systems can be built. Hydraulic loads like waves and currents will not impede or even hinder the installation of an effective filter.

2.2 *Bank and bottom protection with mattresses*

In hydraulic structures, "mattresses” are used in many places. They serve as protection of banks in large rivers, large canals, estuaries and at the coast. They are used for bottom protection of waterways and harbours and they serve for foundations of breakwaters, barriers and other hydraulic structures. Following the development, they can be grouped in fascine mattresses, stone mattresses and geosynthetic mattresses.

In coastal protection works, the traditional type of bottom protection is the fascine mattress, also called sinker mat. For such mattresses willow bundles tied up with a diameter of 10 to 40 cm are used. In the old days fascines and brushwood were combined into a mattress, the brushwood acting as a filter. Fascine mattresses can be prepared in all sizes, but usually they are effective only when larger areas are to be covered. If they have to be placed around structures like groynes or piers, either some smaller fascines can be placed, overlapping each other, or one large fascine is manufactured with a gap. The great advantage of fascines is the fact that they are made (preferably) of willow which is a regenerative raw material. But with such material there remains always the problem to guarantee a constant quality concerning material and fabric. The mat is dragged to the place where it is to be sunk and stones dumped on it to keep it in place even under severe dynamic hydraulic loading. This method is applicable on a horizontal sea floor or on mild slopes, it can not be used if the subgrade is very uneven or significantly inclined.

Traditional stone mattresses are made of riprap or smaller stones filled in a wire mesh basket. They are thinner than the possibly better known gabions, but cover a larger area. They are very versatile elements concerning the shape of the single element as well as the shape of the whole cover layer. Their stability against all hydraulic loads is very high, since the basket keeps the fill in place while loose material like rip rap would be washed away from much lower hydraulic impact. Stone mattresses are prefabricated or - in the dry only - filled in place. If placed in the dry, they can be connected to each other, thus creating a continuous armour layer. Prefabricated mattresses can be manufactured up to a few square metres only, due to the weight. Stone mattresses are endangered by corrosion of the wire mesh and abrasion. So the long term stability is limited. Abrasion is due to sediment transport or due to the relative movement of the mesh and the armour elements. The mattresses cannot be filled so tightly that the stones do not agitate at all under the hydraulic load. Stone mattresses need a filter underneath like rip rap or similar armour layers.

Both types of mattresses can be improved using geosynthetics. For a long time, woven geotextiles for fascine mattresses have been used as a base and as a filter with the fascines tied on it. The fascines ensure the spreading of the geotextile and the floating of the mattress while the geotextile acts as a filter and adds tensile strength. A brushwood layer is still added, however, when it is necessary to protect the geotextile from mechanical impact. Since the geotextile is usually a woven fabric, it is difficult to design it correctly as a filter. Therefore the filter can be improved by using a geocomposite of woven and nonwoven fabric. A nonwoven fabric also increases the friction angle at the interface of fabric and subsoil.

Stone mattresses are today also made from polymer wires. With polymers corrosion is no problem, but abrasion remains a threat to the stability of such structures.

A perhaps better solution is provided by concrete mattresses with geosynthetic casing that have no similar predecessor. Such elements also belong to the family of geosynthetic containers. Usually they are filled on site, which might create difficulties due to the floating of the fabric before being filled. But they have the advantage that continuous armour layers without overlaps can be built.

Mattresses of uniform thickness and filled with impermeable mortar are used as an impermeable lining, but they are inflexible. To achieve a certain flexibility and permeability, articulated 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.

As with fascine mattresses with a woven base, a nonwoven casing provides only a limited friction angle at the interface of fabric and soil. But the cement grout penetrating the fabric causes some extra friction.

Block mattresses are made by casting concrete blocks on a woven or nonwoven geotextile. They are similar to stone mattresses, but incorporate the filter layer. Their advantage is the combination of armour and filter in one element, but they can be manufactured with limited area weight only. Such mattresses are usually assembled in the dry and placed by special cranes.

2.3 *Scour protection using geosynthetic containers instead of fascines*

Fascines are traditional large single elements for scour protection and repair (Fig.3). Large willow bundles are assembled with a core of rubble or riprap. Due to their size and weight they provide a sufficient resistance against the current. The advantage of using willow, the regenerative raw material, was mentioned already with the fascine mattresses. 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 to prevent erosion of the bottom soil of a river or in coastal environment cannot always be fulfilled in the desired manner. Fascines will not function as a filter. Only coarse soil may be retained efficiently by fascines. Erosion may be slowed down due to the damping of the erosive effect of the current, but it will not be stopped. Therefore elements are needed that combine the required filter capacity with sufficient weight to resist the hydraulic load: geosynthetic tubes and containers can meet these requirements.

