

## Coastal protection with BMS: the first experience in Italy

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### **Abstract:**

The paper deals with the first Italian project of a new coastal protection system, consisting in draining the emerged beach face (BMS). The system was built in Ostia starting from December 2000 and was working since February 2001.

The BMS (Beach Management System) can be classified between a soft approach and a beach management one and has no environmental impact. It essentially consists of a series of drainage pipes connected with a pumping station and a discharge pipe. It is mainly a coastline maintenance system and can be also applied as a stabilisation system for artificial nourishment.

In the present paper the Ostia BMS characteristics will be described, with the difficulties encountered during the construction phases. Moreover, even if the systematic monitoring of the site is not yet started, the paper will enlighten the first results observed, which appears very satisfactory.

BMS is a new method that is between a soft approach and a beach management one. In 1999 *Impresub, Diving and Marine Contractor s.r.l.* bought BMS rights for Italy. This system was patented in 1985 by Danish Geotechnical Institute, who co-operated in many facilities installation all

over the world (Denmark, Sweden, Great Britain, Japan, United States, Germany, Malaysia, Spain, and France etc.).

Unfortunately not many monitoring results are available, above all about what concerns sea states. That means that the beach growth observed during the BMS working could depend by natural events.

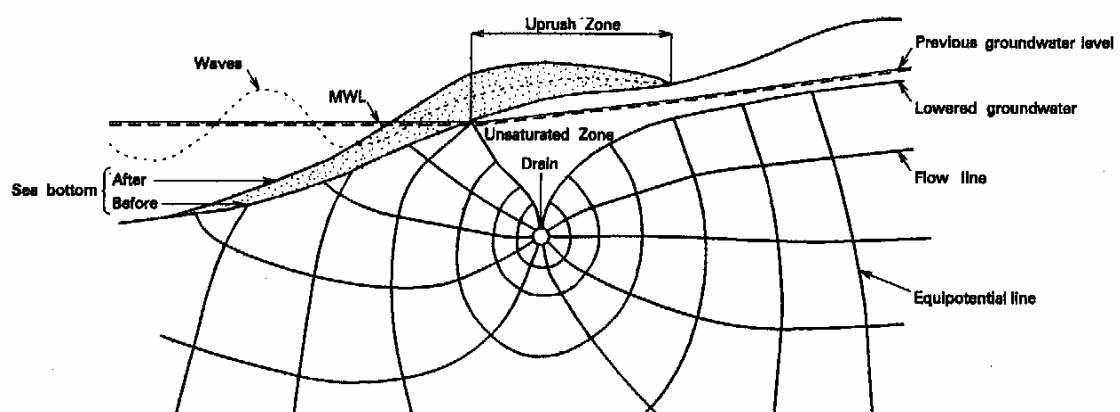
The drain influence can be analysed by comparing the behaviour of two beaches with the same natural conditions protected by BMS and not protected (i.e. the boundary regions of a BMS facility).

In Italy, thanks to a convention between Regione Lazio Administration and Impresub, a BMS pilot facility was built in the South Eastern part of “Lido di Ostia”. It consists in three independent sections covering a length of approx. 400 m along “Vecchia Pineta” and “Nuova Pineta” beach. The BMS construction was finished at the beginning of February 2001. A first monitoring action has been performed to verify the BMS effects on the coastline and beach profile evolution during its first working year.

Even if the monitoring results are not yet completely processed, the recent coastline evolution shows that BMS produced good effects on beach evolution.

The evolution observed will be compared with the surrounding places one, considered as a zero level condition, and correlated with meteo-marine conditions occurring during the experimental period.

The facility will be included in a wide research program under the responsibility of Polytechnic of Bari, which is developing BMS mathematical, and 3D physical modelling and planning a complete monitoring program on Ostia facility, aimed also to understand the relationship among water table oscillations, sea states and beach evolution.



