GUIDELINES FOR CONCEPT DESIGN

FIBERTEX GEOTEXTILE SAND CONTAINERS

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Author(s)	Esteban Escobar-Valencia
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V1	8-July-2021	Eric Fernagu	Project Director	

RECIPIENTS

Name	Entity
Burger Fourie	Fibertex South Africa
Lancelot Austin Woolley	Fibertex Nonwovens
Mikael Møller	Fibertex Nonwovens
Nicolas Racana	Fibertex France SARL

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1 - INTRODUCTION

Geotextile sand containers (GSC) units are essentially geotextile bags filled with sand or other materials used to mitigate erosion mitigation caused by the action of waves, tides, currents and other water movements acting on erodible structures. The consequences of erosion can range from a simple loss of soil surface to scouring and collapse of structures.

Geocontainers aim at creating a stable and permeable massif to mitigate erosion. The product made of nonwoven filtering geotextile and local sand has high hydraulic characteristics allowing to take into account a constraining hydraulic environment. The size of the geocontainers and the choice of the geotextile has to be driven by local conditions and more specifically relate to the hydraulic and the implementation constraints.

Among the various types of geobags existing on the market, FIBERTEX has designed a product and a filling process for these geobags called FiberRock®. Today, Fibertex has limited documented return of experience in terms of specific design for this product.

FIBERTEX intends to apply these solutions in Europe and more especially in France. The purpose of the document is to introduce guidelines for the preliminary design of technical solutions using GSC, with the aim to mitigate erosion, ensure coastal stabilization or riverbank reinforcement.

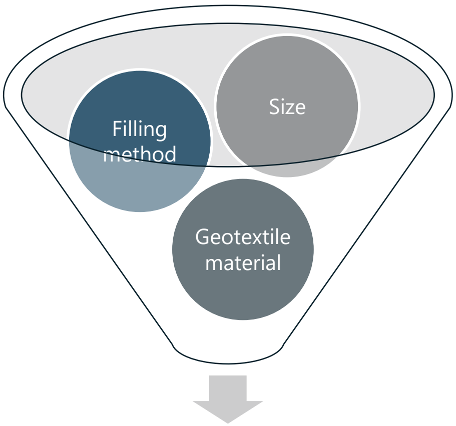
In order to assist the engineers/ sellers and clients in the proper selection of the products and then in its design, a computer tool, in the form of an Excel spreadsheet calculator, was developed for the preliminary design of FiberRock® structures. The objective of this document is to provide technical information in order to explain the theoretical framework/hypothesis/parameters used on the spreadsheet calculator. The present guideline describes the main mechanical properties and their influence on the hydraulic stability of the structures. This document is not a detailed design manual and as such does not address in detail all factors that may affect the related detailed design.

In conclusion, the Worksheet calculator provide a **first pre-design estimation** of CSG structures. **The worksheet calculator can only be used for information purpose. This application of the worksheet cannot replace detailed design studies (including any potential necessary wave flume studies) required to validate design assumptions based on the site conditions.**

Egis is not responsible for any claim by FIBERTEX or any third party that may result from the use of tools developed in this project. The conditions which apply to the use of this document are described in Section 6.

2 - GSC UNITS

In general, the choice of the range is the combination of three criteria represented in the following diagram (Figure 1). These elements are defined in the following sections.



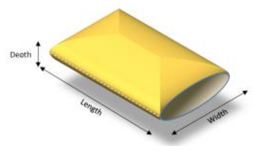
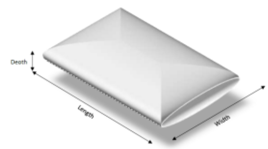
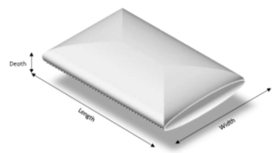
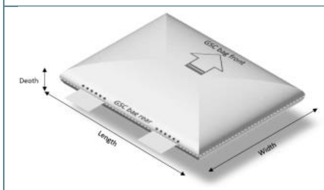
FiberRock Containers range

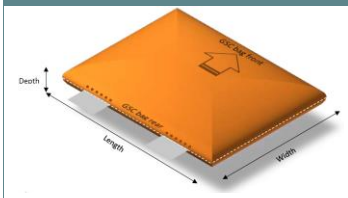
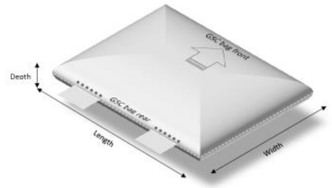
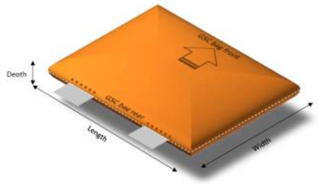
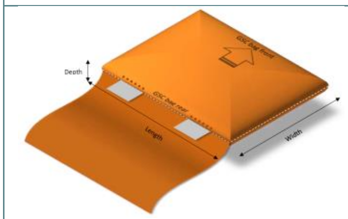
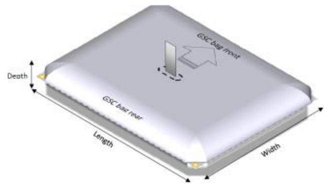
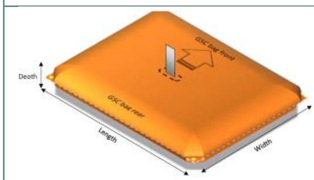
FIGURE 1 – SELECTION CRITERIA OF FIBERROCK CONTAINERS RANGE: SIZES, FILLING METHOD AND GEOTEXTILE MATERIAL

2.1 - Size description of FiberRock products

The geotextile sand containers once filled with wetted out sand and ready for placement with suitable equipment will have the following characteristics (assuming a minimum filling ratio of 80%):

TABLEAU 1 – RANGE OF FIBERROCK GEOTEXTILE SAND CONTAINERS

	FIberRock Product	Characteristics
	**20S** Dimensions – 0,55 m X 0,3m X 0,3m Standard Volume – 0,2 m^3	Manual filling S index for standard single layer Approximately 70kg
	**30S** Dimensions – 1,2m X 0,8m X 0,3m Standard Volume – 0,3 m^3	Manual filling S index for standard single layer Approximately 400kg
	**75S** Dimensions – 1,7 m X 1,45m X 0,4m Standard Volume – 0,75 m^3	Manual filling S index for standard single layer Approximately 1400kg
	**100S** Dimensions – 2,2 m X 1,4m X 0,4m Standard Volume – 1 m^3	Mechanized filling S index for standard single layer Approximately 1800kg

	FIberRock Product	Characteristics
	**100V** Dimensions – 2,2 m X 1,4m X 0,4m Standard Volume – 1 m^3	Mechanized filling V index with Anti-vandal layer Approximately 1800kg
	**250 S** Dimensions – 2,3 m X 1,8m X 0,6m Standard Volume – 2,5 m^3	Mechanized filling S index for standard single layer Approximately 4000kg
	**250 V** Dimensions – 2,3 m X 1,8m X 0,6m Standard Volume – 2,5 m^3	Mechanized filling V index with Anti-vandal layer Approximately 4000kg
	**250 F** Dimensions – 2,3 m X 1,8m X 0,6m Standard Volume – 2,5 m^3	Mechanized filling F index for anchor flap option with Anti-vandal layer Approximately 4000kg
	**250 SX** Dimensions – 2,3 m X 1,8m X 0,6m Standard Volume – 2,5 m^3	Hydraulic filling X index S index for standard single layer Approximately 4000kg
	**250 VX** Dimensions – 2,3 m X 1,8m X 0,6m Standard Volume – 2,5 m^3	Hydraulic filling X index V index with Anti-vandal layer Approximately 4000kg

2.2 - Main principles of filling and installation

GSC can be filled in various ways, mechanically or hydraulically, or by hand. The main filling methods are illustrated in Figure 2. Whatever the filling method used, the most important criteria in terms of design if the filling ratio achieved.

