Submerged barrier for coastal protection application built with tubes in geosynthetics of big diameter in Tuscany – Italy

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ABSTRACT:
In this paper we present an ongoing field study aimed at the detailed monitoring process of a new submerged breakwater built with PET geocomposite geotextile tubes of big diameter, focusing on installation issues and medium term behaviour. Field monitoring confirms that design methods are not sufficiently accurate to predict the final shape of the structure and that hydraulically filled elements have a very limited environmental impact during construction; nevertheless construction technology requires very accurate control during installation. The system performed very well with limited environmental impact during construction and under severe sea storms and colonization by marine flora on the geocomposite surface is very rapid.

1 INTRODUCTION

Geosynthetic containers filled with sand represent a good alternative to traditional rubble mound costal structures, in terms of cost reduction, reversibility and environmental impact. Furthermore, the use of hydraulically filled elements, such as tubes, reduces construction timing. However the nearshore circulation and local morphodynamic could be reasonably different from those characterizing a rubble mound structure due to significant differences in the structure roughness and permeability. Moreover in the designing of coastal protection structures using geosynthetics elements filled with sand there is uncertainty about the final shape due to the effects of wave load, adjustment to local scour, settlement, damage and loss of material across the textile (Aminti and Mori, 2008).

The geotextile is exposed to abrasion due to interaction of the fabric with sand and gravel in the surf zone. Effects of marine growth on the durability of geotextiles are under special debate as it can protect fabric but also induce even more stress. For exposed structures, vandalism could be a peculiar issue as well. Field monitoring is currently the only way to test the performance of different geotextiles and improve engineering and building techniques. Physical models, widely used to improve the efficiency of maritime structures, are in this case of limited use, due to the difficulty of a correct representation of strength and deformation in reduced scale models. Updated knowledge about the durability of geofabric in fully-exposed marine environments is still needed.

For this reasons, a field experiment has been conducted on a 100m long barrier built with a series of geotextiles tubes in order to collect information about: (i) initial (post-installation) shape of the tubes, (ii) post-consolidation shape, (iii) medium term shape variations due to loss of material, local scour due to wave action, and creep, (iv) medium and long term analysis of durability of the fabric, (v) local morphodynamic around the barrier, (vi) interaction of the geotextile with marine growth.

2 STUDY SITE AND METHOD

The submerged barrier was installed on the beach facing San Vincenzo (LI), where an enlargement of the marina is in progress (Figure 1). This breakwater is both an experimental structure made in order to collect information that will be of use in future constructions, as well as an emergency device built with the aim of protecting the beach nourishment in the meanwhile.

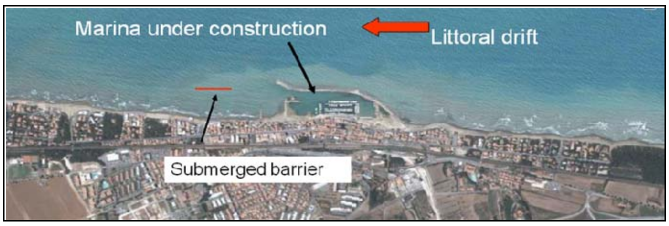


Figure 1 Location map of the experimental breakwater

Construction phases were monitored in order to define assessments, deformations and short term bottom interaction. Monitoring after construction includes beach profile surveys, detailed periodic survey on tube shape, diving inspections and sampling of damaged fabric if present. Also the effect of marine growth has been studied. The field program is still ongoing.

3 DESIGN OF THE BREAKWATER

3.1 *Geometry and constitutive materials*

The tube is designed with the hypothesis that the structure made of tubes in geotextile has the same hydraulic response (i.e. protection of the beach), of a rubble mound structure. A structure was therefore designed, of about 0.5 m submergence, 100 m length parallel to the shore and 80 m distance from the beach (Figure 2). Tubes have a nominal diameter of 3.0 m and a final height of 1.6 m installed at the average depth of 2.0 m (Figure 2, Figure 3).