## 1. Introduction:

BMS is a new method that is between a soft approach and a beach management one. In 1999 *Impresub, Diving and Marine Contractor s.r.l.* bought BMS rights for Italy. This system was patented in 1985 by Danish Geotechnical Institute [24, 25, 26], who co-operated in many facilities installation all over the world (Denmark, Sweden, Great Britain, Japan, United States, Germany, Malaysia, Spain, France etc.).

Unfortunately not many monitoring results are available, above all about what concerns sea states [4, 8]. That means that the beach growth observed during the BMS working could depend by natural events [1].

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In Italy, thanks to a convention between Regione Lazio Administration and Impresub, a BMS pilot facility was built in the South Eastern part of “Lido di Ostia”. It consists in three independent sections covering a length of approx. 400 m along “Vecchia Pineta” and “Nuova Pineta” beach. The BMS construction was finished at the beginning of February 2001. A first monitoring action has been performed to verify the BMS effects on the coastline and beach profile evolution during its first working year.

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## **2. Working Principle:**

When breaking waves impact on a beach, they propagate beyond the point where the water table intersects the beach face and run up to a height controlled by excess wave energy, beach permeability, beach slope and roughness.

In the run up phase the suspended sediment load tends to deposit on the beach face. The subsequent backwash flow accelerates down-slope the beach face and transports offshore the sand sediment [14]. The net balance can be beach erosion or accretion, according to the specific site and environmental conditions and wave nature [2, 12].

In this process the level of the ground water table plays an important role [9, 18, 19, 22]. When the water table level is high in the beach, due to flow from the hinterland, tidal level or percolated water from the swash zone [10, 16], the backwash flow is increased on the beach face, thus also the potential erosion of the retreating wave is increased. Moreover, the seepage flow occurring between the water table level and the mean sea level is mainly offshore directed, thus contributing to make unstable the sand in the run up region.

On the contrary, when the water table level is low compared to mean sea level, a seepage flow will occur towards the beach during the run up process. The available experiments [5] show that this seepage flow does not affect the run up height, but reduces the backwash flow, reducing its erosive potential. Moreover, in this case, the sub vertical seepage flow contributes to stabilise the sand in the run up region.

On most sandy beaches these conditions occur naturally in summertime, when natural drainage will maintain the water table level low and waves usually have a nourishing nature [2]. On the contrary, during winter, the large amount of ground water occurring on the beach produces a natural growth of water table and the natural drainage is not effective enough to reduce the backwash flow produced by storm waves; in these conditions the beach face erosion is more likely to occur. The Beach Management System attempts to interplay with these natural phenomena by favouring deposition of sediment transported by waves during the up rush and contrasting its offshore movements during the backwash, thus tipping the balance off erosion, so in a sense, by recreating all over the year the conditions naturally occurring in summer. The system is based on the principle of the artificial drainage of the beach to keep the water table level low [6, 12, 14, 17]. A drainage pipe is buried under the beach almost parallel the shoreline removes the excess pore water, which is driven by gravity to a collector pump station located further on-shore. The pumps discharge the drained water back to the sea or – as it is drained salty water – to plants that can make productive use of it, such as seawater swimming pools, marine aquarium or fish farming plants.

The beach de-watering process allows water percolation into the beach during wave run up [20, 27] and acts as a counter measure against the seaward water seepage in the downwash phase. The zone of lowered water table further acts to cut off local groundwater flow to the sea and reduces the hydraulic pore water pressure on the sand, thus increasing its resistance to erosion forces and contributing to stabilize the beach slope.

The BMS system constitutes an innovative solution to the erosion with many advantages with respect to traditional coastal protection systems, like negligible environmental impact, low installation and maintenance costs, no negative secondary effects on the nearby beaches.

On the contrary, the actual knowledge does not permit to completely understand the beach drainage effects, so that the design characteristics can be defined only on empirical basis and not on scientific criteria [3].

### **3. Site Investigations And Characteristics:**

The Ostia BMS installation can be considered as the first field experimental facility in Italy. The site was chosen by Regione Lazio Authority, following a deep analysis in which all the relevant historical information about the site has been found and a number of on site experimental investigation have been carried out to acquire site specific data.