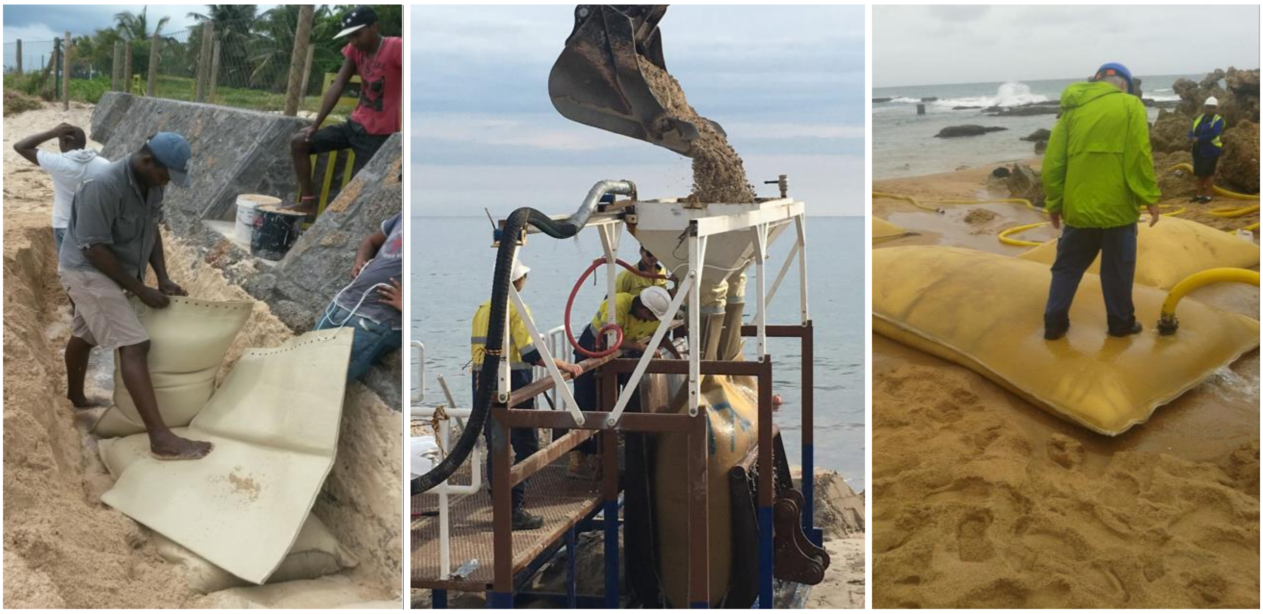


FIGURE 2 – FILLING METHOD: (A)MANUAL, (B)MECHANICAL AND (C)HYDRAULIC

Associated with the above, various methods for installation could apply:

- manually or mechanically after filling, if this filling is manual or mechanical
- if the filling is hydraulic, mechanically after filling or units preplaced manually before filling.

Placement of GSC can be done using a hydraulic crane equipped with a lifting frame or large grab, on land or on water. Land-based placement may be less suitable for dykes that are difficult to access, or have inadequate stability. For large scour holes it is also possible to dump geotextile bags with a side stone dumper or split-bottom barge. In using the latter method, one has to ensure that no sharp edges are present in the barge that could damage the geotextile bags during dumping. Dumping of geotextile bags has also been done using dump-trucks. For more details, see Appendix A.

2.3 - Material description

The product FiberRock GSC are manufactured from needle-punched nonwoven filter geotextiles. In addition to single-layer (S index) nonwoven GSCs for covered applications, double-layer (V index) nonwoven GSCs are available. These two layers are assembled by needling and this composite material constitutes the premium version of the FiberRock® range (Figure 3). The Anti-Vandal layer is made from heavy, coarse highly UV stabilised polypropylene fibres which are designed to trap sand particles and promote growth of natural marine vegetation which enhances its durability characteristics.

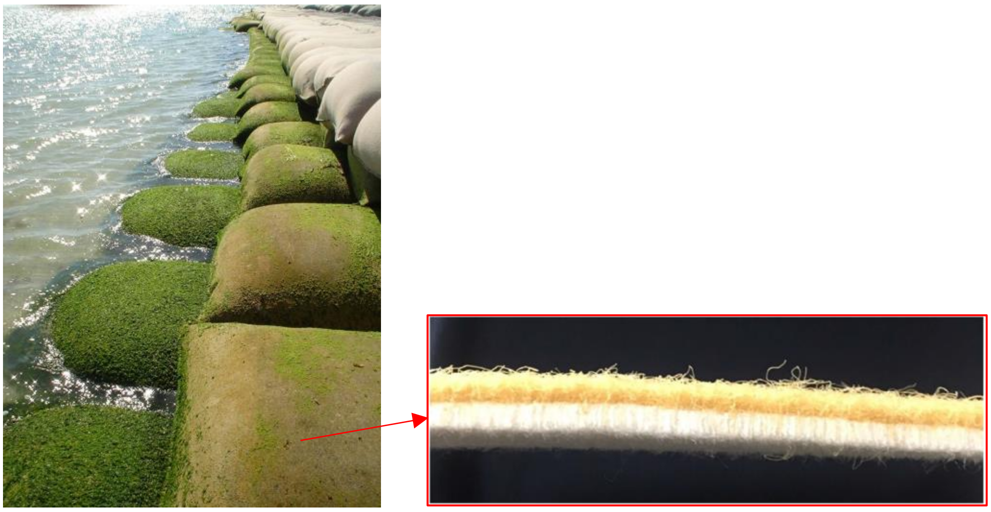


FIGURE 3 – EXEMPLE OF GSC NATURAL MARINE VEGETATION AND CROSS-SECTION PHOTOGRAPH OF THE COMPOSITE GEOTEXTILE MATERIAL (V INDEX)

Temporary geotextile bag structures do not always have to be covered. For permanent structures it is necessary to prevent ageing of the geotextile skin by UV light and the bags are covered with double layer material. When used at greater water depth (as in scour holes) no cover is needed since the effect of UV light is low under water. However, a cover layer could be useful against vandalism and other mechanical damage when the geotextile bags are used as exposed surface protection. The Worksheet calculator include the input parameter fallowing the next chart flow:

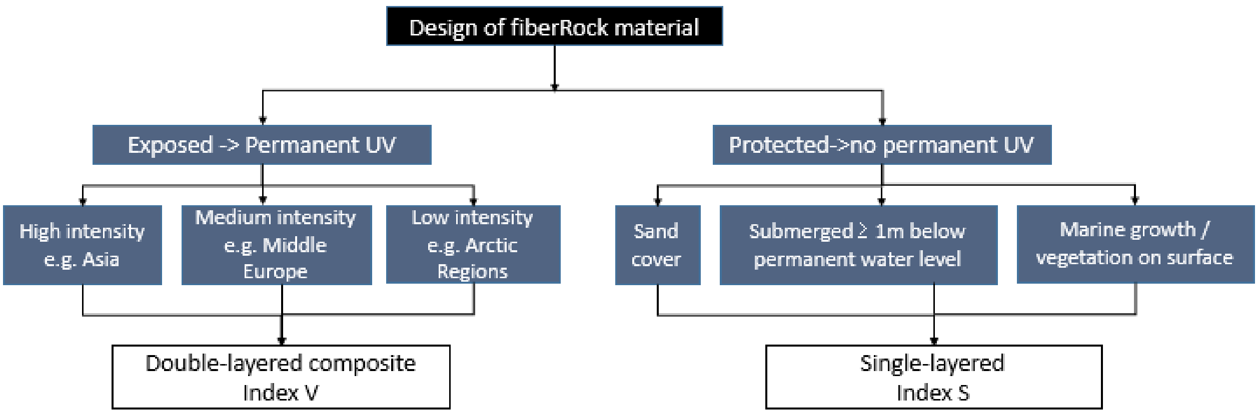


FIGURE 4 – CHART FLOW FOR DESIGN OF FIBERROCK MATERIAL

2.4 - Main usage for the FiberRock products

The main proposed usage of the FiberRock products, as proposed by Fibertex, are river bank protection (Figure 5(a)), coastal and dune protection (Figure 5(b)), groins (Figure 5(c)), artificial reefs (Figure 5(d)), scour prevention (Figure 5(e)) and temporary protection dykes (Figure 5(f)).

These applications are discussed in further detail later in this chapter.