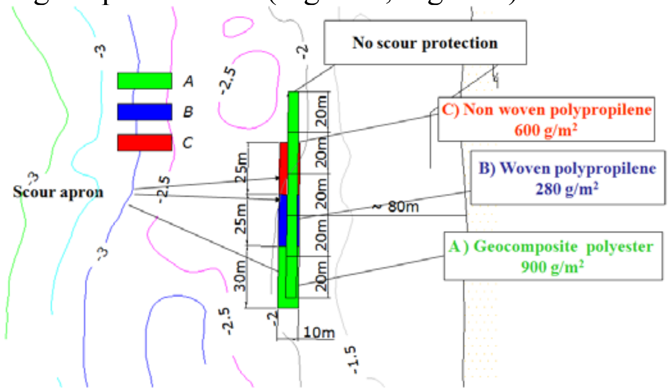


Figure 2 Outline of tubes placement and materials employed

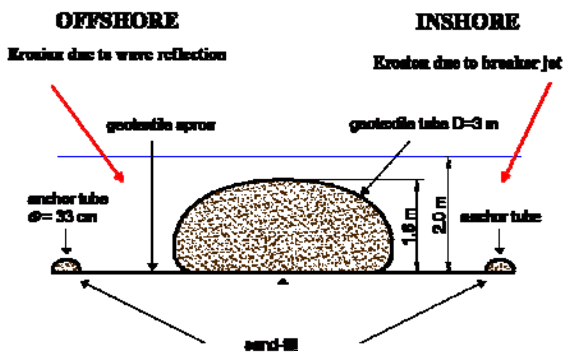


Figure 3 Section of tube and scour apron

Due to the action of currents and waves, structures formed by one or more tubes can lead to local scour, possibly resulting in geotechnical instability. Therefore, for protecting against scouring the design included a filter fabric apron. A filter fabric apron, also known as a scour apron, usually consists of a small tube, called an anchor tube, built into the seaward edge of the apron or around the entire perimeter. The anchor tube is filled with dredged material to stabilise the scour apron. The scour apron should extend for a sufficient distance in front of and behind the geotextile tube structure, in order to prevent from foundation scouring. The costs for material and installation of both tubes and scour aprons are comparable. However, when designing coastal protection systems made of geotextile, there is uncertainty on choosing to protect the tube with a scour apron or, instead, to duplicate the number of tubes, for example. This is the reason why in this experimental structure three different materials are used for the apron, and 20 meters are left without scour protection; in other words, part of the barrier is protected by a 10 m wide geotextile apron, and part was put directly onto the sea bottom in order to evaluate the protection effects (Figure 2). Three different materials were used in the construction of the scour apron, and their location and properties are indicated in Figure 2, Table 1. The constitutive material of the tube is a polyester (PET) geocomposite. The geocomposite is a high modulus PET woven assembled exclusively by mechanical needle-punching process with a high UV resistance PET non woven. The geocomposite (Geotextile A) used to manufacture the tubes and one of the scour aprons, was chosen with the main scope of taking advantage of the good mechanical properties of the inner woven geotextile (high tensile strength, high stiffness and low creep at long term) and of the outer filtering properties of the non woven (soil retention) together with high abrasion resistance and good substrate for algae. The two other geotextiles used for score aprons were a woven polypropylene (PP) geotextile (B), and a reinforced PP woven/needle punched non woven, geocomposite, (C):.

Technical data	Geotextile A Hate®175/175 DW A30 –-	Geotextile B woven Hate® A20.606 SP -	Geotextile C Hate® B600J
Constitutive material	non woven:PET woven:PET	PP	NonWoven: PP woven: PP
Unit weight UNI EN ISO 9864	non woven 300 g/m^2 geocomposite 900 g/m2	280 g/m^2	600 g/m^2
Tensile Strength MD and CMD UNI EN ISO 10319	≥ 175 KN/m	≥ 55 KN/m	≥ 20 KN/m
Elongation MD and CMD UNI EN ISO 10319	≤ 14 % ≤ 14 %	15 % ± 4% 11 % ± 3 %	< 20 % < 20 %
Characteristic opening size O_{90} UNI EN ISO 12956	0,11 mm	270 µm	0,10 mm

Table 1 Main technical properties of Geotextiles A, B and C

The required tensile strength of the geocomposite used to manufacture the tube, as well as an approximation of the shape, have been designed with the commercial software GeoCoPS (3.0): values of input and output parameters of the design are reported in

Table 2. The required strength in working condition is about 1/3 of the strength required during filling. In other words tensile strength is an important issue to prevent failure during installation/filling process. Prediction of the final shape is a peculiar issue in the design of geotextile tubes, because there is not a design method that is both accurate and simple. The fundamental parameter in low crested breakwater design is submergence. In case of underestimating of this design parameter, the object of the total project can lead to a partial failure.

