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MODELLING THE EFFECT OF GEOTEXTILE SUBMERGED BREAKWATER ON HYDRODYNAMICS IN LA CAPTE BEACH

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Abstract
The nice and attractive beach located south of La Capte port is subject to coastal erosion. It gradually disappears under the impact of waves and storms, especially in the autumn and winter. To limit this erosion, geotextile submerged breakwaters were established in February-March 2008 accompanying beach nourishment. The implementation of these submerged structures highly modified local hydrodynamics, sediment transport and the evolution of coastline of La Capte beach. The paper presents modeling this area before and after the installation of breakwaters. The simulation is implemented using Mike coupled models which takes into account the presence of Posidonia seagrass. The results of this work will be compared with those of measurements and monitoring which were conducted for many years. Thenceforth, the general overview of the site shall be presented, the effect of this breakwater on the proximity of La Capte beach will be also analysed and uncovered.

Keywords: La Capte, geotextile, coupled models, wave transmission coefficient.

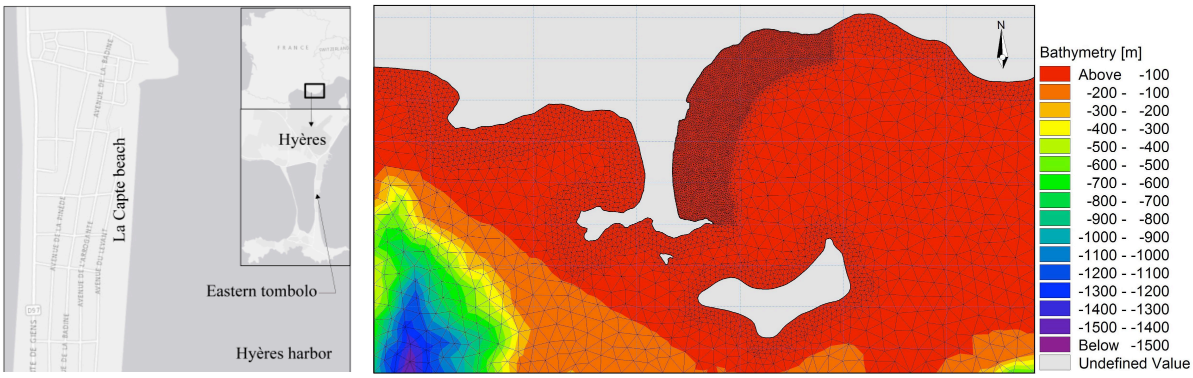
1. INTRODUCTION

La Capte beach is located in the town of Hyères, South East of France (Figure 1a). This is a shallow sandy beach which lies on the south of the eastern part of Giens tombolo. This tombolo was mainly formed due to the refraction of waves by the islands (Meulé, 2010). This is one of the most famous and attractive touristic places in France, especially in the summer. The beach of La Capte extends over more than one kilometer from the southern breakwater of La Capte marina to the end of urbanization.

The coastline of La Capte suffered a decline under the impacts of waves and storms for many years which lead to a gradual disappearance of its beach. The primary reason of this disappearance pointed out by the researchers and specialists is that of the change of sediment transport mechanism. The main sediment input in Hyères bay comes from Gapeau river 6 km north and Pansard-Maravenne river 11 km north-east. The current of longshore drift from the north to the south allows sediment redistribution on the coast. However, some of the sediment is trapped in the Posidonia seagrass while most of the sediment flux is stopped by the port facilities (Meulé, 2010). Futhermore, many groynes were constructed between Gapeau river and the beach of La Capte.

To sustain La Capte beach, to limit the loss of materials as well as to stabilize the coastline, two geotextile submerged breakwaters (GSB) of 100 and 150 m long were built. This installation took place during the spring of 2008 together with sand reloading to restore and nourish the beach (Richard, 2009). These breakwaters are composed of two geotextile tubes, side by side, 1.80 m diameter and final height of about 1 m. The two breakwaters were installed at approximately 120 and 160 m respectively from the shore, at a depth from 1.8 to 2.2 m, and from 2.5 to 2.8 m respectively.

