CHAPTER 164

GEOTEXTILE SYSTEMS IN COASTAL ENGINEERING- an overview -

Krystian W. Pilarczyk, M.Sc.[1]

Abstract

Geosystems has gained popularity in recent years because of their simplicity in placement and constructability, cost effectiveness and their minimum impact on the environment. An overview is given on application of the existing geosynthetic systems in hydraulic and coastal engineering.

Introduction

Various structures/systems can be of use in coastal engineering, from traditional rubble or concrete systems to more novel methods as geosystems and others. There is a growing interest both in developed and in developing countries in low cost or novel methods of shoreline protection particularly as the capital cost of defence works and their maintenance continues to rise. The shortage of naturl rock in certain geographical regions can also be a reason for looking to other materials.

The geotextile systems as bags, mattresses, tubes and containers filled with sand or mortar, and artificial seaweed and geotextile curtains, can be a good and mostly cheaper alternative for more traditional materials/systems as rock, concrete units or asphalt. These new systems were applied successfully in number of countries and they deserve to be applied on a larger scale. Because of the lower price and easier execution these systems can be a good alternative for coastal protection and coastal structures in developing countries. The main obstacle in their application is however the lack of proper design criteria. An overview is given on application of the

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[1] Manager R&D, Rijkswaterstaat, Hydraulic Engineering Division, P.O. Box 5044, 2600 GA, Delft, The Netherlands, Fax +31-15-2611361

existing geosystems and reference is made to the design criteria.

Systems and applications

Geotextile systems utilize a high strengt synthetic fabric as a form for casting large units by filling by sand or mortar, or as curtains collecting sand. At this moment there is a relative large number of products of this type on the markt provided by some specialistic companies all over the world.

The following types and applications of geosynthetic systems can be distinguised:

1. Closed forms/units filled with sand, gravel or mortar: bags, mattresses, tubes, containers
2. Open-matting bags filled with stone or asphalt
3. Geotextile forms/moulds sand-filled structures
4. Geosynthetic sheets for dune reinforcement
5. Geotextile curtains for shore erosion control
6. Artificial seaweed mainly for scour prevention
7. Silt fences with various applications (pollution)
8. Geocells for surface (slope) erosion control
9. Geocomposite mats for drainage/erosion control
10. Traditional applications as geotextile filters
11. Water- or air-filled dams
12. Other (unclassified) systems (bearer for blockmats, temporary slope protection, landfill covers, cabling, pins, pipes, connections).

More informations on these systems can be found in (Pilar czyk, 1995, Pilarczyk & Zeidler, 1996) and in references.

Geosynthetic forms

Mattresses are mainly applied as slope and bed protection. Bags are also suitable for slope protection and retaining walls or toe protection but the main application is construction of groyns, perched beaches and offshore breakwaters. The tubes and containers are mainly applicable for construction of groyns, perched beaches and offshore breakwaters.

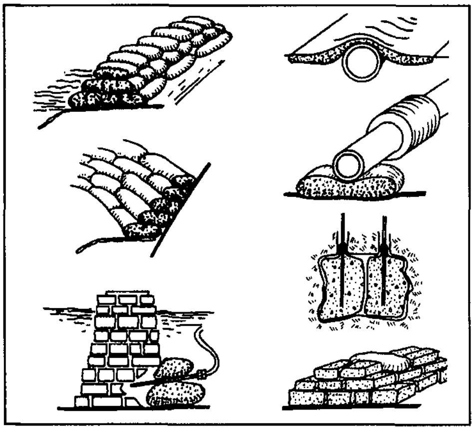

Figure 1. Application of bags

They can form an individual structure conform some functional requirements for the project but also they can be used complementary with the artificial beach nourishment to increase its lifetime.Especially for creating the perched beaches the sand bags and /or sand tubes can be an ideal (often low-cost) solution for constructing the submerged sill (with a low wave loading).