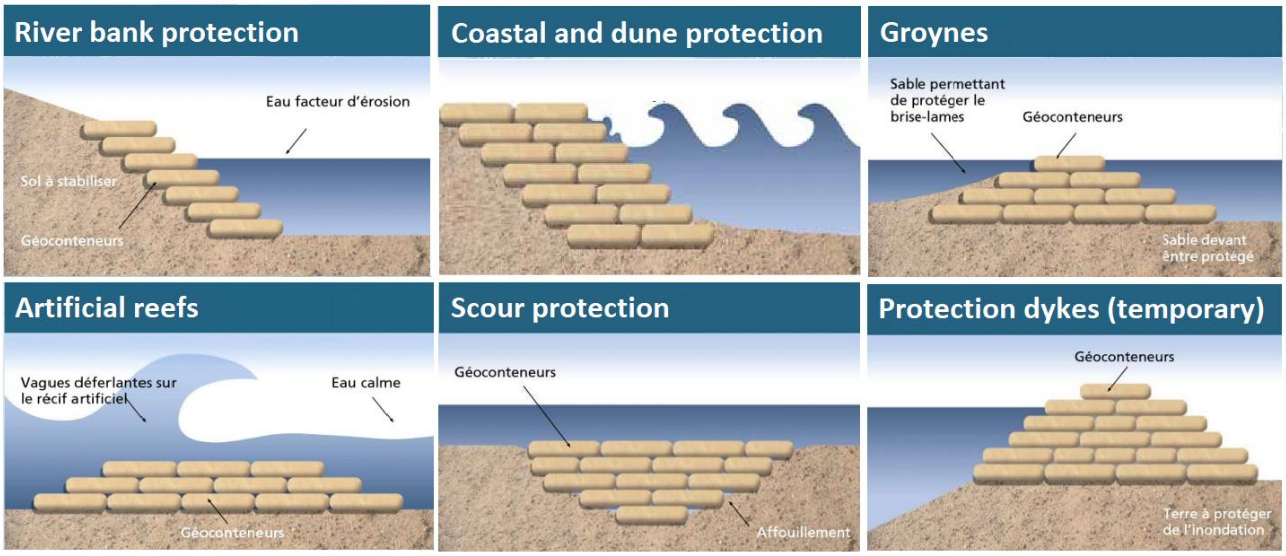


FIGURE 5 – MANUAL/MECHANICAL/HYDRAULIC

3 - SYMBOLS AND DEFINITIONS

Symbol	Description	Unit
α	Slope angle of structure	(◦)
Δ	Relative density of the structural elements	(–)
ξ_0	Breaker parameter	(–)
ϕ	Stability parameter, depending on the application	(–)
Ψ	Shields parameter	(–)
n	Porosity of fill material	(–)
ρ_E	Density of sand container elements	(kg/m^3)
ρ_S	Density of grain material	(kg/m^3)
ρ_W	Density of water	(kg/m^3)
D	Effective thickness of the geotextile-encapsulated sand element	(m)
F	stability factor	(-)
g	Gravitational acceleration constant	(m/s^2)
hs	Water depth	(m)
Hs	Significant wave height	(m)
K_T	Turbulence factor	(–)
K_S	Factor related to the slope angle	(–)
K_h	Factor related to the depth	(–)
k_r	Equivalent roughness according to Nikuradse	(–)
Lc	Length of slope containers	(m)
L_0	Wave length in deep water	(m)
$N_{s,slope}$	Slope stability number	(–)
$N_{s,crest}$	Crest stability number	(–)
Rc	Crest freeboard of the structure	(m)
Tp	Peak period of waves	(s)
u_{cr}	Critical horizontal flow velocity along the surface of the structure	(m/s)
	Abbreviations	
CD	Chart datum	
GSC	Geotextile sand containers	
SWL	Sea water level	
WRL	Water Research Laboratory	

4 - Functional requirements and site parameters

In order to design and propose the adequate unit within the range of products FiberRock, it is of paramount importance to define the functional requirements and site conditions, as accurately as possible, all subject to the effective information available.

The most important functional requirements for the design of such hydraulic protection structure are:

- The required lifetime of the structure, which could varies depending on whether the structure is a temporary structure (typically less than a 5-year design life), interim measure (5-20 year design life), or long-term solution (20-50 year design life).
- The return period, which shall be estimated on basis of the State of the Art (Table 1). In the present worksheet, values from 10 years for temporary protection solution to 50/100 years for permanent protection structures is recommended; It is good engineering practice to consider a return period event with occurrence of about 40% during the selected lifetime of the structure.
- Allowable overtopping, for which values shall be agreed at detailed design stage with the Client, in light of the structures to be protected and associated traffic (pedestrian, ...) ;
- Construction aspects (e.g. equipment on side, sequence of operations during filling).

TABLE 1 – PROBABILITY OF EVENT OCCURRENCE WITHIN A SPECIFIED TIME FRAME

Design life (years)	Event probability (per cent) for various return periods (years)								
	5	10	20	30	50	100	200	500	1000
1	20	10	5	3	2	1	< 1	< 1	< 1
2	36	19	10	7	4	2	1	< 1	< 1
3	49	27	14	10	6	3	1	< 1	< 1
5	67	41	23	16	10	5	2	1	< 1
7	79	52	30	21	13	7	3	1	1
10	89	65	40	29	18	10	5	2	1
15	96	79	54	40	26	14	7	3	1
20	99	88	64	49	33	18	10	4	2
30	> 99	96	78	64	**45**	26	**14**	6	3
50	> 99	99	92	82	64	39	22	9	4
75	> 99	> 99	98	92	78	53	31	14	7
100	> 99	> 99	99	97	87	63	39	18	10

The most important boundary conditions for the design are:

- The design wave height Hs and period Tp;
- Critical horizontal flow velocity along the surface of the structure u_{cr}
- The design water level (high water and low water);
- The bathymetry;
- Surcharge loads,
- The soil conditions;

The above boundary conditions are partly used in the present calculation sheet based on preliminary information available. They shall however be carefully defined before the detailed design stage through a process which is not detailed here.

To go further, the following documents provide design guidance on coastal structures, which could be applied for the applications related to geobags:

- CIRIA. 2007. The Rock Manual: The Use of Rock in Civil Engineering. 2nd edition, Publication C683. London: CIRIA.
- DoA. 1984. Shore Protection Manual: Volume 1. Vicksburg, MS: Coastal Engineering Research Center, United States Army Engineers Waterways Experiment Station.
- DoA. 1995. Design of Coastal Revetments, Seawalls, and Bulkheads. EM 1110-2-1614, Vicksburg, MS: United States Department of the Army.
- EurOtop. 2007. Wave Overtopping of Sea Defences and Related Structures: Assessment Manual. United Kingdom: Environment Agency.
- EurOtop. 2016. EurOtop II—Manual on Wave Overtopping of Sea Defences and Related Structures. An Overtopping Manual Largely Based on European Research, but for Worldwide Application. 2nd edition Prerelease. J.W. Van der Meer, N.W.H. Allsop, T. Bruce, J. De Rouck, A. Kortenhaus, T. Pullen, H. Schüttrumpf, P. Troch, and B. Zanuttigh
- USACE. 2006. Coastal Engineering Manual. Washington, DC: United States Army Corps of Engineers

5 - HYDRAULIC STABILITY

Due to the different wave loads and boundary conditions which prevails on the slope and on the crest of a coastal structure, a different stability behavior and thus different stability formulae are expected for the containers on the slope and those on the crest.

5.1 - Slope design

5.1.1 - Theory

The sand containers on the slope which are located around the still water level are repeatedly moved up and down by the waves rushing up and down the slope, leading to an incremental seaward displacement of the containers. This dislodgement/pull out effect is illustrated by Figure 6 as observed in the wave flume and in the field.

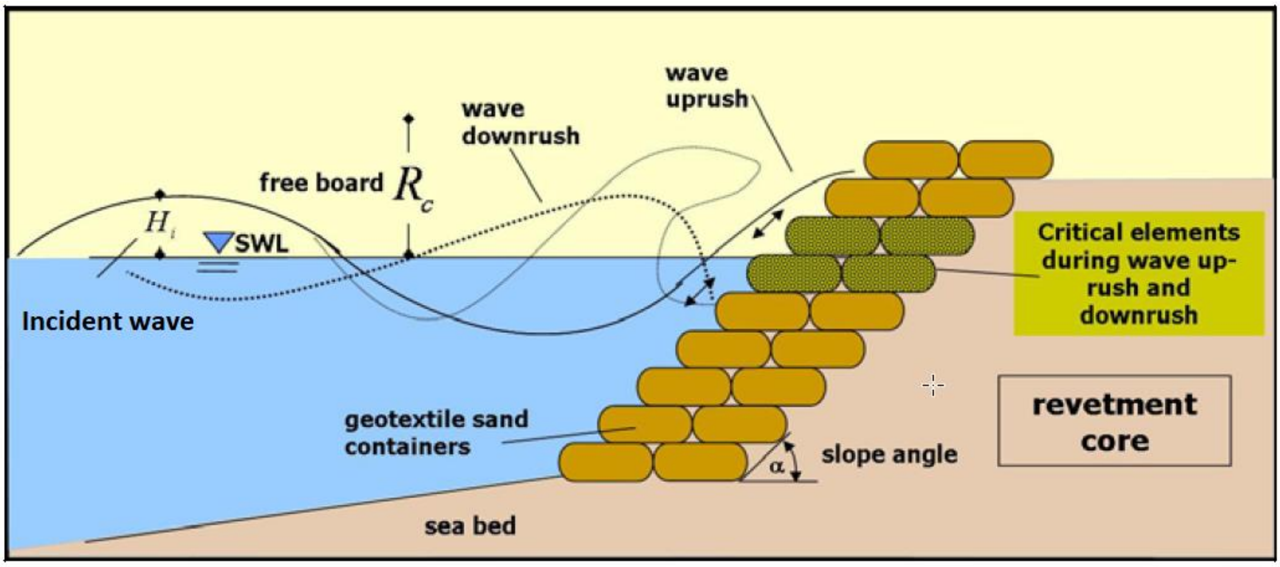


FIGURE 6 – CRITICAL LOCATIONS FOR SAND CONTAINERS IN THE SLOPE STRUCTURE

Oumeraci et al 2002, carried out large-scale model tests and proposed a modified equation for GSC revetments structures. The results of these tests yield the following stability criterion:

$$N_{s,slope} = \frac{H_s}{\left(\frac{\rho_E}{\rho_W} - 1\right) D} < \frac{C_W}{\sqrt{\xi_o}}$$