After 8 years, many studies and surveys have been conducted to evaluate the efficiency of GSB. Koffler et al. (2009) indicate that the beach was protected against erosion after the storms in December 2009. The scientific monitoring of the beach of La Capte before and after the implementation of GSB is conducted by S. Meulé. The results of measurements show that the geotextile tubes impact on the geometry of the beach, the sustainability of sand, and hydrodynamics in the area as well as the dynamics of Posidonia meadows significantly. The coastline in 2009 was enlarged 10 meters compared to the initial state established in 2007. Most of authors agreed that the geotextile works prove to be a solution for stabilizing in part the coastline and limit erosion but they did not stop completely, because they are often too immersed (Lenoble, 2011). They play the role in mitigating storm waves, but little attenuate moderate waves which also participate in sediment transport. Therefore, to provide an up-to-date overview, it is necessary to model the effect of GSB on the status quo of La Capte beach.



(a) ***(b)***

Figure 1: (a) Location of the La Capte beach, (b) Computational mesh of regional model.

2. MATERIALS AND METHODS

2.1. Data processing

Firstly, the bathymetric data obtained from EGB (European Marine Observation and Data Network Gridded Bathymetry), Litto3D (edited by SHOM, Service Hydrographique et Océanographique de la Marine) and EOL (Etude et Observation du Littoral, an association) were processed and analysed. The result shows a mean slope of 0.5% for the area study and contours of 0.5 m from the coast to the 15 m depth (200 m wide).

Next, the data of sea level and storm surge are obtained from these sources. The range of astronomical tide on the SHOM map is less than 0.5 m. In addition, the rise of mean sea level (MSL) due to global warming is also estimated about 35 cm between 2010 and 2060 (Lenoble, 2010). From all this, the retained sea levels for the scenarios are +1.00, +1.30, and 1.50 m above NGF (Nivellement Général de la France) for the annual, decadal, and fiftieth storms, respectively.

The off-shore wave data is measured and recorded by the buoys 08301 and 08302 located approximately 1.8 km south of Porquerolles island (42°58,00'N and 6°12,29'E), at 90 m depth. Afterward, this data is processed statistically by CETMEF (Centre d'Etudes Techniques Maritimes et Fluviales). Moreover, ANEMOC (Atlas Numérique d'Etats de Mer Océanique et Côtier) also supplied the off-shore wave data via the points of MEDIT-2185, MEDIT-2610, and MEDIT-6975. The off-shore waves come from two main directions. The most frequent direction is south-western (frequency of about 40%), but these waves generally have low energy with heights of 0.5 to 1 m and periods of less than 6 seconds in 80% of cases. The second direction is southeastern waves. They are less frequent (25% of total annual duration). However, they have the heights of more than 2 m in 40% of cases, with periods of more than 6 seconds over 25% of cases (Capanni, 2011). Regarding to the wave data in La Capte beach, it was measured by Samuel Meulé in February 2008. The exact location of the measurement is 43°3.8'N and 6°9.17'E in water at a depth of 3-4 m. The measurement was carried out in the period from 13 to 19 February 2008.

The wind has very different statistical characteristics, both in terms of overall average of extreme values and frequency. The east winds are responsible for the majority of morphogenesis events, which has the maximum speed up to 23 m/s, frequency of 11.4% and an average speed of 5.84 m/s.

