State of the art report - geotextiles in waterfront applications

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ABSTRACT:

A working committee (MarCom 56) of PIANC, the international navigation association, has prepared a report on the application of geotextiles in waterfront protection application. The committee consisted of geotextile experts from several countries, who have collected pertinent experience in their geographical areas. Previous guidelines have been evaluated and summarized.

The report is a guideline for application of geotextiles in the areas of waterfront, harbour works and coastal applications. An overview of applications, examples of executed projects, design requirements, and guidelines for the use of geotextiles in these specific conditions are given. It is prepared to be used by engineers considering the use of geotextiles in waterfront and coastal areas to replace or supplement traditional structures. It is also especially to be used by engineers in developing countries who have less experience with geotextiles in these applications. It contains an inventory of worldwide experience with examples.

1 INTRODUCTION

The Permanent International Association of Navigation Congresses (PIANC) is comprised of several commissions. Under the auspices of the commissions are Working Groups that are charged with preparing guidance documents on a variety of pertinent topics. MarCom is the Maritime Navigation Commission. The work described in this paper has been developed by MarCom Working Group 56 and is entitled "Application of Geotextiles in Waterfront Protection."

There has been an increased use of geotextile elements in hydraulic and coastal engineering since the first PIANC reports were prepared on the subject. These reports include Working Group 4 "Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles for Inland Waterways," 1987, Working Group 21 "Guidelines for the Design and Construction of Flexible Revetments Incorporating Geotextiles in Marine Environment," 1992, and Working Group 12 "Reinforced Vegetative Bank Protections Utilising Geotextiles," 1996. Additionally, improvements and innovations in geotextiles coupled with a longer history of successful use, require an updated guidance document.

Port and waterway managers may find it difficult to decide whether geotextiles and geosynthetic components are acceptable alternatives for classical waterfront structures. For example, geotextile filters can replace graded stone layers in some cases. Since there are a wide variety of geotextile types (e.g. woven, nonwoven or knitted, polyester and polypropylene, etc.), one of the most important responsibilities facing port, waterway and coastal managers is to independently determine whether a geotextile is a suitable alternative and what is the best geotextile for the application at hand. The design professional needs to consider cost, longevity, and performance of the geotextiles.

1.1.1 *Objective of the Study and Report*

The objective of Working Group 56 is to produce a relatively short guideline for application of geotextiles in waterfront protection. The objective is not to give detailed design procedures for such structures. For design procedures, the reader will be referred to existing literature on the specific topic. For example, an extensive book on this subject is "Geosynthetics and geosystems in Hydraulic and Coastal Engineering", by Pilarczyk (2000). At more than 900 pages, this book is not a short guideline. It was also found during this work effort that design philosophies differ subtly between countries, and various countries have produced excellent guidance documents or standards that have not been translated.

Heibaum, et. al (2006) describes the state-of-the-science in filtration and erosion control.

1.1.2 *Matters Investigated*

The Working Group 56 report is to provide an overview of the types of available geotextiles, types of structures, ranges of loads in which the structures can be applied (i.e. maximum waves and current conditions), considerations related to damage mechanisms such as aging and vandalism, what design aspects have to be considered, and construction and quality control. Also, environmental aspects are taken into account.

2 TYPES OF STRUCTURES DESCRIBED

Waterfront structures are used in coastal defense schemes with the objective of preventing shoreline erosion and flooding of the hinterland. Other objectives include sheltering of harbor basins and harbor entrances against waves, stabilization of navigation channels at inlets, and protection of water intakes and outfalls.

2.1 Sea dikes

Sea dikes are onshore structures with the principal function of protecting low-lying areas against episodic flooding. Sea dikes are usually built as a mound of fine materials like sand and clay with a gentle seaward slope in order to reduce the wave runup and the erodible effect of the waves. The surface of the dike is often armored with grass, asphalt, stones, block revetments or concrete slabs. Typical applications of geotextiles in sea dikes are as a filter layer at the outside slope of the dike, erosion protection at the inside of the dike, and as base reinforcement for weak subsoils.

A recent example of a sea dike design approach was in Grand Isle, Louisiana. An emergency dike was constructed by wrapping a clay core with geotextile and covering with sand. This design did not function well in areas subjected to nearly constant wave action.

Figure 1. "Geo-burrito" Grand Isle, Louisiana. A woven geotextile was used to wrap a clay core to provide emergency protection.

2.2 Revetments

Revetments are shoreline structures with the principal function of protecting the upland from erosion. Revetment structures typically consist of a cladding of stone, concrete, asphalt or stone-filled geogrid mattresses to armor sloping shoreline profiles. Geotextiles are often used to replace a graded stone/sand layer as part of the filter structure.