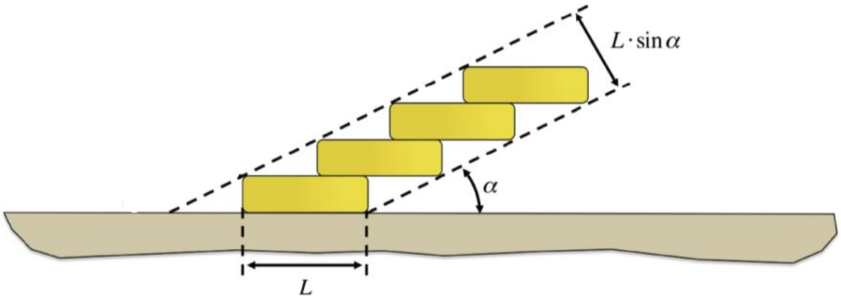
where:

- $N_{s,slope}$ = Slope stability number [-];
- Hs = significant wave height [m];
- ρ_E = Density of sand container elements [kg/m^3] as defined as :

$$\rho_E = (1 - n)\rho_s + \rho_w n$$

- n = Is the porosity of the filling sand [-];
- ρ_S = density of the fill material which is approximately 2 650 [kg/m^3];
- ρ_w = density of water (1 000 [kg/m^3] for freshwater 1 025 [kg/m^3] for saltwater);
- D = Effective thickness of the geotextile-encapsulated sand element;
- C_w= 2.75 (empirical parameter based on test results) [-];
- ξ_0 = breaker parameter [-];

The effective thickness of the structural elements is partly dependent on the manner in which the units are installed. On Figure 7, the most common installation geometry is shown. **An horizontal placement with approximately 50% overlap between adjacent geotextile bags is recommended**. In the definition of the effective thickness D, L is the length of the geotextile bag, with the long side perpendicular to the revetment axis and α the slope of the structure.



D = Lc sin α

FIGURE 7 – DEFINITION OF EFFECTIVE THICKNESS FOR INSTALLATION GEOMETRY

With the breaker parameter expressed in terms of the deep water length:

$$\xi_0 = \frac{\tan\alpha}{\sqrt{H_s / L_0}}$$

$$L_0 = \frac{gT_p^2}{2\pi}$$

The following stability formula is obtained in terms of the length Lc of the slope containers as:

$$Lc = \frac{H_S{}^{3/4}\sqrt{T_p}}{1.74\left(\frac{\rho_E}{\rho_w} - 1\right)\sqrt{\sin(2\alpha)}}$$

5.1.2 - Input parameters to be entered in the calculation sheet

The slope design calculations apply for following applications:

- **Coastal and dune protection**,
- **Groynes,**
- **Protection dykes (temporary).**

The following input parameters are to be set into the calculation sheet for the slope design calculations:

- **Porosity of bag fill material, n** =by default 0.45 (for fine to medium sand);
- **Fill material density, ρs** = by default 2 650 kg/m^3(for sand);
- **Water Density, ρw** = by default 1 025 [kg/m^3] for saltwater;
- **Significant wave height, Hs** = extreme value which could be expected during the selected return period of the structure (Table 1), derived from extremes analysis for the considered design water level below; It shall be highlighted that most of the time, values of Hs will not exceed the water depth available in front of the structure.

- **Peak Period, Tp** = extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;
- **Slope of the structure, V:H** = 1:0,5 to 1:3
- **Bottom Level, Ztn** = to be defined in function of the maximum potential scouring depth on the site; based on good engineering practice (Refer to CEM or Rock Manual, 1.8 x Hs shall be considered). This could be reduced and optimized by adopting a toe scour protection (see section 5.5)
- **Crest level, Zcrest** = to be defined in function of the overtopping criteria or boundary site conditions (e.g. the top of the slope to be protected);
- **Design water level, Zw** = appropriate design event in function of tides, wave set up, sea level rise… it is recommended to use the Highest astronomical tide level.

5.1.3 - Design charts for the required size of slope containers

It is possible from the equations described above to plot the relationship between the design wave height (Hs) as a fonction of the FiberRock standard volume unit for slope containers, for a structure slope angle α = 45°.

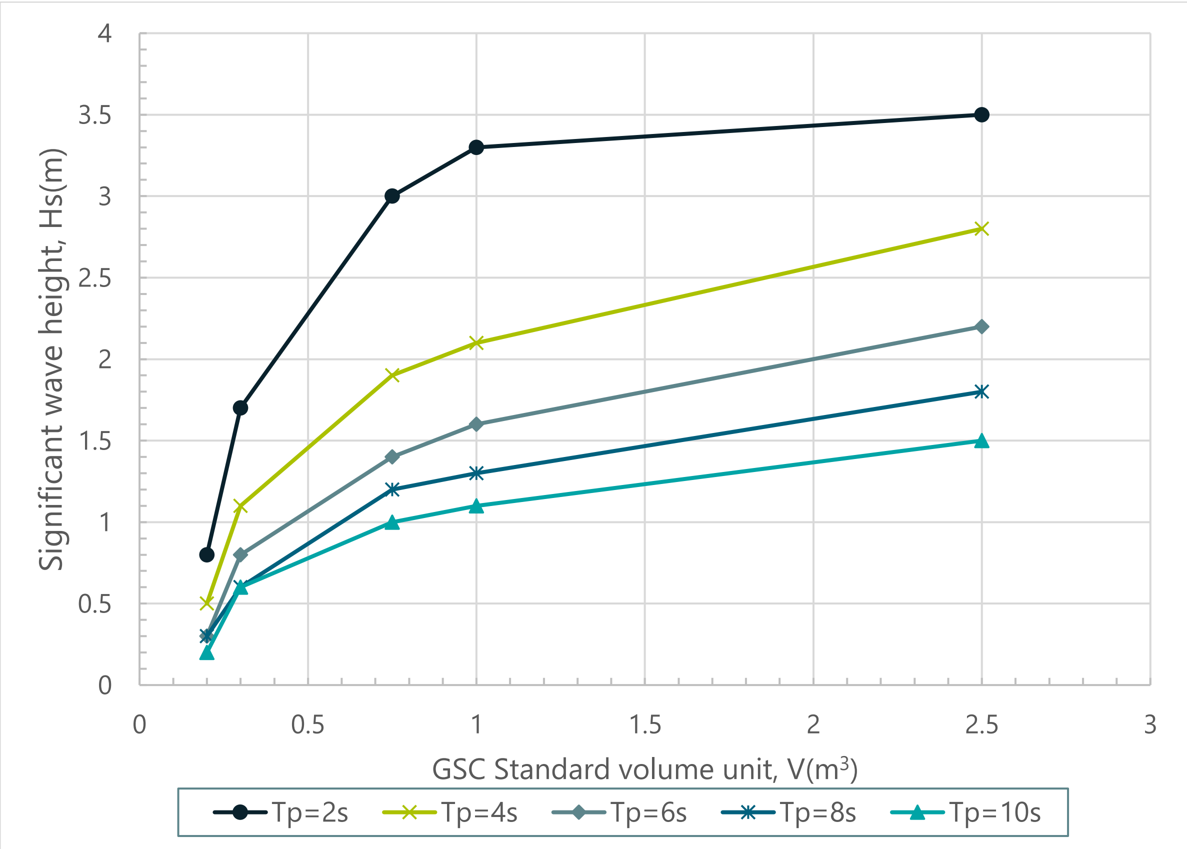


FIGURE 8 – RELATIONSHIP BETWEEN THE DESIGN WAVE HEIGHT (HS) AS A FONCTION OF THE GSC VOLUME UNIT FOR SLOPE CONTAINERS. THIS GRAPH IS VALID FOR SLOPE ANGLE OF 1H:1V AND DENSITY OF SAND CONTAINER OF 1920 KG/M3

5.2 - Crest container design

5.2.1 - Theory

The sand containers on the crest of the structure may fail due to two possible mechanisms (Figure 9):

- uplifting during the wave uprush process and shoreward displacement by the wave overtopping flow,

- dislodgement and pull-out effect similar to the mechanism observed for the slope containers.

Due to the boundary conditions applied on the crest containers which are more critical than those of the slope containers (no overburden from upper layers), it is expected that the stability number of the crest containers $N_{s,crest}$ will be more critical than that of the slope containers if the crest level of the structure is not high enough. The relative freeboard Rc/Hs, therefore, represents the most important influencing parameter. **This means that crest units are less stable than the ones on the slope and needs to be therefore heavier.**

$$N_{s,crest} = \frac{H_s}{\left(\frac{\rho_E}{\rho_W} - 1\right) D} < 0.79 + 0.09\,\frac{R_C}{H}$$

where:

- $N_{s,slope}$ = Slope stability number [-];
- Rc = The distance between the crest and the still water line, but is zero when the crest is below the still water line.