Some coastal engineering concepts are shown in Figure 2. Underwater breakwaters and sills (purched beaches) are not easy to construct with traditional materials. In this respect (sand)tubes, although based on the same principle, are more advanced even by comparison with sandbags, which are only 1.0 to 5.0 m^3 in capacity and are time-consuming as concerns both manufacturing and installation while hydraulic filling of tubes provides a few hunderds m^3 of sand in few hours.

The sand-filled bags and /or tubes can be of use for constructing of groyns. Up till now there is no reliable design methods concerning the functioning of groyns. When the groyne will work satisfactorily such groyne can be strengthend additionally (if necessary) to get a permanent function. If not, the groyne can be easily demolished. In general, the sand-filled structure can be used as a temporary structures to learn the natural interactions/ responses, or as the permanent structures

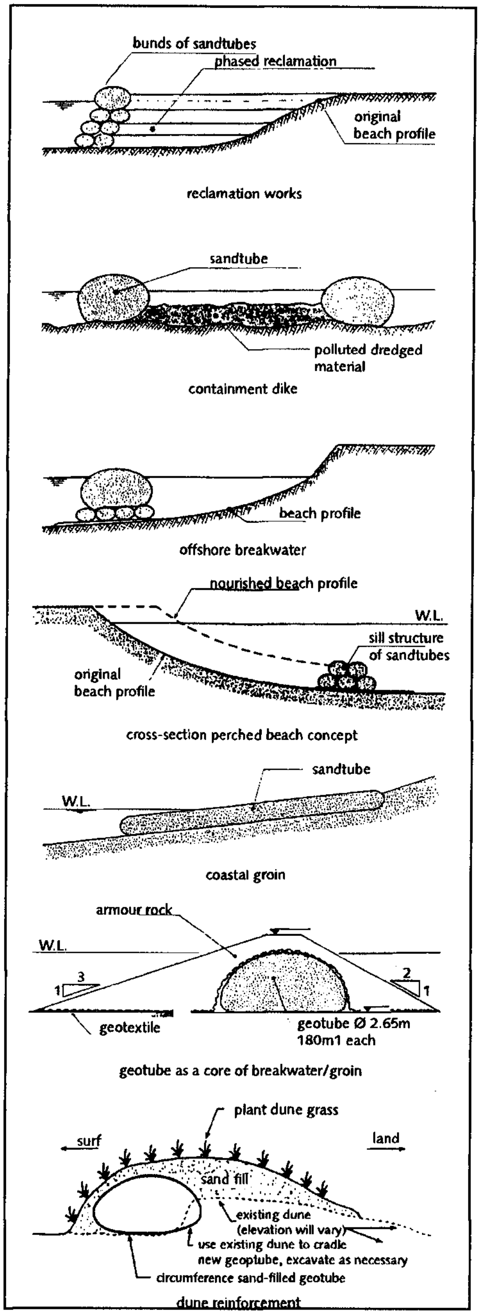

Figure 2. Coastal applications of geotubes/containers

at locations with relatively low wave attack (H<1.5m), or as submerged structures where direct wave forces are reduced by submergence. The units (if necessary) can be interconnected by bars or by creating a special interlocking shape.

These systems can also be applied in hydraulic/river engineering for constructing of spurdikes, guide dams, revetments, bottom groins, bottom protection, etc.. As other possible applications can be mentioned: containment dikes for storage of (contaminated) dredged material, dike or dune reinforcement, moulds for artificial sand structures, etc.

The main advantages of these systems in comparison with more traditional methods (rock, prefabricated concrete units, blockmats, asphalt, etc.) are: a reduction in work volume, a reduction in execution time, a reduction in cost, a use of local materials, a low-skilled labour and (mostly) locally available equipment.
That means that in most, not too extreme cases/conditions the werk can be done by a local contractor under supervision of the specialistic experts/company.

Geocurtains

There are a number of various applications of geocurtains, i.e. silt- and/or pollution curtains, guiding screens for sediment control in rivers and harbours, fences for surface erosion control, etc.
Information on these systems can be found in references.