Figure 3 Preparing fascines for scour countermeasure

Such elements are geosynthetic containers. They can be prepared with the same size and weight as fascines, but with a geosynthetic casing that is designed as a filter. The only demand as to the fill material is sufficient permeability to allow the water to drain. To improve the filter reliability, the fill can be designed as a granular filter. Sometimes the geosynthetic casing is used solely as a containment for filter material, as for example was done for the foundation of the piers of the Oosterschelde storm surge barrier (The Netherlands). Filtering geosynthetic containers are covered by an armour layer in many cases. But as long as there is not heavy bed load transport, they even can be left without armour. With great success groynes have been built with extra resistance against UV degradation but without an extra armour layer (Hornsey et al. 2002).

2.4 *Breakwaters, artificial reefs and groynes*

Breakwaters and artificial reefs are detached structures that are built in the sea in front of the coast while groynes stretch from the coast into the sea. All structures are intended to alter the wave and current attack of the coastline and to change the transport capacities both along and perpendicular to the coast. The traditional construction material is rock or rubble mound. If such material is not available, concrete elements are used. Such structures are loaded by external and internal water motion and have to be designed accordingly. Breakwaters and groynes are built either low-crested, i.e. some overtopping will take place under design conditions, or submerged. Artificial reefs are always submerged.

When planning such structures, the environment, the construction method, operation and maintenance have to be taken into consideration. There are several design approaches (e.g. Pilarczyk 1990), but still there is discussion about the correct design of the armour elements of such structures (Melby / Kobayashi 1998). One problem is ageing and deterioration of the armour material and the risk that the peak of a storm might be higher than the design assumption and then the armour elements will be transported.

To overcome such shortcomings, geotextile containers in a large variety of forms have been used for the last ca. 20 years to build coastal protection structures. Predominantly in Australasia such structures have been developed to such a stage that they can be regarded as providing a standard solution and not only an alternative construction method. In several cases, the traditional materials and their impacts and costs were hardly acceptable and therefore the geosynthetic solution (without an additional armour layer!) was preferred (Hornsey et al. 2002). The first structures incorporated geosynthetic tubes. But since any damage to a single long tube will cause the failure of the whole structure, a trend in recent years has been to deploy containers of limited length but still of a size that no hydraulic impact can remove these elements.

Geosynthetic containers today are filled with sand – in the early days concrete was used as fill – and this gives several advantages: using locally available sand for fill keeps the costs rather low. The sand fill allows limited deformation of the container, so the container can adapt to an uneven subsoil and to the neighbouring element. Avoiding any hard elements and sharp edges that could pose some health and safety risk to swimmers, surfers and beach goers increases the leisure value of those parts of the beach needing a protection structure. The porous fabric of nonwoven casing makes it an ideal platform for marine growth like seaweed and the whole structure offers a habitat for many marine creatures. To increase the resistance against mechanical impact and UV degradation, composite material can be used that allows sand to be entrapped in the outer part of the fabric. Thus geosynthetic solutions for breakwaters, artificial reefs or groynes deliver high reliability at low costs.

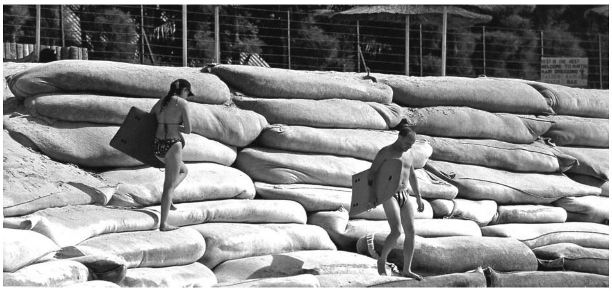

Figure 4 Geosynthetic containers for beach protection (WWF 2000)

3 UNRIVALLED PROTECTION WORK USING GEOSYNTHETIC CONTAINERS

3.1 *Coastal protection of sandy islands*

The armour of coastal protection work is made of rock, if available. Alternatively concrete elements are installed, but mostly causing higher costs. Such solutions are not possible if there is neither rock nor concrete available and transport distances are to long to carry or ship the armour material. For example, this happens on Islands in the South Pacific. On these islands coastal erosion endangers the beaches that are an attraction to tourists and therefore guarantee the living of the islanders. If these beaches were to vanish, so would the tourists, the most important economical factor in this region (WWF 2000, Fig.4). Geosynthetic containers helped to solve the dilemma. The fabric is lightweight, so transport costs were limited despite the large amount of containers needed. Sand as a perfect fill material was locally available in any quantity and local labourers were easily taught to fill the containers correctly with simple equipment. Once filled and closed, the containers have sufficient resistance against heavy hydraulic impact from currents and waves. In this case, geosynthetic containers proved to be the only solution to the problem of guaranteeing beach stability, and therefore the livelihood of the inhabitants through tourism.