2.3 Seawalls

Seawalls are shoreline structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves. Seawalls are built parallel to the shoreline. Seawalls range from vertical face structures such as massive gravity concrete walls, tied walls using steel or concrete piling, and stone-filled cribwork to sloping structures with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble. Geosynthetics are used in seawalls for reinforcement or separation of fill layers

2.4 Bulkheads

Bulkhead is the term for structures primarily intended to retain or prevent sliding of the land, whereas protecting the hinterland against flooding and wave action is of secondary design importance. Bulkheads are built as soil retaining structures, and in most cases as a vertical wall anchored with tie rods, or in some cases geosynthetics.

Figure 2. Use of geotextile separation fabric under stone toe fronting a steel sheet pile bulkhead, Strathmere, New Jersey.

The most common application of bulkheads is in the construction of mooring facilities in harbors and marinas where exposure to wave action is minimized. Some reference literature may not make a distinction between bulkheads and seawalls.

2.5 Breakwaters

Breakwaters are designed to reduce wave action in the lee of the structure. Wave action is reduced through a combination of reflection and dissipation of incoming wave energy. When used for harbors, breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbor facilities. Breakwaters are also built to improve maneuvering conditions at harbor entrances and to help regulate sedimentation by directing currents and by creating areas with differing levels of wave disturbance. Protection of water intakes for power stations and protection of coastlines against tsunami waves are other applications of breakwaters. When used for shore protection, breakwaters are built in nearshore waters and usually oriented parallel to the shore. Breakwaters protecting beaches, harbors or channel entrances can be either detached or shore-connected. Geotextiles are used in breakwaters as part of the filter structure, as reinforcement, and also as sand-filled tubes forming the core of the structure.

2.6 Groins

Groins are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to net longshore loss of beach material. Groins function only when longshore transport occurs. Groins are narrow structures, usually straight and perpendicular to the preproject shoreline. The effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side; both effects extend some distance from the structure. Consequently, a groin system (series of groins) often results in a saw-tooth-shaped shoreline within the groin field and a differential in beach level on either side of the groins.

Sand-filled geotextile tubes have been used as "low profile" groins (see Figure 3). This type of groin differs from the traditional timber or stone groin in that it follows the existing profile in the surf zone allowing more sediment bypassing, and interrupts littoral transport in a reduced area of the beach, thus minimizing downdrift impacts.

Figure 3. Low profile geotextile tube groin, Stump Pass, Florida.

2.7 Reef breakwaters / artificial reefs

Reef breakwaters are coast-parallel, long or short submerged structures built with the objective of reducing the wave action on the beach by forcing wave breaking over the *reef.* Reef breakwaters are normally rubble-mound structures constructed as a homogeneous pile of stone or concrete armor units. The breakwater can be designed to be stable or it may be allowed to reshape under wave action. Reef breakwaters might be *narrow crested* like detached breakwaters in shallow water or, in deeper water, they might be *wide crested* with lower crest elevation like most natural reefs that cover a fairly wide rim parallel to the coastline. Sand-filled geotextile containers, bags and/or tubes are often used in this application.

2.8 Submerged sills

A submerged sill is a special version of a reef breakwater built nearshore and used to retard offshore sand movements by introducing a structural barrier at one point on the beach profile. However, the sill may also interrupt the onshore sand movement. The sill introduces a discontinuity into the beach profile so that the beach behind it becomes *a perched* beach as it is at higher elevation and thus wider than adjacent beaches. Submerged sills are also used to retain beach material artificially placed on the beach profile behind the sill. Submerged sills are usually built as rock-armored, rubble-mound structures or commercially available prefabricated units.

2.9 Pipelines

Pipelines in the coastal zone are typically used for outlet of treated sewage, transport of oil and gas from offshore fields, and water supply between islands/mainlands and across inlets. Typical types of pipelines are small-diameter flexible PVC pipes used for water supply and small sewage outfalls, large low-pressure sewage outfalls constructed of stiff reinforced concrete pipe elements up to several meters in diameter, and semi-flexible concrete-covered steel pipes used for high-pressure transport of oil and gas. Pipelines might be buried or placed on the seabed with or without surface protection, depending on the risk of damage caused by scour and flow-induced instability, or damage by surface loads from collision with ships, anchors, and fishing gear. Where significant changes in the seabed are expected, e.g., surf zones and eroding beaches, it is common to bury the pipelines to depths below the expected maximum eroded profile. In some cases it is prudent to provide scour protection due to uncertainty in predicting the eroded beach profile. Geotextiles with concrete blocks attached, or as a form for pumped grout are often used as protection and erosion prevention layers.