An interesting application for shore erosion control is the geocurtain known under the name BEROSIN (Fig. 3).

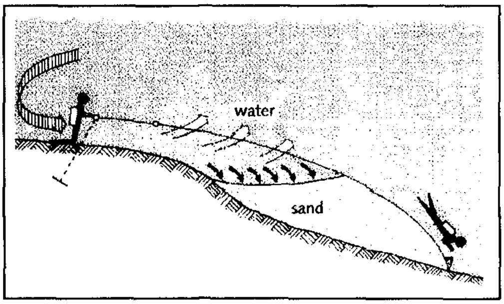

Figure 3. Application of geocurtains (BEROSIN)

The **BEROSIN** curtain is a flexible structure made of various woven geotextiles which after placing by divers near the shore and anchoring to the bed catches the sand transported by currents and waves providing accretion on a shore and preventing the erosion. The horizontal curtain (sheet) can be easily spread (at proper sea conditions) by a small workboat and two divers. The upper (shore-side) edge, equipped with some depth-compensated floaters, should be properly anchored at the projected line. The sea-side edge is kept in position by the workboat. By ballasting some of the outside pockets at the lower edge with sand or other materials and with help of divers, the lower edge is sinking to the required position. The proper choice of permeability of geotextile creates the proper conditions for sedimentation of suspended sediment in front/or under the curtain and at the same time allowing the water to flow out without creating too high forces on the curtain and thus, on the anchors. In case of coast of Vlieland (NL), some of the horizontal curtains placed in the intertidal zone have provided a growth of a beach/foreshore of 0.5 to 1.0 m within a week while others within a few weeks. It was also recognized that the sheets (curtains) can be easily damaged in vicinity of rock due to abrasion (one curtain was connected to the existing rock groyne). On the other hand, the heads of the existing groynes were badly damaged and the beach between the groynes was eroded during the storms while the area protected by the curtains remained in proper condition.

It seems that this system can provide a low-cost measure for steering of the morfological processes. However, more prototype experiments in various wave climate are needed before the final conclusions on the effectiveness and durability of this system in various design conditions can be drawn.

The most recent development concerns the application of a number of (anchored) floating screens (grids), placed in a certain pattern along the sea bed (Huygens et al, 1995). However, the first in site experiment has failed because of high wave induced forces and resulting anchorage problems.

Artificial seaweed

The field observations provided that in some coastal areas the natural seaweed plays an important role in retaining sand along the coastlines due to the reduction of the shear stresses exerted by currents and waves on the seabed. This fact was the base of the idea to produce and apply the artificial seaweed for erosion control.
The first users of artificial fibres for erosion control and/or to prevent marine scouring date back to the 60-ies (England, Denmark, Netherlands). The artificial seaweed was composed on polypropylene tape (having a specific gravity of less than one), 3 to 10 mm wide, connected edge to edge to form a continuous serrated sheet. In some cases dozens of tapes were bundled together to form individual tufts of seaweed. Fronds varied from 1 to 2 m in length. In the Netherlands, research on artificial seaweed has been conducted in cooperation with the Shell Plastics Laboratory, Nicolon Geotextiles Company and the Rijkswaterstaat (Dutch Public Works),(Bakker et al, 1972) The unproper anchorage was the main reason of the failures with this system .

The experience from US and European projects indicate that the artificial seaweed can be successfully applied for scour prevention around the legs of offshore platforms and around offshore pipelines when the anchorage is designed properly. Applications of artificial seaweed to beach erosion control were till now less successful. There were often no discernable differences between the shoreline protected with artificial seaweed and adjacent unprotected shorelines. The materials appear to be inadequate to survive moderate to high wave activity. One of the main reason for that was again the problem with anchoring (Rogers, 1987). Due to the high forces of breaking waves in a surf zone the necessary anchorage needs special expensive measures which makes this system less competitive with more conventional solutions.