As in the previous case, the stability formula for crest containers is obtained in terms of the required container length Lc:

$$Lc = \frac{H_s}{\left(\frac{\rho_E}{\rho_W} - 1\right)\left(0.79 + 0.09\frac{R_C}{H_s}\right) sin\alpha}$$

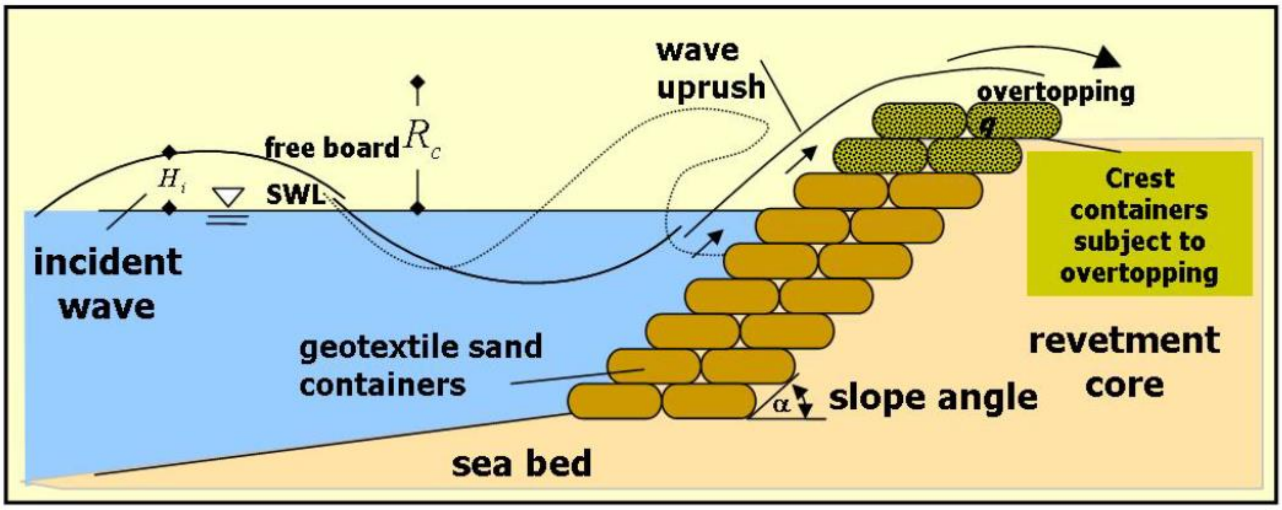


FIGURE 9 – CRITICAL LOCATIONS FOR SAND CONTAINERS IN THE CREST STRUCTURE

5.2.2 - Input parameters to be entered in the calculation sheet

The crest design calculations apply for following applications:

- **Coastal and dune protection**,
- **Groynes,**
- **Protection dykes (temporary).**

The following input parameters are to be set into the calculation sheet for the slope design calculations:

- **Porosity of bag fill material, n** =by default 0.45 (for fine to medium sand);

- **Fill material density, ρs** = by default 2 650 kg/m^3(for sand);
- **Water Density, ρw** = by default 1 025 [kg/m^3] for saltwater;
- **Significant wave height, Hs** = extreme value which could be expected during the selected return period of the structure (Table 1), derived from extremes analysis for the considered design water level below; It shall be highlighted that most of the time, values of Hs will not exceed the water depth available in front of the structure.
- **Peak Period, Tp** = extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;
- **Slope of the structure, V:H** = 1:0,5 to 1:3
- **Bottom Level, Ztn** = to be defined in function of the maximum potential scouring depth on the site; based on good engineering practice (Refer to CEM or Rock Manual, 1.8 x Hs shall be considered). This could be reduced and optimized by adopting a toe scour protection (see section 5.5)
- **Crest level, Zcrest** = to be defined in function of the overtopping criteria or boundary site conditions (e.g. the top of the slope to be protected);
- **Design water level, Zw** = appropriate design event in function of tides, wave set up, sea level rise… it is recommended to use the Highest astronomical tide level.

5.2.3 - Design charts for the required size of crest containers

In a similar way as slope containers, the required crest container volume unit is plotted against the design wave height Hs for different relative freeboard Rc/Hs = 0 – 2.0. This for a structure slope angle α = 45° and density of GSC of 1920 kg/m^3 (porosity of 0.45).

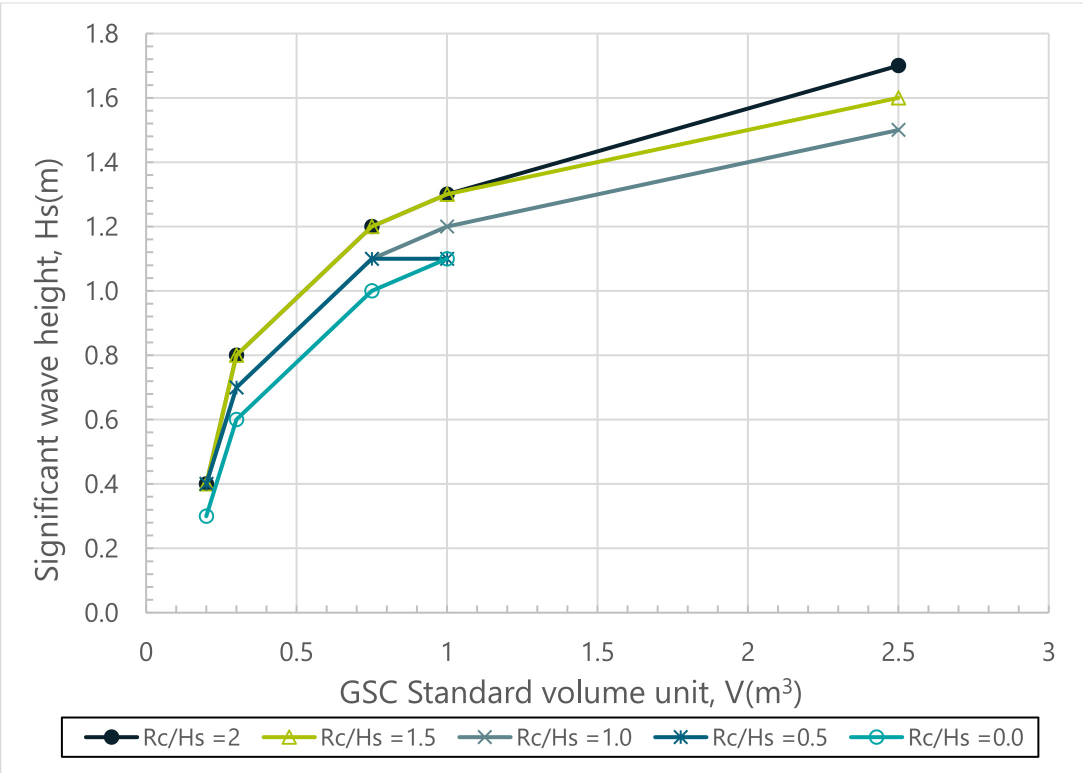


FIGURE 10 – RELATIONSHIP BETWEEN THE DESIGN WAVE HEIGHT (HS) AS A FONCTION OF THE GSC VOLUME UNIT FOR SLOPE CONTAINERS. THIS GRAPH IS VALID FOR SLOPE ANGLE OF 1H:1V AND DENSITY OF SAND CONTAINER OF 1920 KG/M3

5.3 - Stability when subject to longitudinal current flows

5.3.1 - Theory

To determine the stability of geotextile-encapsulated sand elements when subject to longitudinal current flows (current flow parallel to the structure, see Figure 11), as in the application for canals and rivers, use can be made of the Pilarczyk relationship, based on a fully protected foundation of sand:

$$\Delta\, D \geq 0.035 \frac{\phi\, K_T\, K_h\, {u_{cr}}^2}{\Psi\, K_s\, 2\, g}$$

where:

- D = effective thickness of the geotextile-encapsulated sand element [m];
- Δ = relative density of the geotextile-encapsulated sand element [–];
- u_{cr} = critical horizontal flow velocity along the surface of the structure [m/s];
- ϕ = stability parameter, depending on the application [–];
- Ψ = Shields parameter [–];
- K_T = turbulence factor [–];
- K_h = factor related to the depth [–];
- K_s = factor related to the slope angle [–].

For the stability parameter ϕ the following values apply:

- for continuous top layer: ϕ = 1.0;
- for edges: ϕ = 1.5.

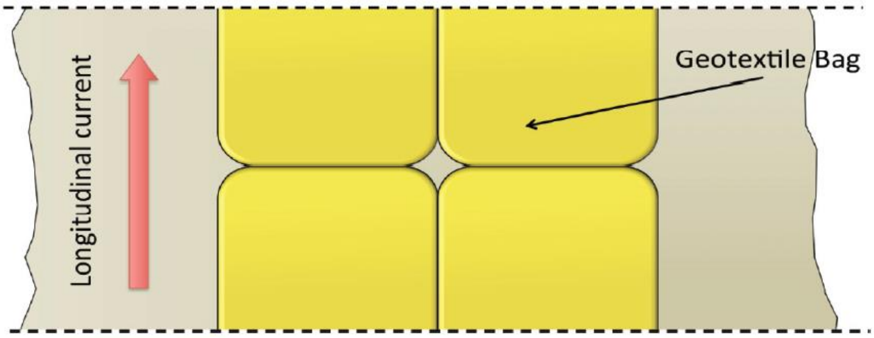


FIGURE 11 – VIEW FROM ABOVE OF LONGITUDINAL CURRENT FLOW IN A GEOTEXTILE BAGS STRUCTURE.