INPUT DATA	
Circumference of tube, [m]	9.4
Unit weight of lower layer of slurry, [kN/m^3]	14.20
Unit weight of upper layer of slurry, [kN/m^3]	14.20
Unit weight of fluid outside tube,lower layer, [kN/m^3]	10.10
Unit weight of fluid outside tube, upper layer, [kN/m^3]	0.00
Specified height of lower layer of slurry, Hin-L, [m]	2.5
RESULTS	
Geosynthetic in CIRCUMFERENTIAL direction:	
Tensial force at WORKING conditions, [kN/m]	41
Required ULTIMATE strength, [kN/m]	113
Geosynthetic in AXIAL direction:	
Tensial force at WORKING conditions, [kN/m]	23
Required ULTIMATE strength, [kN/m]	64
Maximum height of tube, H [m]	2.6
Maximum width of tube, W [m] (max. width is at height 1.2 [m] from base)	3.3
Ratio H / W	0.786
CONSOLIDATED TUBE:	
Unit weight of consolidated (saturated) fill, [kN/m^3]	17.0
Consolidated cross-section area, [m^2]	4.2
Final height, H [m]	1.6

Table 2 Main Input, computed and graphic outputs of GeoCoPS (3.0)

3.2 *Installation process*

Installation demanded about two months of work (June-July 2008), and the work of three employees. Placing aprons and filling the tube require both a very still wave climate - moreover a good underwater visibility is very useful in order to have an accurate result within a short time. This kind of building process and the use of the appropriate PET geocomposite did not created any muddy effect in the sea during filling process and does not interfere with beach recreational activities at all, so it was possible for the municipality to install a coastal defence structure during the summer season without loosing tourism income.

4 PRELIMINARY RESULTS

Underwater surveys were performed during the two month period of structure construction, and several times after that. As observed during the construction, the big diameter tube in geosynthetics were placed in the right position while installation difficulties have been noticed for the scour apron, and the small anchoring tubes. Furthermore polypropylene aprons (B and C) tend to float, and this leads to an increased stress abrasion of the fabric (Figure 4).

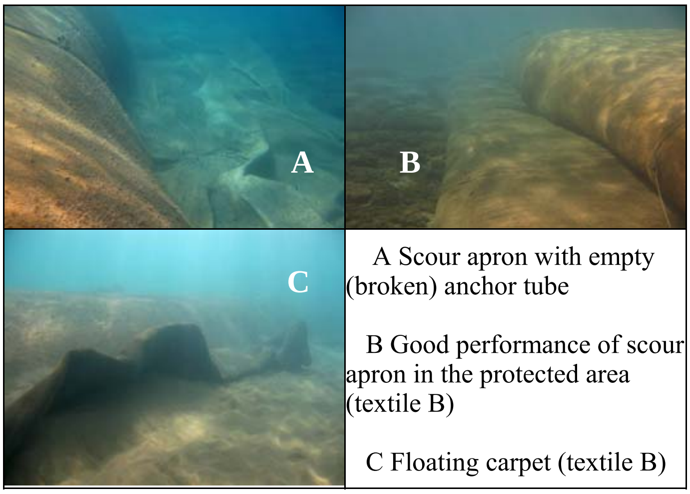


Figure 4 Different performance of scour aprons

Filling ratio of the big tubes was not completely regular on the full length of the barrier, most likely due to the low pumping capacity used for filling the trial tubes section

In this site, the sandy bottom has very high mobility, and strong interaction with the tubes was evident from the first surveys- in many cases the scour apron was even covered. An example is shown in Figure 5 and Figure 6 where the tube on the right was installed at 2 m depth and became almost completely covered by sand.