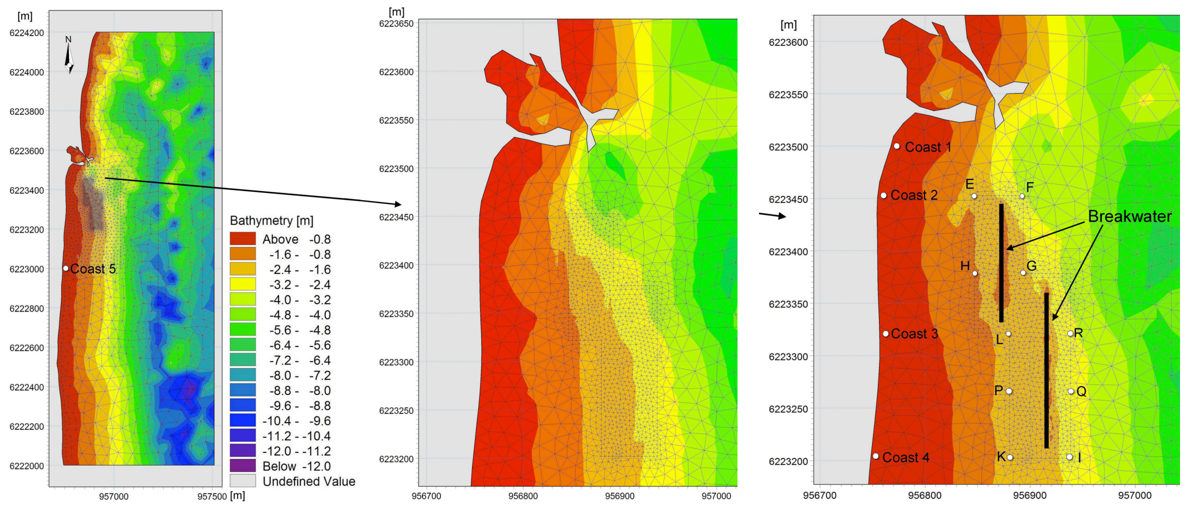
The current data used in our model comes from the thesis of Courtaud (2000). The wave-related currents play a key role in sediment transport. In the normal sea condition, the long-shore currents were measured in the order of 0.4 m/s on average Southeastern wind with maxima observed at 0.8 m/s. In the stormy sea condition, the flow velocities can exceed 1.3 m/s.

Finally, the most famous characteristic of marine biocenosis in Hyères bay is that Posidonia seagrass. It plays an important role in reducing the hydrodynamic forces and the trapping of sediments (Meulé, 2010). Hence, the distribution of Posidonia affects the evolution of the coastline.

2.2. Implementation of numerical simulation

First of all, all available information and data concerning the study area such as sea level, waves, winds, currents, bathymetry, coastal line, sediments, and marine biocenosis was gathered. Afterwards, this huge datum was classified and processed by using some tools. Moreover, this datum was divided into two sets: the first set used to be input parameters for the Mike 21 coupled model, and the second set devoted to calibrate a numerical model simulated in Mike 21 software.

Second of all, this area before and after constructing the GSB is simulated and modeled by applying Mike 21 coupled model. It is coupled by one spectral wave model (SW), one flow model (FM), and one sand transport model (ST) in Mike 21 package. Thus, it allows to simulate and depict the mechanism of hydrodynamic factors.



(a) *(b)*

Figure 2: Computational mesh and local bathymetry before (a) and after (b) installing the GSB.

Subsequently, the model will be calibrated and validated by selecting specific short time periods, adjusting friction coefficients and dimension of sediment so as to satisfy the best fitting criteria of simulation towards the dedicated periods. If the results of this model meet the criteria as well as agree with the measurements and monitoring, analysis will be operated in the following step. In the worst case, the Mike 21 coupled model can be modified again.

The first step of the simulation is that of generating two types of meshes: the regional and local scale. The regional scale spreads from Cap Brun to Cap Bénat (32 km East-West) (Figure 1b) with 8 147 nodes and 15 456 elements. The local scale comprises 2 529 nodes and 4 810 elements. In addition, the boundary conditions of this scale are calculated from the models in the regional scale. Both the regional and local scale employ the SW and FM models. The representation of geotextile breakwaters is showed by the change of local bathymetry (Figure 2a,b).

After creating the computational meshes, the regional model is simulated with the change of MSL as defined in annual (A) and decadal (D) scenarios. The input data used in this model is described in Table 1. From the results of regional simulations, the area around La Capte beach will be modeled in local models. With each mean sea level, two scenarios including the breakwaters (0) or excluding them (1) shall be taken into account by using the different bathymetries. Consequently, four cases are considered in this study, namely A0, A1, D0, and D1.

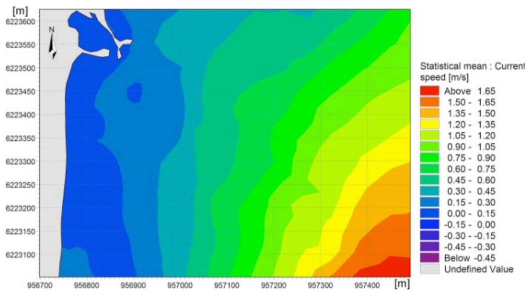
Table 1: The characteristic parameters of hydrodynamic data in the regional model.