Historical information collected includes:

- Generic and thematic cartography (IGM maps, nautical charts, geological charts, CNR maps of Italian Beaches, aerophotogrammetry of the site and satellite images). All this information allowed to evaluate present coast situation and its historical evolution
- Previous studies on hydro-geology of the beach and the nearby costal area, with the aim to evaluate the water table level in normal and extreme conditions
- Previous studies relevant for the evaluation of the coastal transport and sedimentary balance (river transport, amount of littoral and

cross-shore transport, beach nourishment intervention works performed, works done on the backshore dune, coastal protection works)

- Studies on site meteo-oceanographic condition (wind, waves, currents and tides)
- Bathymetry and morphology of near shore sea bottom
- Geo-technical and hydrological characteristics of the beach and near shore sea bottom.

The following site specific investigation has been performed for the feasibility analysis of the BMS:

- Geodetic survey on the data points provided by the Lazio Region Administration, aimed to create a basis of repeatable and correlable points for the positioning of all the data collected or to be collected during BMS monitoring.
- Topographic survey to identify the shoreline position prior to the installation of the BMS and to define the beach face and the bathymetry up to  $-1.5$  m isobaths
- Collection of geological samples on the emerged beach. The coring was performed with a horizontal spacing of  $30\div 50$ m, down to  $-5$ m from the beach level, aimed to characterize the beach stratigraphy and to identify the water table level.
- In situ hydro-geological tests, aimed to evaluate permeability and other hydraulic characteristics of the beach
- Bathy-morphological survey in the near shore zone of the selected area and sea bottom sampling. This survey has been performed with



a low draught boat, equipped with an RTK (Real Time Kinematics) satellite positioning, in order to be sure of repeatability of the positioning either at sea and on land during the site monitoring planned after the start up of BMS system. The boat had a double frequency (30-200 kHz) echo sounder, heave compensator, computer with navigation software and Shipec grabber for bottom sampling. The survey has been performed on alongshore and cross-shore transects and the data have been returned on a regular grid, with 50 m spacing, referred to the datum points of the Italian Geodetic System and to the points indicated by the Lazio Region.

- Laboratory analysis on the beach samples (geological description, grain size distribution, chemical analysis of the pore water).

All the previous analysis allowed defining both the site characteristics and the design parameters.

Ostia beach (*fig. 1*) has been undergone for many years to severe erosion, probably caused by a progressive reduction of river Tevere sediment supply and by a significant local divergence of the littoral transport, which is estimated to 20.000-40.000m<sup>3</sup> per year southwards. The coastline near the built-up area of Ostia has been subject to several coastal protection intervention works, which occasionally have worsened the beach conditions.



**Figure 1 - Ostia beach**

In fact, the approx 4 Km long beach section situated between *Canale dei Pescatori*, on the south part of Ostia built-up area, and *Castel Fusano*, shows a very important erosion problem, with an estimated rate of shoreline regression of 5 m per year.

The suitable site for the installation of BMS is approximately 400 metres long covering the beach from *Vecchia Pineta* to *Nuova Pineta* located southward of *Canale dei Pescatori* (fig. 2).

The very attractive beach, approximately 45 m large with a slight slope estimated to be approx 1:40, has got three wooden cabin piers and the restaurant *La Vecchia Pineta*.



**Figure 2 – BMS location**

The beach is essentially composed of well-sorted fine sand with  $d_{50} \approx 150 \div 200$   $\mu$ m. During the geotechnical investigation on site it was observed that the groundwater from the beach profile was seeping out of the foreshore. During 1999, the 3.5 Km long beach was artificially nourished with 600.000  $m^3$  of sand, with the aim to get an advance of approximately 40 m of the shoreline. Based on numerical simulations, maintenance of this nourishment will require about

15.000  $m^3$  /year of which 3.000 $m^3$ /year can be obtained by the sand

accumulated near the channel entrance, which should be removed anyway to prevent the risk of obstructing the mouth.