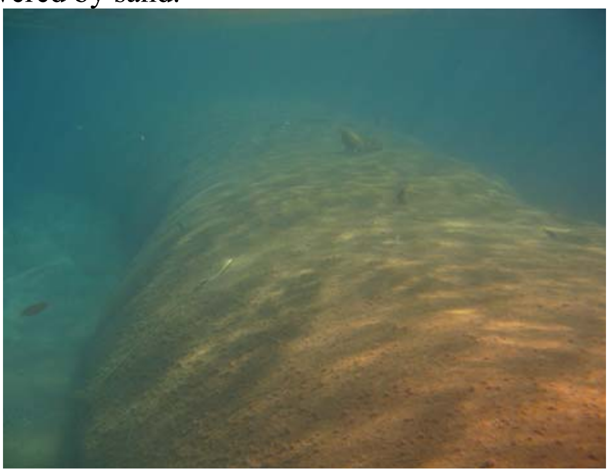


Figure 5 Initial tube shape

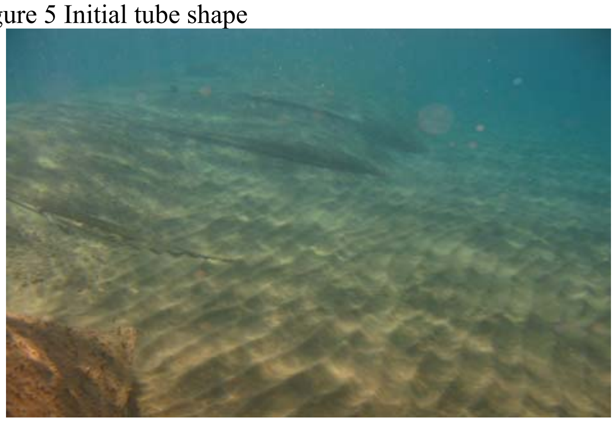


Figure 6 Sand-covered tube

4.1 *Geometry*

Three measurements of the sea bottom in the surroundings of the tube were carried out using a single-beam echo sounder. Moreover a Differential Global Positioning System (DGPS) measured specific marked points placed on the surface of the tube and on the coastline with 1 cm accuracy. These marks on tubes (Figure 7) were placed in order to have their movements followed over the time: their position is indicated in Figure 8.

In this way information on changes in the shape of the tube includes a time series of some specific points, and is more accurate than what could be obtained with the echo sounder survey only (Figure 10).

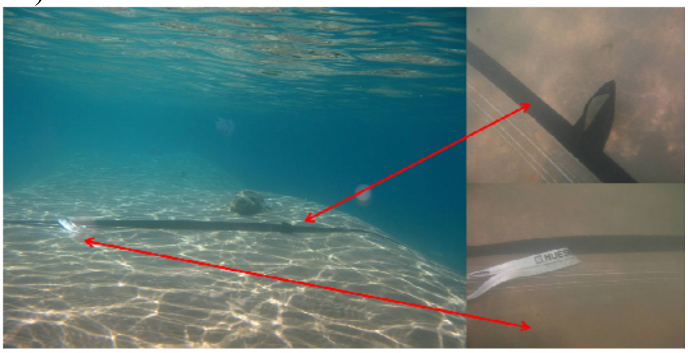


Figure 7 Marks on tube surface

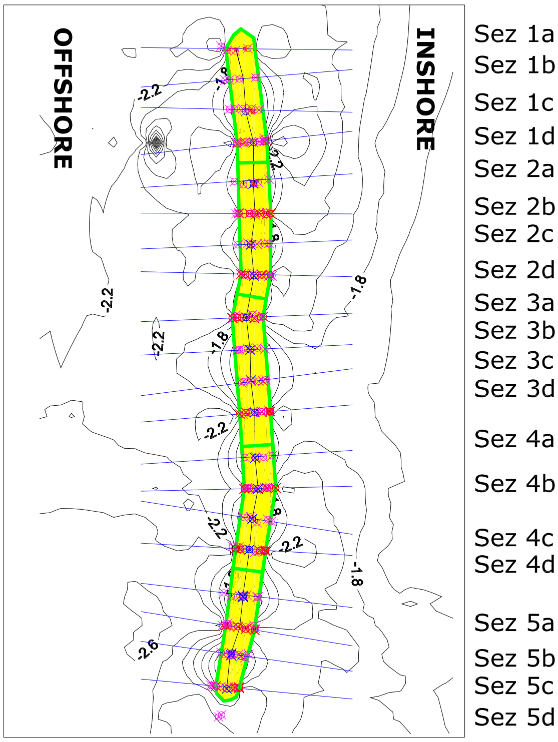


Figure 8 Position of the tubes and sketch of DGPS campaign

The longitudinal section that was obtained from the survey made immediately after the consolidation of the tubes (Figure 9), shows that the breakwater is few parts is lower than what had been designed; this is due to the natural unevenness of the bathymetry, and in part to a partial filling of the tube.