3.2 *Scour repair*

After severe scouring at the Eider storm surge barrier in Germany, with the scour hole progressing towards the structure, geosynthetic nonwoven containers proved to be the only applicable solution to stop scouring and provide protection in the future (Heibaum 1999). The barrier is opened to allow low and high tide to pass except during storm surges. The structure, including the sea- and landside bottom protection, was built inside a temporary polder, accepting the disadvantage of a short bottom protection.

During a longer period of repair work the southern opening of the barrier was closed and caused severe scouring due to the increased velocity and the added bending of the tidal flow. A scour hole with a maximum depth of 31 m below MSL developed, i.e. a 'hole' of approx. 25 m below the original sea floor. Progressive erosion at the barrier-side slope of the scour hole caused had already caused failure of the edge part of the bottom protection. So an urgent stabilization measure was needed.

To fill the scour hole with seabed material dredged from further out at sea would have been very economical. However, this was rated impossible due to the fact that the barrier could not be closed long enough to refill and cover the scour hole. It was therefore decided not to refill the hole but to protect the barrier-side slope of the scour, even though it had an inclination of 1:1 in the upper part due to some "reinforcing" clay layers in the sandy subsoil.

The main problem was the placement of a filter under the armour layer as mentioned generally above. A geosynthetic cloth could not be placed properly and a granular filter would be eroded before it could be covered. Fascine mattresses could not be used due to the risk of sliding on

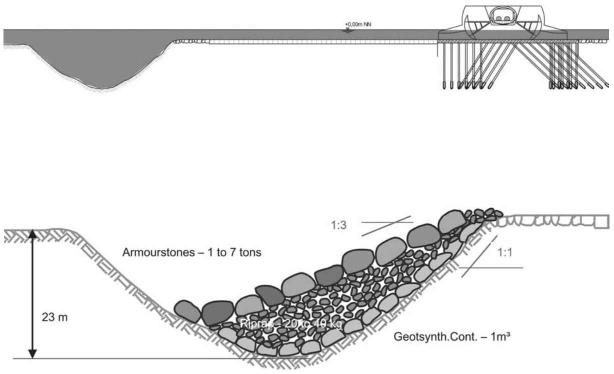

Figure 5 Scour-hole at Eider storm surge barrier
cross section of scour and barrier (top)
slope protection of scour hole (bottom)

the steep slope. Placing only armour material, large enough to withstand the erosive forces of the tidal flow, would not guarantee long-term stability of the protection measure, since the fine sand would be eroded through the armour stones.

Finally, the perhaps only solution possible was found to combine the resistance of larger elements against hydraulic loads and the filtration capacity demanded: Geotextile nonwoven containers (volume ≥ 1 m³) filled with granular material were dumped from bottom to top on the slope of the scour hole and covered with fill and armour (Fig.5). This layer of geosynthetic containers had sufficient resistance against the hydraulic loads until the final armour system was installed. The nonwoven fabric was designed as a filter versus the subsoil and provided a high angle of friction of geotextile and subsoil to prevent sliding. Other advantages of a nonwoven fabric have been mentioned already.

3.3 *Flood barrier*

Increasing rain intensity in recent years has caused flooding in many parts of the world. In many cases it would be an effective first countermeasure to erect merely a low wall around houses or industrial plants to prevent them from being affected. But there is the necessity of erecting such a wall nearly instantaneously, since the flood rise is quite rapid in most cases. The solution could be an impermeable geosynthetic tube around a house or at least in the lower parts of the ground. The tube can be filled with water rather quickly and will then act like a rubber weir (Fig.6). The ground on which the tube is placed should be as smooth as possible to avoid underflow. Certainly this cannot be a long lasting countermeasure, but often it is extremely important just to gain some time – this can be provided by this method.

Figure 6 Geosynthetic tube as flood barrier

4 SUMMARY

The use of geosynthetic containers is still a relatively new science, however a number of approaches for planning and design are available (e.g. Pilarczyk 2000). Increasingly often, geosynthetic containers can replace other elements in many structures, especially in hydraulic works. They can be adapted to the individual application in form, strength and permeability. Often they result in lower costs compared to traditional construction methods. They allow easy adaptation to local conditions in respect of preparation, filling, transport and installation. Until now, there is a large number of examples in operation that prove the long term stability of both the material and the entire structure. However, a great deal can still be learnt from the few cases of failure and from any new structure. So taking into account the advantages in so many cases, everybody should be encouraged to think about such alternative construction methods.

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