2.10 Pile structures

The most common pile structures in coastal engineering are bridge piers extending from the shore into the water where they are exposed to loads from waves, currents, and in cold regions, ice loads. The supporting pile structure might consist of timber, steel or reinforced concrete piles driven into the seabed, or of large diameter piles or pillars placed directly on the seabed or on pile work, depending on the bearing capacity and settlement characteristics of the seabed. Large diameter piles would commonly be constructed of concrete or be steel pipes filled with mass concrete. Offshore, pile structures support oil platforms or can be the foundation for wind turbines ("monopiles").

Large geotextile bags were used as temporary scour protection during the construction of the Sutong Bridge in China (Bittner, et. al, 2005). The use of bags allowed the river bed to be protected while boring the piles.

3 DESIGN CONSIDERATIONS

For each structure type described, the Working Group 56 report identifies a variety of design and construction issues that are relevant. Since all of the structures identified are in the proximity of the waterfront, hydraulic loading (tides and waves) is a primary concern. Often, the geotextile must combine sufficient permeability with soil retention characteristics.

Geotextile properties are discussed including physical (thickness and mass per unit area for nonwovens), hydraulic (permeability), mechanical (tensile strength, elongation, puncture, burst and tear strength), themal and durability (weathering, oxidation, stress cracking) properties. Other factors such as durability, maintenance, safety, social and environmental acceptability and cost are discussed. In many structure types, the geotextile is simply one component of a larger system and must be evaluated as a whole. In structures that rely almost solely on the geotextile to contain fill material or is in direct contact with the environment, durability and function over the life of the project is paramount.

Mechanical and hydraulic loads must be determined, and then used to define the index properties of the geotextile. For example, if puncture, in the form of debris during a storm is anticipated, the selection of the geotextile would include a minimum puncture strength. There are a variety of puncture test standards available from organizations such as ASTM, European Standards (EN) and ISO. Often, the choice of minimum values will be determined from a review of the published index properties of the class of suitable geotextiles. As one index property increases (such as puncture resistance), the designer may find that another index property (such as permeability) may decrease. The selection of geotextile may be a trade-off of minimum properties, or a different class of geotextile is required.

In the case of large sand-filled geotextile tubes, designers have been working to develop outer layers that can resist damage during storms. Outer layers have included fabric shrouds sewn to the tubes, rock placed over the tubes, and more recently, a polyurea coating sprayed on the tube at the factory. This coating adds to the durability of the tube, but also increases cost and alters the tube filling procedure.

In some design scenarios, the engineer may require performance testing in addition to index tests. This is particularly true for structures having very long design lives. An example of this would be if damage to the geotextile during construction is anticipated. An installation test would be devised using the actual fill materials (such as a quarry run blinding layer or amour layer, and dredged sand core material in an embankment) and construction methods to be employed. This testing could check for the adequacy of the overlap of seamed joints, abrasion and puncture. Once exhumed the geotextile could then be tested for its remaining tensile strength and hydraulic properties. If damage to the geotextile is excessive, changes to the construction method of the class of geotextiles should be considered.

4 CONCLUSIONS

Geotextiles are similar to other manufactured construction materials in that they each have certain properties and must be used in the design in the correct way. It is therefore imperative that the design professional be familiar with the functions of geotextiles. Geotextiles have been used with much success over the last 60 years, and it is the intention of PIANC Working Group 56 to provide port, coastal and waterway managers with an overview of pertinent uses, and guidance as to the selection of geotextiles in structures.

Since the geotextile marketplace is constantly evolving, the manager must be familiar with the classes of geotextiles that are available and their function, so that new innovations can be utilized to their full advantage. Additionally, assurances through testing are available to the design engineer, and should be required on coastal and waterway projects.

REFERENCES

Bittner, R.B., Safaqah, O., Zhang, X., & Jensen, O.J. 2005. Design and Construction of the Sutong Bridge Foundations. *Proceedings - DFI Specialty Seminar, Marine Foundations.*

Heibaum, M., Fourie, A., Girard, H., Karunaratne, G.P., Lafleur, J. & Palmeira, E.M. 2006. Hydraulic Applications of Geosynthetics, *Proceedings 8ICG, Geosynthetics*.

Pilarczyk, K.W. 2000. *Geosynthetics and Geosystems in Hydraulic and Coastal Engineering.* A.A. Balkema, Rotterdam, Netherlands.