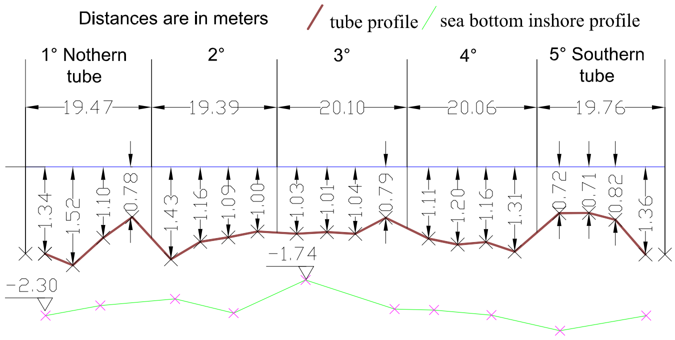


Figure 9 Longitudinal section of the barrier after consolidation (August 2008)

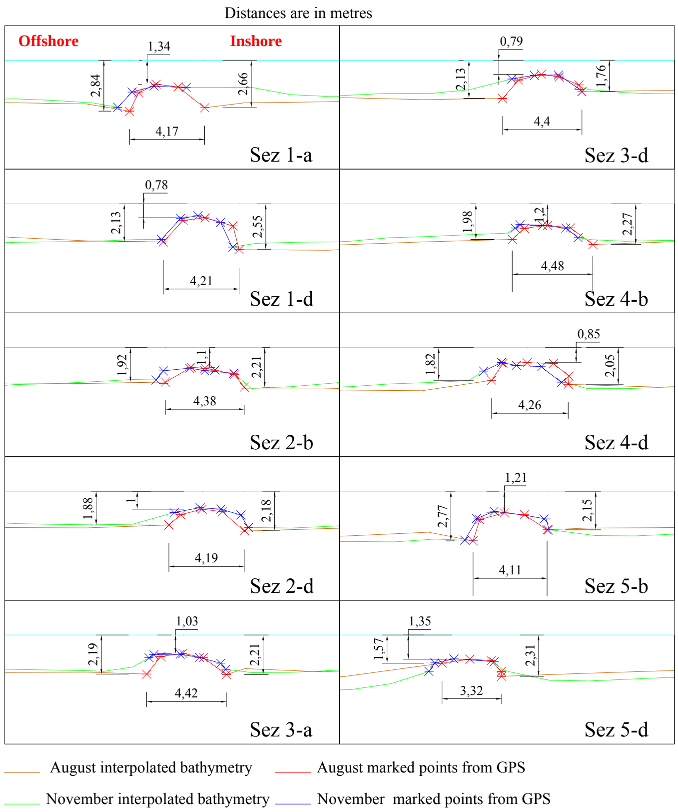


Figure 10 Geometrical evolution of the tube and surrounding sea-bottom - quotes are referred to the first survey.

4.2 *Performance of the overall protection system*

Even if this structure is mainly an experimental field test site, it was designed also to protect the sandy beach form erosion. As mentioned in the previous section, three bathymetric surveys were performed: the first was carried before the installation of the tube, the second was conducted one month after the construction ended, and the last was performed three months after conclusion of works.

In Figure 11 (left) the latest results on detailed bathymetry are shown. There is an accumulation of sand immediately inshore and offshore the barrier. This means that accreting storms occurred and the tubes interacted with the sand that was moving shoreward; sand accumulated offshore the tubes, and in part overpassed the barrier. Wave and barrier interaction created a tombolo, at one meter below the mean sea level: this indicates that the designed level of protection was achieved.