Scenarios	$H_{1/3}$ (m)	T_p (s)	MWD (^{o})	DSD (^{o})	V_w (m/s)	WL (m)
A	3.3	8	120	35	19	0.65
D	4.4	10	90	25	23	0.95

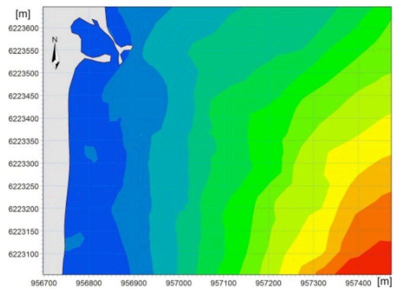
$H_{1/3}$ - Significant wave height, T_p - Peak wave period, MWD - Mean wave direction, DSD - Directional standard deviation, V_w - Wind speed, WL - Sea level.

3. RESULTS AND DISCUSSIONS

First of all, the sea level in 2008 with the scenarios A of MSL +0.65 m is a little higher than those in 2007 approximately from 1 to 2 cm. Specifically, the sea level along La Capte beach in 2008 is measured about +0.804 m. Meanwhile, the sea level along this beach ranged from +0.792 to +0.798 m in 2007. It comes from the wave breaking when the wave passes the submerged breakwaters. This conclusion is also valid for the scenario D with MSL +0.95 m. The sea level around the breakwater in 2008 is modified, but this change is negligeable. On the contrary, the sea level behind the breakwater and near shoreline alters considerably when the comparison is done between 2007 and 2008. The sea level above 1.085 m occurs along La Capte beach in 2008.



(a)



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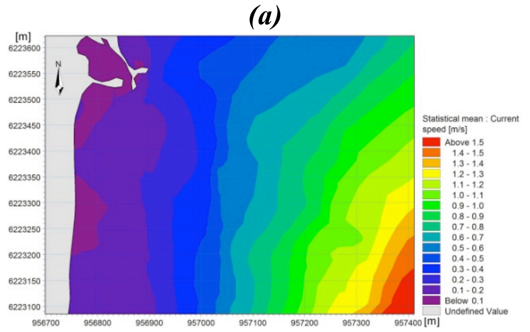
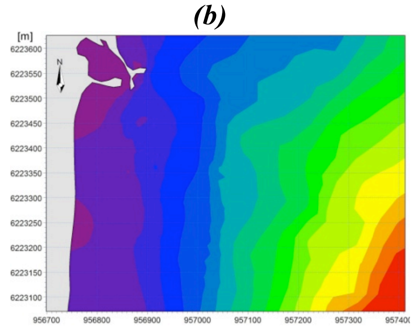


(c)



(d)

Figure 3: Maps of mean current speed near La Capte beach in the scenarios A0 (a), A1 (b), D0 (c), and D1 (d).

On the other hand, the wave breaking also obviously causes the change of current speed and the disturbance of current direction in the MSL of +0.65 m. The current speed evidently reduces in the near shore area inside the breakwater when comparing with those in 2007 (Figure 3a,b). The water area behind the breakwater usually has the current speed from 0 to 0.15 m/s. Their direction is changed and dispersed in the proximity of the breakwater. Similar to A scenarios, the speed of current and the direction of current in 2008 with D scenarios have a light difference when comparing with those in 2007 (Figure 3c,d). This small difference is mainly focused on the area of the breakwater. Conversely, the value of current speed and current direction close to the shoreline in 2008 is the same as those in 2007. The current speed of below 0.1 m/s distributes inside and close to the basin of La Capte marina. Along La Capte beach, the current speed usually ranges from 0.1 to 0.2 m/s.

One of the most important factors that will be used to analyze the results of local simulations is that wave field. The wave height in local model in 2007 and 2008 with the scenario A of MSL +0.65m is displayed in Figure 4a,b. Visually, the significant wave height near La Capte beach in 2008 (Figure 4b) is lower than that of 2007 (Figure 4a). Along with the wave height, the direction of wave behind the submerged breakwater is also changed significantly. In 2007, there is a small area with wave direction from 78^{o} to 84^{o}, which appears near La Capte beach. Nevertheless, this area almost vanishes in 2008. On the other hand, in the scenarios D of MSL +0.95m, the magnitude of wave height and wave direction in the simulation with and without breakwater is not clear. In Figure 4c,d, it is obviously seen that the contours of wave height do not change much.