Geotextile bags must be designed to account for the stability parameter at the edges (ϕ = 1.5) due to the higher forces at the edges.

The Shields parameter depends on the type of element:

- for small geotextile bags (< 0.3 m^3): Ψ = 0.035;
- for larger geotextile bags: Ψ = 0.05.

The turbulence factor accounts for the extent of turbulence in the current. In Table 2 several values are given.

TABLE 2 – TURBULENCE FACTOR K_T FOR VARIOUS HYDRAULIC CONDITIONS

Condition	K_T [−]
Normal turbulence in rivers	1.0
Higher turbulence: river bends	1.5
Turbulence at groynes	2.0
Strong turbulence: hydraulic jumps, sharp bends, local disruptions	2.0
Turbulence as the result of propeller jets and other water jets	3.0-4.0

Using the depth factor (K_h), the depth-average flow velocity is translated into a flow velocity at any depth (h) along the structure:

$$K_h = \frac{2}{\left(\log\left(\frac{12h}{k_r}\right)\right)^2}$$

where:

- h = water depth [m];
- k_r = equivalent roughness according to Nikuradse [m].

For the equivalent roughness k_r, an initial estimate of the effective thickness (D) of the geotextile bags can be used. It should be noted that this formula applies to a fully developed current profile. If this is not the case, then the following relationship should apply:

$$K_h = \left(\frac{h}{k_r}\right)^{-0.2}$$ undeveloped current profile

$K_h \approx 1.0$ for a very rough current ($h/k_r < 5$)

The slope factor K_s is a function of the influence of the angle of shearing resistance between the geotextile bag and the subsoil:

$$K_s = \sqrt{1 - \left(\frac{\sin\alpha}{\sin\delta}\right)^2}$$

where:

- α = slope angle of the structure [deg];
- δ = friction angle between the geotextile bag surface and the subsoil [deg].

Various tests have been performed to determine the friction angle between geotextiles and different subsoils. The results show a large range of friction angles: δ = 20°–40°. For applications under water, or where a subsoil is comprised of wet clay, it is recommended to use a friction angle of δ = 20°. If the calculations result in low stability under longitudinal currents due to a low surface friction angle between the bags and the subsoil slope, it is recommended that actual testing be performed to determine the appropriate geotextile bag/subsoil friction angle. Additionally, a toe structure can be used to prevent the lowest geotextile bags sliding from the slope.

Another aspect that has to be considered is the possibility of sand movement within the geotextile bag. With a continuous external water flow the geotextile bag may be internally stable, but if the sand in the geotextile bag moves, this could result in deformation of the bag and lead to bag instability.

This phenomenon was first reported in 1968 in one of the earliest studies into geotextile-encapsulated sand elements. This early small-scale study into the stability under current flows showed that at a flow velocity of more than 1.5 m/s, internal sand movement occurred in the geotextile bag. Moreover, geotextile bags placed on a slope as low as 1:8 would become unstable at a flow velocity of 2.5 m/s because of internal sand movement irrespective of the size of the geotextile bags.

5.3.2 - Input parameters to be entered in the calculation sheet

The structure design calculations apply for following applications:

- **River bank protection,**
- **Groynes.**

The following input parameters are to be set into the calculation sheet for the slope design calculations:

- **Porosity of bag fill material, n** =by default 0.45 (for fine to medium sand);
- **Fill material density, ρs** = by default 2 650 kg/m^3(for sand);
- **Water Density, ρw** = by default 1 000 [kg/m^3] for freshwater and 1 025 [kg/m^3] for saltwater;
- **Slope of the structure, V:H** = 1:0,5 to 1:3
- **Bottom Level, Ztn** = to be defined in function of the maximum potential scouring depth on the site; This could be reduced and optimized by adopting a toe scour protection (see section 5.5).
- **Crest level, Zcrest** = to be defined in function of the overtopping criteria or boundary site conditions (e.g. the top of the slope to be protected);
- **Design water level, Zw** = extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;
- **Critical horizontal flow velocity along the surface of the structure, u_{cr}** = extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;
- **Turbulence factor, K_T** = see Table 2

5.4 - Stability when subject to overtopping currents

5.4.1 - Theory

For some structures, such as artificial reef, groynes and scour protection, the stability under current attack must be checked. The following dimensionless relationship, formula (3.16), between the external current acting on the structure and the resistance (weight) of the geotextile bags can be used.

$$\frac{u_{cr}}{\sqrt{g\Delta D}} \leq F$$

where:

u_{cr} = maximum allowable flow velocity over the crest of the structure [m/s];

F = stability factor [–].

Various values of the stability factor F have been documented:

- $F = 1.2$;
- $F = 0.5 - 1.0$;

- $F = 0.9 - 1.8$.

It is recommended to use a value of $F = 1$ for either where an external current is perpendicular to the axis of the structure or where geotextile bags are placed in mounds.

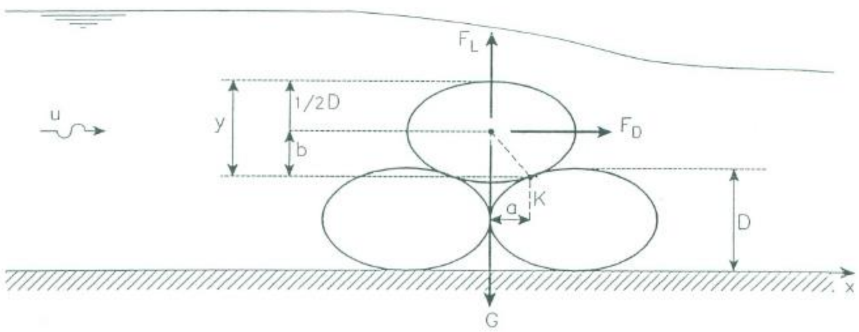


FIGURE 12 – DEFINITION SKETCH OFGSC SUBJECTED TO UNIDIRECTIONAL FLOW

5.4.2 - Input parameters to be entered in the calculation sheet

The structure design calculations apply for following applications:

- **Artificial reefs;**
- **Scour protection.**

The following input parameters are to be set into the calculation sheet for the slope design calculations:

- **Porosity of bag fill material, n** =by default 0.45 (for fine to medium sand);
- **Fill material density, ρs** = by default 2 650 kg/m^3(for sand);
- **Water Density, ρw** = by default 1 000 [kg/m^3] for freshwater and 1 025 [kg/m^3] for saltwater;
- **Slope of the structure, V:H** = 1:0,5 to 1:3
- **Bottom Level, Ztn** = to be defined in function of the maximum potential scouring depth on the site; This could be reduced and optimized by adopting a toe scour protection (see section 5.5).
- **Crest level, Zcrest** = to be defined in function of the overtopping criteria or boundary site conditions (e.g. the top of the slope to be protected);
- **Design water level, Zw** = extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;
- **Maximum overtopping flow velocity, Ucr =** extreme value which could be expected during the selected return period of the structure (Table 1) and derived from extremes analysis;

5.5 - Toe design

As with all coastal structures, toe stability is critical in ensuring the survival of a geotextile sand container structure. The toe of the structure should be located at a level where it is unlikely to be undermined. In most cases if the base of the structure is founded at 0 m LAT the structure will perform adequately, however, site specific assessment is required. In extreme storm events large scale erosion can occur at the toe of the structure and in order to overcome this issue it is recommended that an additional scour container be incorporated in the design which will prevent undermining of the structure.

The technique involves burying the toe of the structure in the foreshore slope, adding a third row of GSCs to the bottom layer (second row in the case of single layer GSC armour revetment) and wrapping this third layer to form an "encapsulated self-healing toe". WRL (2008) found this toe restraint arrangement to be very strong and prevented slip failures.

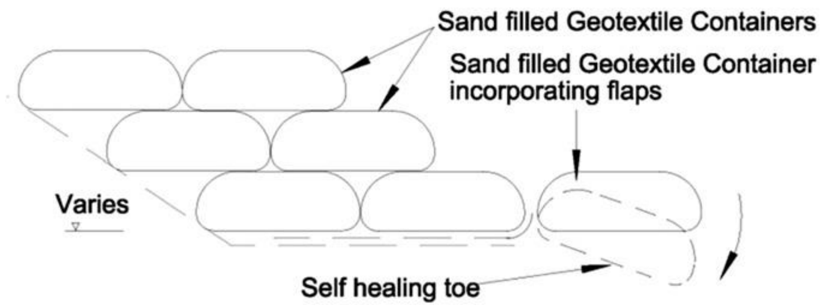


FIGURE 13 – FLEXIBLE TOE CONTAINER DETAIL.