Moving southward from the channel jetties, the coast is characterized by a shallow sandy beach limited in the backshore by a mild sloped dune. The sea bottom in the near shore area has one or occasionally two long shore bars, which testify for the presence of an active cross-shore dynamics. Available data on the wave climate along the Lazio coast indicate that most frequent events comes from South and South West sectors. Taking into account the orientation of the local shoreline, with normal to about 210°N, waves are more frequent from sectors above the normal to the shoreline than from sectors below, coherently with the estimated direction of the net littoral transport, which is locally southward.

The gross littoral transport across the river Tevere mouth is estimated – with the high uncertainties typical of such evaluation – to about 220.000 m<sup>3</sup>/year, with a southward-directed net transport of about 20.000 m<sup>3</sup>/year. In ancient periods this weak divergence was more than compensated by the sediment carried to the sea by the river itself, but in recent years the works done on river banks and the soil stabilization measures on the river valley have significantly reduced the river transport, causing the inception of beach erosion on the Ostia littoral. The shore protection measures adopted to contrast this erosion in front of the city have progressively moved its effects southward.

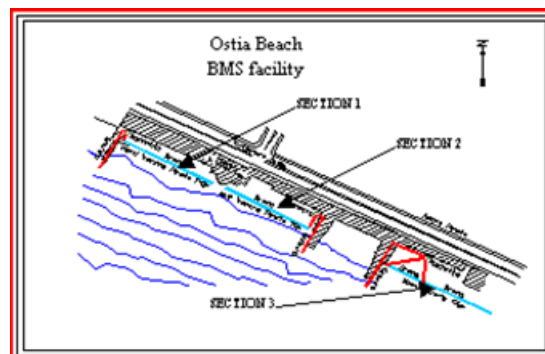
In this situation, the installation of the BMS system had a twofold objective:

- The stabilization of the artificial beach nourishment intervention, thus increasing its duration and limiting the maintenance and restoration costs
- Determine a further advance of the coastline, due to its capabilities of causing the deposition of sediment transported into suspension by waves.

#### **4. Design Of The Prototype BMS Plant:**

In the original design, made at the beginning of 2000, a continuous 400 m long BMS was foreseen. The strong erosion occurred before installation made necessary a deep revision of the design. In fact in some stretches of the protecting beach, the strong withdrawing of shoreline made impossible to locate the drain. Therefore three independent BMS was constructed, each one with its own pumping station (*fig. 3*). The installation work has been performed under the supervision of the technicians of the Lazio Region.

The three sections of the drainage pipe, the filter and the drained water collecting pipes were installed with a patented pipe lay plough machine, from Denmark. The perforated drain pipe was

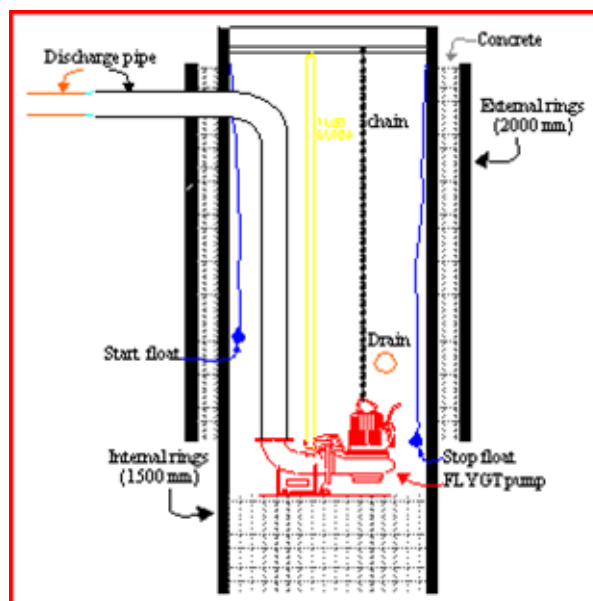


**Figure 3 - BMS project**

made of PVC, with a diameter of 160 mm. Different filtering system have been employed (gravel, sand and geo-textile in different associations) in order to optimise the filter capabilities of the BMS). In the detailed design