However, to assess the efficiency of the breakwaters more exactly, the wave transmission coefficient, K_t, is used in this paper. The wave transmission coefficient is defined as the ratio of the transmitted wave height at the shoreward toe of the breakwater to the incident wave height at the seaward toe of the breakwater. The wave transmission coefficient should range from 0 to 1, for which a value of 0 implies no transmission, and a value of 1 implies complete transmission (Pilarczyk, 2003). Four points at the shoreward toe of the breakwater and four points at the seaward toe of breakwater (Figure 2a,b) have been extracted from the local simulation. The values of these points are shown in Table 2. The wave transmission coefficients vary from 0.77 to 0.86 with the scenarios A of MSL +0.65 m and from 0.82 to 0.91 with the scenarios D of MSL +0.95 m. It is easily observed that K-I is the most efficient section for wave attenuation. Moreover, the values of K_t in D scenarios are greater than those in A scenarios. The increase of the transmission coefficient comes from the sea level rise which makes the breakwaters deeper. All above-mentioned comments reveal that the GSB does not keep the key role in wave-breaking and coastal protection at the sea level of +0.95 m.

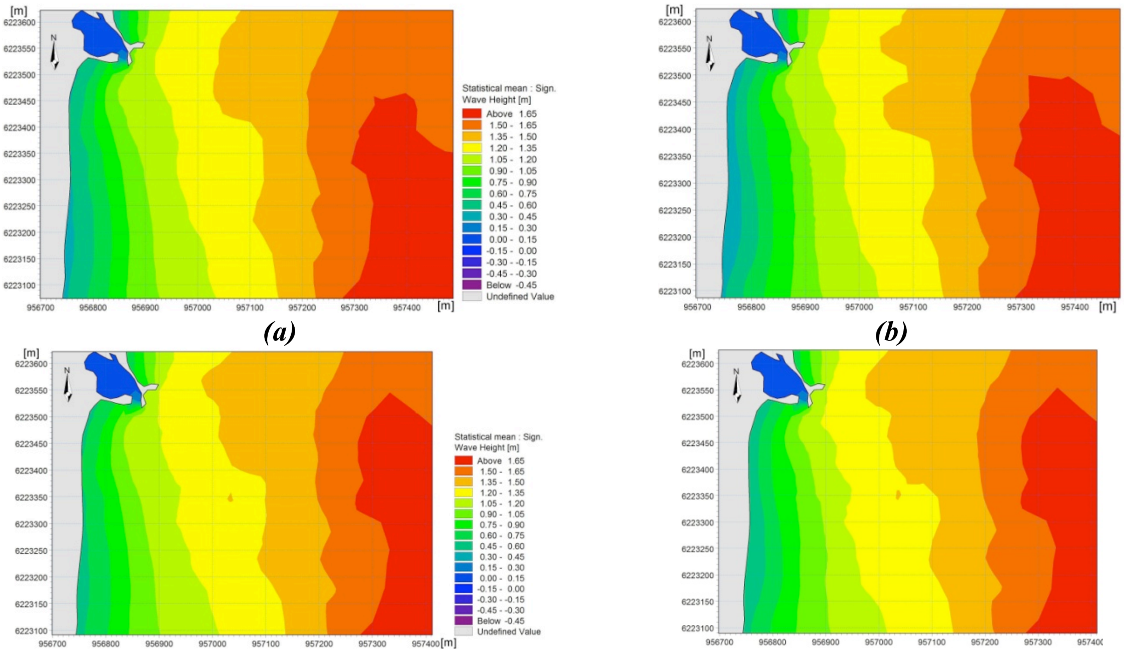


Figure 4. Maps of significant wave height near La Capte beach in the scenarios A0 (a), A1 (b), D0 (c), and D1 (d).