Additionally, GSC revetments should be constructed with a geotextile filter placed on the protected soil surface before the geotextile container armour units are placed. Here, the geotextile filter performs the same function as it does in rock revetments. Figure 14 present two examples of geotextile filter detail (line in blue color) for dune and river bank protection.

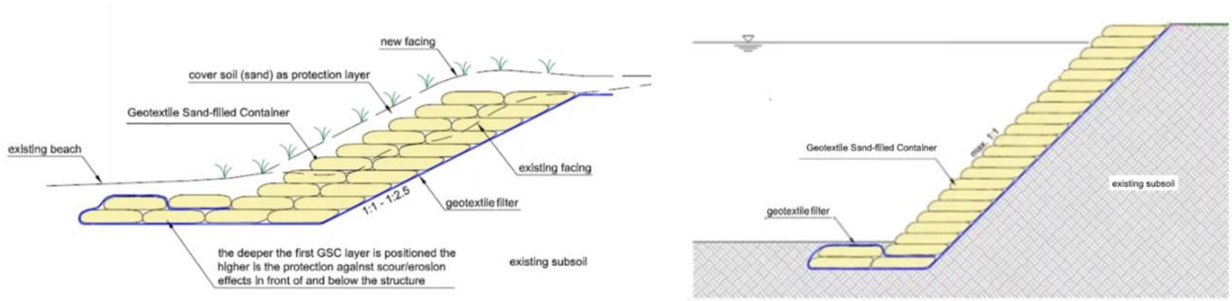


FIGURE 14 – CONCEP DRAWING EXEMPLES FOR (A) DUNE APPLICATION AND (B) RIVER BANK PROTECTION

6 - CONDITIONS OF USE

In this document, Egis provides some considerations for designers who intend to incorporate FIBERTEX GSC units in a design. The following conditions apply to the guidelines presented by Egis in this document:

- This document is based on Egis's current professional insights. Changes in these insights may lead to changes in the contents of this document. Before using this document, Designer is requested to check if this document is the latest revision.
- This document does not contain a complete description of all factors that shall be defined and considered for a detailed design.
- Designer shall be responsible for designs made by using the contents of this document and shall take into account the various factors that affect the design.
- The guidelines provided by Egis regarding the design with FiberRock GSC units are subject to confirmative physical model tests, at detailed design stage.

It is recommended that a suitably qualified professional be involved in the assessment and design process to ensure a robust and reliable outcome. Furthermore, a full understanding of the local setting is critical to the development of any design solution. Egis provides assistance to the owners, developers, designers and contractors at all stages of projects.

7 - APPENDIX

7.1 - APPENDIX A – FIBERTEX NON WOVENS FIBERROCK SAND CONTAINERs: Filling & Installation Method statement

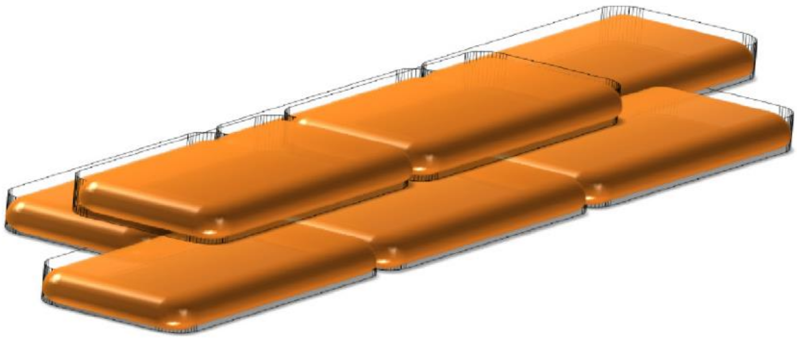
F I B E R T E X   N O N W O V E N S

FIBERTEX NON WOVENS

FIBERROCK GEOSYNTHETIC SAND CONTAINER

Filling & Installation

Method statement



Fibertex
NONWOVENS

Method statement: Fibertex Geosynthetic Sand Container (GSC)

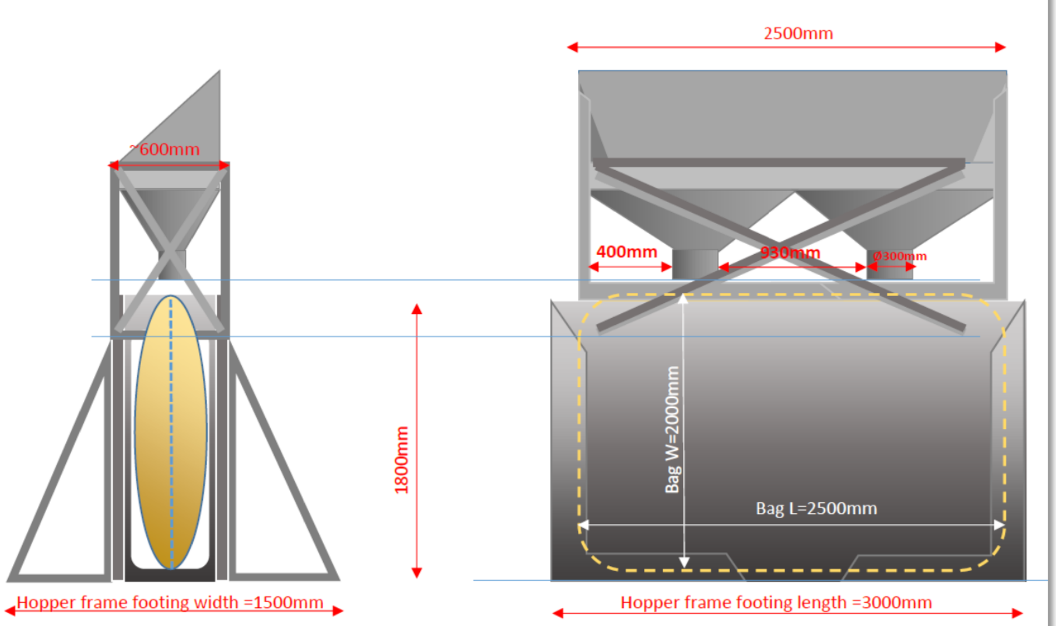
Products needed for GSC filling and installation:

•Fibertex FiberRock Geocontainer bags and carrier straps

•Clean filling sand and source of water *(pumped or scooped seawater is also suitable)*

•GSC Filling frame and Filling hopper *(Please Note: this is the contractors responsibility to secure this plant)*

GSC Filling Hopper Detail:



Empty GSC Handling :

•Fibertex GSC product are supplied in compacted stacked formation on pallets and film wrapped before shipping.

•Care should be taken when removing the film wrapping and strapping from the wrapped pallet. (*No sharp blades should be used to avoid possible damage to GSC fabric)*

•Unpack and layout GSC bags on flat surface.

•Insure all components of GSC package are present: Complete GSC order/ Filling port rope *(if needed)*

FiberRock GSC Product Storage:

•Even though Fibertex FiberRock GSC products are highly durable, care should be taken when stored before application to avoid possible construction damage. Always store under cover in a secured area.

•Ensure products are stored away from excessive heat and open fire.

•Ensure products are stored away from other chemicals *(Acids and Alkalis)*

Filling Sand:

•Ensure a clean source of permeable sand (beach sand) is available for filling GSC bags

•Ensure sand is free from debris and other possibly damaging objects

FiberRock GSC Filling:

•Place Carrier strap in filling frame at a distance>600mm from the edge of the filling frame

•Place empty Fibertex FiberRock GSC in the filling frame, ensure filling ports are facing upwards

•Place filling hopper on top of filling frame

•Join filling ports to filling hopper funnels, ensure strap is secure around filling funnel

Hydro filling (Slurry pump):

•By using a slurry pump, simply suck saturated beach sand and feed through to GSC hopper

•If needed, wash down sand in hopper with water *(scooped or hose fed)*

•Ensure bag is optimally filled, when sand reached top of filling port after washing in sand with water

•Close filling port by machine or hand sewing ensuring no open gaps, roll filling port into GSC opening and close with filling port rope

Filled FiberRock GSC Handling:

•Ensure all strap loops are secure hooked around carrier plant (excavator/ loader) bucket teeth.