The past experience with the artificial seaweed indicates that the most promissing application for this product is prevention of localized scour at offshore structures (platforms, pipelines, etc.). The wave induced currents are there of a limited strength (less problems with proper anchorage), because of larger depths no problem with UV-resistance, and less problems with effect of fouling and debris. That also explains why the recent developments and applications are related (limited) to that area.

The product which actually successfully operates on the markt for offshore applications has a form of a underwater artificial sea grass field/mats (developed in 80-ies), and is known as Seabed Scour Control System (SSCS, 1995). Based on the artificial seaweed concept of "arrested sedimentation" SSCS system (mat) suffers none of the drawbacks of similar previous systems. It has superb positional stability, it is not prone to phylloplankton colonisation, it requires no special tools or skills for installation and it actually serves to enhance its own effectiveness and that of other conventional sea defence forms.

The functioning principles are straight-forward; buoyant fronds floating upright from the seabed act to reduce seabed and near-seabed current velocities, encouraging the deposition of transported (eroded) seabed material. In conjunction with this action, at relatively shallow water the fronds also interfere with wave-induced orbital forces, effectively causing waves to break early and thus reducing the impact on threatend shorelines, breakwaters, etc.

This technique employs chemically inert materials to create a flexible barrier to retard the flow of water. The SSCS scour control mats are retained on the seabed by anchores hydraulically driven to a depth of 1 m. The system has been designed and tested for stability in current velocities in exess of 10 knots (> 0.5 m/s). The flexible fronds-mat can also be incorporated into flexible concrete block mats to provide added effectiveness in stability and in wave dissipation. The main applications are in protecting fixed offshore platforms, mobile rigs and pipelines from the effects of scour.

Stability of geosystems

The main obstacle in application of geosystems is the lack of proper design criteria. However, from the literature review it is possible to formulate some stability criteria based on small scale experiments. It can be concluded that the stability of the coastal structures composed of geosystems (bags, mattresses, geotubes) can mostly be expressed in the similar way as for rock, namely in term of $H_s/\Delta D$ parameter.

* Sand and mortar filled bags

For the time being it can be concluded that the stability of sandbags with the width-length ratio not larger than 1 to 3 and properly filled (> 70%), can be computed in the similar way as riprap. It is recommended to calculate the stability acc. to Pilarczyk's formula (Pilarczyk, 1990) with stability coefficient **c = 2.5**, nl.:

$$H_s/\Delta D = \mathbf{c} \cos\alpha \ \xi^{-1/2} \quad \text{for } \xi <= 3 \ ,$$

(for ξ > 3, the values calculated for ξ = 3 can be used),

where: H_s = significant wave height, Δ = relative density of the bags, $(\rho_s - \rho_w)/\rho_w$, D = average thickness of bags, **c** = stability coefficient defined at ξ = 1, $\cos\alpha$ = slope angle (it can be neglected for slopes milder than 1 on 3), ξ = surf-similarity parameter equal to $\tan a/(H_s/L_o)^{1/2}$, and L_o = wave length. The density of bags (ρ_s) can be assumed 2000 and 2300 kg/m^3 resp. for sand and concrete (Δ resp. 1 and 1.3).

Note: Sand-filled units exposed to direct wave attack are applicable till H_s = 1.5 m (max. 2 m).

* Stability of foreshore protection mattresses incl. sand-sausage mattresses (ProFix-mats)

For the first approximation of stability of sand- or mortar-filled mattresses (i.e. ProFix or Fabriform mats) of more or less uniform thickness the formula proposed by Pilarczyk (1990) can be used:

$$H_s/\Delta D_{eq.} = \mathbf{c} \cos\alpha \ \xi^{-2/3} \quad \text{for } \xi <= 3$$

(for ξ > 3, the values calculated for ξ = 3 can be used) where: Δ = relative density of the mattress, $D_{eq.}$ = equivalent (average) thickness of mattress, **c** = stability coefficient defined at ξ = 1 (definition of other parameters is the same as above).