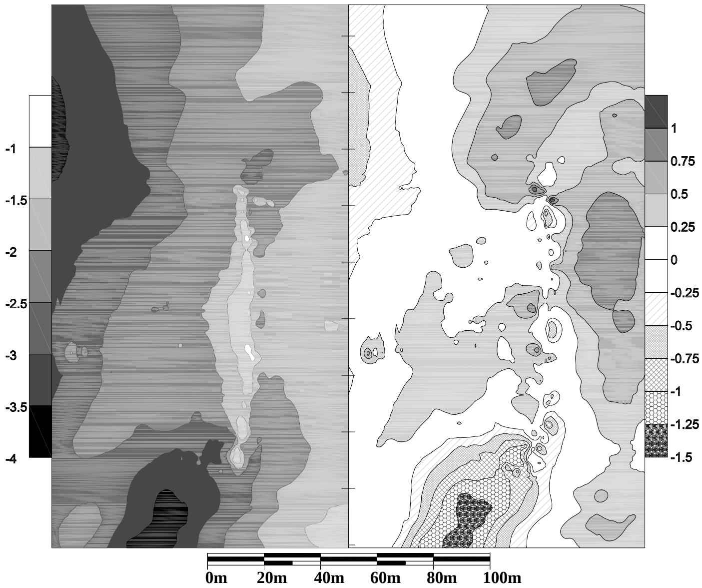


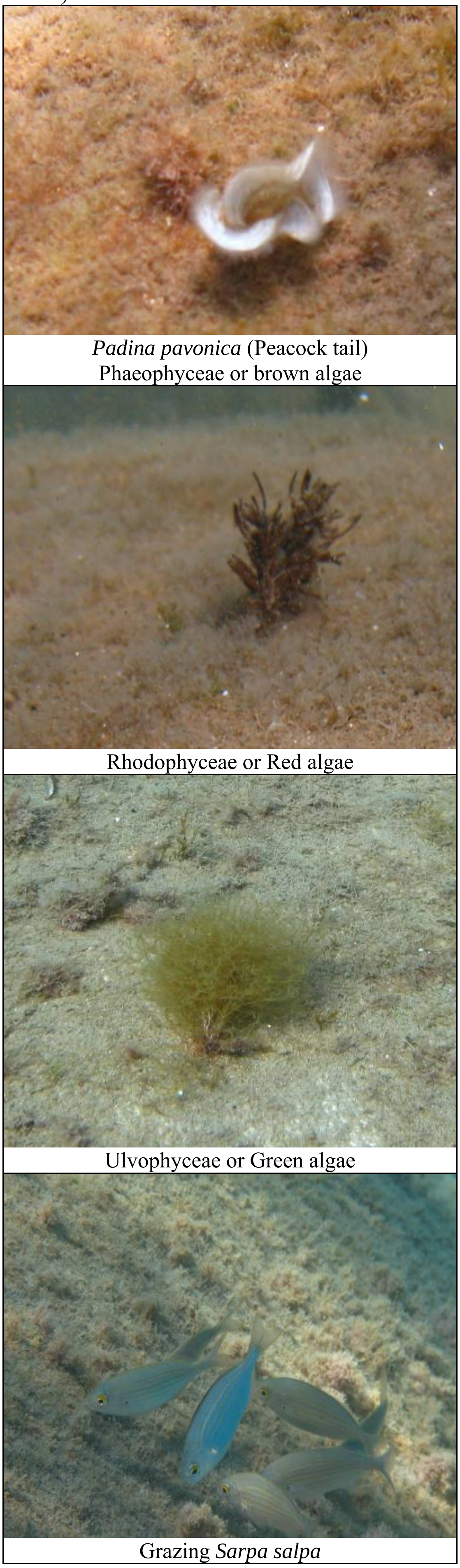
Figure 11 Bathymetry obtained a few months after construction of defence system (18 November 2008) (left); Comparison of bathymetry surveyed in two occasions after installation: 28 August and 18 November 2008 (right).

Figure 11 (right) shows a comparison between the last survey performed (November 2008) and the survey conducted 1 month after the construction of the tube (August 2008). In the southern area an interaction of the structure with longshore currents can be seen. Between the first and the last survey, this lead to an erosion of the sea bottom near the downstream head of the barrier that exceeds one meter. Except for this erosion verified in the offshore area, the bathymetry seems to be in a substantial equilibrium.