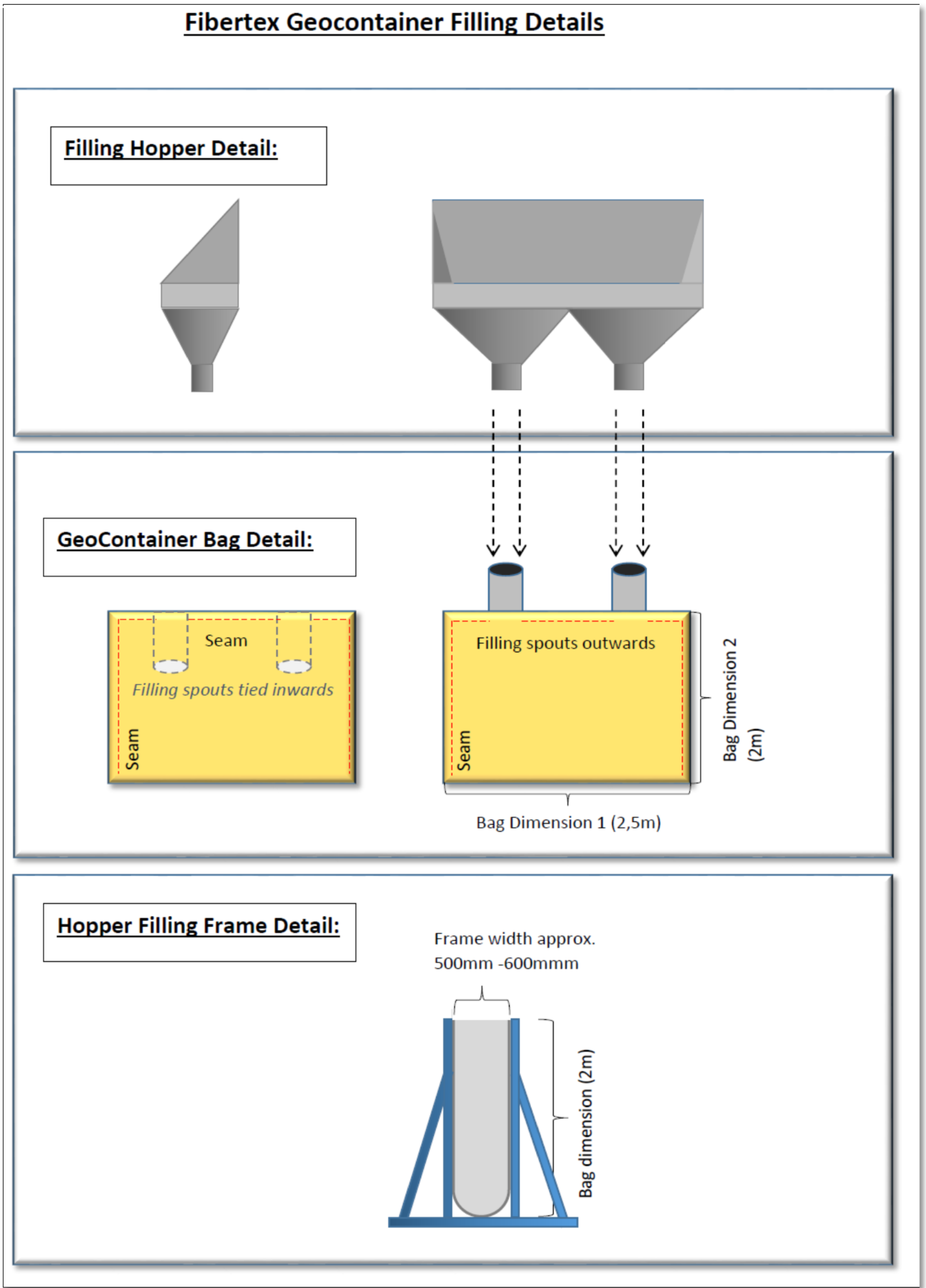
•Ensure FiberRock GSC bag is free from and obstructions before commencing lift procedure

•Gently lift FiberRock GSC bag out of filling frame in a directly upward motion.

•Once suspended and FiberRock GSC has cleared the filling frame, carrier plant can reverse from filling frame

Filled FiberRock GSC Transport:

•FiberRock GSC can be transported to site of placement via carrier plant (excavator/loader)

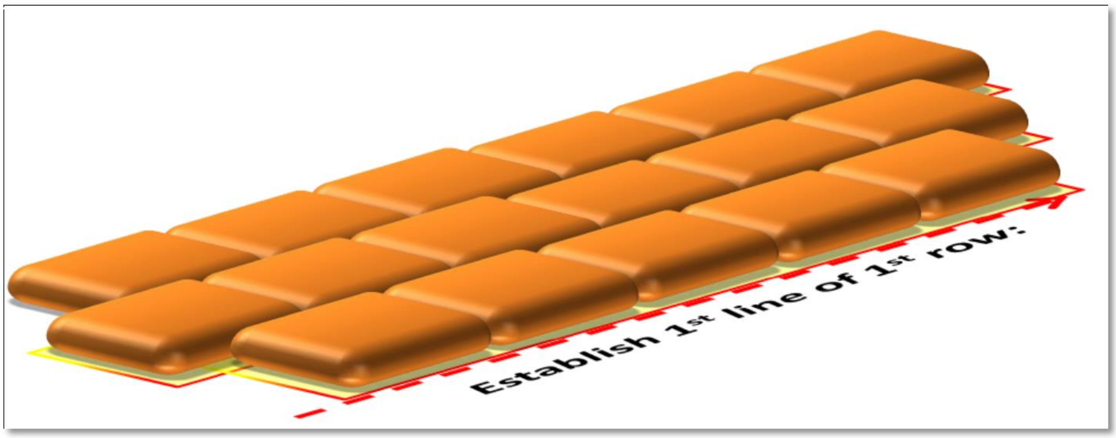

Fibertex Geocontainer Filling Details
Filling Hopper Detail:
GeoContainer Bag Detail:
Seam
Filling spouts tied inwards
Seam
Filling spouts outwards
Seam
Bag Dimension 2 (2m)
Bag Dimension 1 (2,5m)
Hopper Filling Frame Detail:
Frame width approx. 500mm -600mmm
Bag dimension (2m)

Filled FiberRock GSC Placement:

Pioneer 1st line of 1st row:

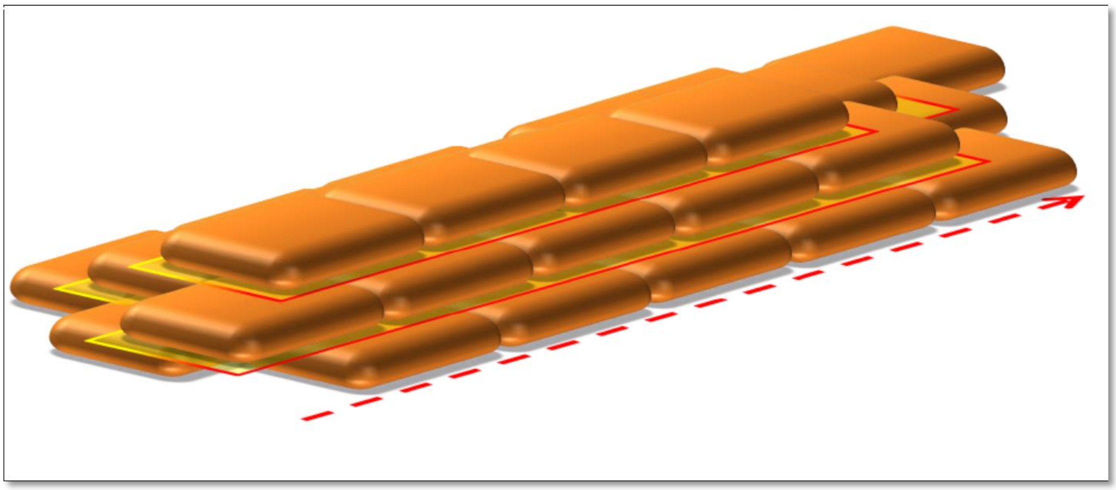
•Ensure designated placement area is clearly demarcated

•Establish and place first line (downstream face) of GSC structure, by gently lowering GSC onto beach, ensuring all adjacent GSC bags are well aligned and in close contact with each other. Avoid gaps between adjacent GSC bags as this might cause future structural in stability



Placement of 2nd line of 1st row:

•Place the next (2nd) line directly in close contact with the 1st line, ensuring a staggered formation between the first and 2nd lines to avoid GSC bag joint alignments, that could allow for future structural instability



Placement of 3rd line and any further base rows:

•Place the next line of GSC bags directly in close contact with the previous line, ensuring a staggered formation between the current and previous lines to avoid GSC bag joint alignments, that could allow for future structural instability

IMPORTANT NOTES:

- Always wear protective gloves when handling and strapping Fibertex 250V GSC bags to avoid injury
- For optimum performance, always ensure bags are optimally filled as described earlier
- To avoid damage to Fibertex 250V GSC, do not drop bags during placement
- No direct vehicle traffic allowed on filled or empty Fibertex 250V GSC bags

The above recommendations have been offered in good faith and to the best of our basic knowledge of the site conditions. It is the engineer's responsibility to approve the appropriateness of these materials and to sign off on their use in the works. Fibertex South Africa will not be held responsible nor be liable in any manner whatsoever should the materials be later deemed ineffective.

Assuring you of our best service at all times.

Kind Regards

Gerard Dirks
Technical Manager FIBERTEX South Africa

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egis

Caisse des Dépôts
GROUPE