The value of coefficient '**c**' depends on the failure mechanism and the ratio between the permeability of the mattress and the permeability of the subsoil, k_m/k_s:

c = 3 to 4 when $k_m/k_s < 1$ with the uplift of mattress and deformation of subsoil as main failure mechanism, and
c = 4 to 6 when $k_m/k_s >= 1$ with the deformation of subsoil as the main failure mechanism.

The range of **c**-values follows from the research projects of Delft Hydraulics with placed block revetments/blockmats and different type of mattresses. It should be noted that the uplift can already start at **c** = 2, but it is so small and of such short duration that it will no result in a serious damage to the mattress protection. Therefore **c = 3 to 4** can be treated as a design value.
In special cases as large mattresses of temporary use and/or when some deformation of the subsoil can be accepted or the subsoil is more resistant to deformation (i.e. clay) the higher values of '**c**' can be chosen (max. 6). The research described in (Delft Hydraulics, 1975; large mattresses on circular island) can be illustration of such case. Using these high **c**-values the structure should be controlled on sliding, and in most cases it will require a special anchoring of mattresses.
Sand-filled units applicable till $H_s <= 1.5$ m.

* General stability criteria for geotubes filled with sand or mortar (Wouters, 1995)
Based on small scale investigations by Delft Hydraulics (Breakwater of concrete filled hoses, M 1085, 1973) and other literature informations, the following stability criteria for geotubes can be formulated:

- tubes on the crest (at S.W.L. or submerged) lying parallely to the axis of breakwater

$$H_s/\Delta\ B = 1$$

where B is the width (horizontal ovality measure) of a tube; one may roughly assume B = 1.1 D (original diameter of a tube).
Note: when the crest layer is composed of two tubes connected artificially to each other (i.e. re-bars) the equivalent width is equal to 2B.

- when the tube is placed perpendicularly to the axis of a breakwater the stability can be approximated by

$$H_s/\Delta\ L = 1$$

where L is the length of a tube.
Sand-filled units are applicable till H_s = 1.5m (max. 2m).

Due to the absence of reinforcement in the mortar filled units it is very likely that for long tubes (say longer than 3D) also cracks will occur; some reinforcement should be recommended or an equivalent length should be taken equal to L < (3 to 4) D.

Conclusions

The geotextile systems can be a good and mostly cheaper alternative for more traditional materials/systems. These new systems were applied successfully in number of countries and they deserve to be applied on a larger scale.

In the past the design of these systems was mostly based on rather vague experience than on the general valid calculation methods. Actually, more proper design rules have been established based on some scale investigations and experience from realized projects.
However, more research, especially concerning the large scale tests and evaluation of performance of already realized projects, is still needed.

The technologies related to geotextile systems have been utilized extensively in Europe, Northern America, Mexico, Japan and Australia, producing often successful installations but only few technical details. Some manufacturers and contractors are inclined to protect know-how to preserve market advantages. Therefore, to effectively commercialize these technologies it is necessary to uncover the technical details. Technically the methodologies have shown to be feasible but there are design and constructibility uncertainties that still must be addressed.

A number of weak points of above reviewed systems can be omitted when the actual knowledge/experience will be applied in the design and technological improving of these systems including such aspects as fabric choice, fabric coating, filling method, installation techniques, stability criteria, and life-time.

The intention of this literature search is to uncover, as far as possible, the technical informations on these systems and make them available for the potential users. It will help to make a proper choice for specific problems/projects and it will stimulate the further developments in this field.

There are more applications of geosynthetic (geotextile) systems in coastal engineering than those mentioned above. It is going too far in the scope of this paper to review all of them. However, the main other applications can be found in the references.

There is a rapid development in the field of geotextiles and geotextile systems and there is always a certain time gap between new developments and publishing that in specialistic books. Therefore, it is recommended to follow the professional literature on this subject (Journal of Geotextiles and Geomembranes, Geotextiles Congresses, Coastal Engineering Congresses, etc.) and manufacturer's brochures for updating the present knowledge.

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