4.3 *Marine ecosystem enhancement*

A descriptive scuba-diving survey was conducted on 31 September and 18 November 2008, in the whole area under study. The defence structure lies on the seabed at a depth ranging from -1 to -3 m, being therefore characterised by high energy which, together with light, temperature and salinity, is a determinant factor in ecological equilibrium. The nature of the substrate (in terms of mineralogical composition and topographic complexity) plays an important role in the stages of site selection and subsequent colonisation, in the accumulation of organic matter, and in providing refuge from predation or grazing activities. So, the type of substrate has a key influence on the distribution and composition of populations and communities in many scales of observation (Lemire and Bourget, 1996).

The survey carried out on 31 September 2008 showed that, about three months after its construction had initiated, the geotextile system presented an almost uniform algal cover. There was greater prevalence of algae from the morphological group of Phaeophyceae or brown algae (Figure 12), mainly in areas sheltered from wave action and well lit. In particular, it was possible to detect the presence of species such as *Dictyota dichotoma*, *Stypocaulon scoparium* and few *Padina pavonica* (Peacock tail) (Figure 12).



Padina pavonica (Peacock tail)
Phaeophyceae or brown algae

Rhodophyceae or Red algae

Ulvophyceae or Green algae

Grazing *Sarpa salpa*

Figure 12 Marine growth on the tube

Even Coralline algae which belong to the group of Rhodophyceae or red algae (Figure 12) were very abundant, such as *Jania rubens*, which covers much of the surface of tubes, with a characteristic yellowish-white colour in areas that are heavily exposed to light and rose-purple in areas receiving less light. The presence of these algal populations, mainly photophilic, attracted several species of fish belonging to the family of Sparidae, such as Seabream or Diplodus, *Oblada melanura* and White salema or *Sarpa salpa*, that browse the substrate for food.

The inspection carried out on 18 November 2008 indicated a modest reduction in the development of some algal species, especially those belonging to the group of Rhodophyceae, such as *Jania rubens*. The cause of this decline is probably due to the severe sea storms which affected the area between the two surveys without any effect and damages of the main structure of tubes in geosynthetic.

Only specific areas being subject to significant mobility of the geotextile, due to wrong positioning, has resulted partially damaged as the PP floating scour apron below the structure that was no longer anchored and around one filling port.(Figure 4).

Although geotextile container systems are simpler when compared to "natural" environments, they could be considered as "semi natural environments", offering the possibility of a permanent colonisation by animal and plant species that generally cannot grow on those depths.

5 CONCLUSION

Whereas this field study is still in progress, an improvement in the amount of measured parameters is considered to be necessary, such as a wave measurement system.

In this phase of the research, it has been possible to reach some concluding remarks:

- Filling methods and pumping pressure should be precisely checked in order to achieve the desired height of the submerged barrier
- Scour protection and anchoring should be improved.
- The use of PET geocomposite, woven/non woven for manufacturing the tubes assures mechanical, hydraulic and filtering properties to the system
- There are not relevant differences in the performance of materials used for scour apron, but if a failure should happen, a non floating polymer is more stable and should therefore be preferred.
- Construction technology requires very accurate control during installation as well as periodic maintenance.
- There is extremely limited environmental impact during construction.
- There is a very rapid colonisation of marine flora.
- Coastal protection submerged barrier system with big diameter geosynhthetic tube performs very well under severe sea storms

6 ACKNOWLEDGMENTS

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7 REFERENCES

Aminti, P.L., Mori, E., 2008. Opere i difesa della costa costruite con contenitori in geotessuto riempiti di sabbia. *Proc. National Conference Prevenire, Programmare, Pianificare.* Maratea, May 2008.

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

Fantini P, Simini A., 2008 Controllo dell'erosione costiera con geosintetici tubolari di grandi dimensioni *Proc. National Conference Prevenire, Programmare, Pianificare.* Maratea, May 2008.

Lawson, C. R., 2006. Geotextile containment for hydraulic and environmental engineering. *8th International Conference on Geosynthetics*, YOKOHAMA, Millpress.

Lemire M. & Bourget E., 1996. Substratum heterogeneity and complexity influence micro-scale selection of Balanus sp. And Tubularia crocea larvae.- *Marine Ecology Progress Series* 135: 77-87.