In addition to the transmission coefficient, the significant wave heights of five points along La Capte beach in 2007 and 2008 are compared as Table 3. All of these points are 5 m far from the coastline (Figure 2a,b). According to this table, the significant wave heights at all points in 2007 (before installing the breakwater) are higher than those in 2008 (after installing the breakwater) from 1 to 8 cm. The coast points 1, 2, 3, and 4 present larger variations because they are in the area protected by both submerged breakwaters and the mound breakwaters of La Capte marina. Besides, the errors in D scenarios are smaller than those in A scenarios.

Table 2: The transmission coefficients with annual and decadal scenarios

	Scenario A1					Scenario D1				
Section	E-F	H-G	L-R	P-Q	K-I	E-F	H-G	L-R	P-Q	K-I
H_t (m)	0.99	0.95	1.05	1.02	1.02	1.19	1.12	t	1.15	1.13
H_i (m)	1.19	1.11	1.32	1.3	1.33	1.3	1.24	1.43	1.37	1.34
K_t	0.84	0.86	0.8	0.78	0.77	0.91	0.9	0.82	0.84	0.85

Table 3: The significant wave heights along La Capte with annual and decadal scenarios

	Scenario A1					Scenario D1				
Point	Coast 1	Coast 2	Coast 3	Coast 4	Coast 5	Coast 1	Coast 2	Coast 3	Coast 4	Coast 5
2007	0.46	0.47	0.46	0.42	0.44	0.58	0.59	0.60	0.55	0.56
2008	0.39	0.39	0.38	0.36	0.42	0.52	0.53	0.52	0.50	0.55
E	6	7	8	6	2	5	6	7	5	1

Significant wave heights in meter, Absolute error (E) in centimeter.

4. CONCLUSIONS

Firstly, the interim simulations of regional model have been done and calibrated with the experimental data. The simulations have reproduced correctly the real mechanism of current, wave and sea level in the study area, especially, along the eastern Giens tombolo that has been mentioned in the previous works. They provide an overview of La Capte beach area before the GSB are installed.

Secondly, the effect of these breakwaters is discussed and clarified more specifically by using the results of local simulations. The presence of the breakwaters has changed the current at La Capte beach in the positive direction. The significant wave height and current speed have been reduced to acceptable levels. Nonetheless, the effect of submerged breakwaters will be reduced when the sea level rises. Therefore, the expansion of these breakwaters could be a positive option to continue protecting La Capte beach area from the phenomenon of global warming and climate change.

Finally, the above-mentioned simulations can be used to predict the development of hydrodynamic factors as well as coastline change in near future if the input data is being updated. Furthermore, they will be employed to optimize the dimension of the GSB in the next study.

5. ACKNOWLEGEMENTS

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6. REFERENCES

Capanni, R. (2011). *Étude et gestion intégrée des transferts sédimentaires dans le système Gapeau/rade d'Hyères.* Aix Marseille 1.

Courtaud, J. (2000). *Dynamiques geomorphologiques et risques littoraux cas du tombolo de giens (Var, France méridionale).* (Ph.D. dissertation), Université Aix-Marseille I.

Koffler, A., Zengerink, E., Ascione, J.-C., & Birukoff, J.-M. (2009). *Un atténuateur de houles en tube géosynthétique pour limiter l'érosion de la plage de la Capte à Hyères.* Paper presented at the Rencontres Géosynthétiques.

Lenoble, A. (2010). Etude pour la protection de la plage du Ceinturon et du secteur Sud du port Saint-Pierre - Phase 1 : Synthèse des connaissances - Rapport.

Lenoble, A. (2011). Etude pour la protection de la plage du Ceinturon et du secteur Sud du port Saint-Pierre - Phase 3 : Définition des scénarios de protection - Analyse préliminaire.

Meulé, S. (2010). IMplantation d'Atténuateur de Houle en GEOtextile: Suivi scientifique de la plage de La Capte, Hyères, Var : Instrumentation, Modélisation (pp. 230-230). Hyères.

Pilarczyk, K. W. (2003). Design of low-crested (submerged) structures - an overview. *6th International Conference on Coastal and Port Engineering in Developing Countries, Colombo, Sri Lanka, 2003.*

Richard, L. (2009). *Suivi de l'evolution de la plage de la Capte suite a la mise en place d'attenuateurs de houle.* (Mémoire de stage d'initiation à la Recherche).