phases the position of the drain pipe trenches with respect to the shoreline and the depth of the drain pipe with respect to the beach face have been defined, taking into account several parameters - e.g. the water table level, the beach permeability, the grain size distribution, the tidal excursion, the characteristics of incoming waves - in order to grant the efficiency of the drain system for beach stabilization. The distance between the shoreline and the drain pipes is about 7-8m, while the depth of the pipe was less than 1 m from the MWL.

During installation works some difficulties were encountered in section 2. In fact, along the trench many big stones were found under the sand so that it was necessary to remove them from the BMS line before installation.



**Figure 4 - Pumping station**

For each section a gravity collector well of the drained water and a submerged pump has been employed. The pumping station is completed

power supply and control switchboard located in a protected area near the beach. The pump power depends on the amount of water to be drained; hence it is site and plant specific. On the basis of experiences at other sites, the estimated power discharge would be 200-300 m<sup>3</sup>/h, with power consumption in the order of 5-10 kw. According to site characteristics, the system can operate continuously or be periodically switched on and off from the control panel. The latter operating mode reduces the power consumption and, provided that the functioning cycles are chosen appropriately, the performance of the system does not deteriorate appreciably. In any case, as it can be guessed taking into account the small amount of the power required, power consumption do not influences significantly the operational costs of the system (*fig. 4*).

Each BMS section is completed with a pipe to discharge to the sea the water drained by the system that is fixed under the wooden cabin pier.

##### **5. Start Up Of The Prototype Plant:**

The start up of the prototype plant has been done in February 2001. At the end of the start up phase, the system maintenance plan has been issued, with a description of the procedures for system management during the plant-testing period. After a few months from the start up of the three system units, an average advance of the shoreline, estimated in the order of 10 m, has been observed, as it can be appreciated from the enclosed photographic sequence (*figg 5 and 6*) showing the first BMS section.



**Figure 5 - Section 1: North  
“Vecchia Pineta” before  
BMS construction**



**Figure 6 - Section 1: North  
“Vecchia Pineta” 3 months  
after BMS construction**

For the second section the effect was really surprising in the first days after the start up (*fig 7 and 8*).

Unfortunately, in the following months (starting from the end of April) the shoreline was undergone to new erosion (*fig. 9*). An inspection of drain pipe, made with a small camera running inside the pipe, showed many bursts.

The probable reason of this trouble is the presence of many stones (the rest of an old protection work), which, moving during sea storms, can damage the pipe.

At the end of September the drain pipe was substituted with another one with the same characteristics, but at a greater distance from the shoreline, producing immediately a new growth of emerged beach (*fig. 10*).



**Figure 7 - Section 2: South  
“Vecchia Pineta” before BMS  
construction**



**Figure 8 – Section 2: South  
“Vechia Pineta” 10 Days  
after BMS construction**



**Figure 9 - Section 2: South  
“Vecchia Pineta” 7 months  
after BMS construction (BMS  
broken)**

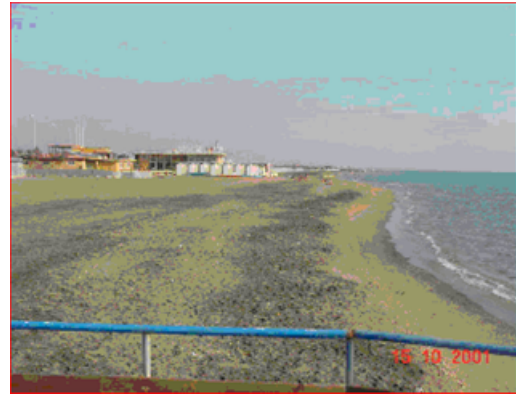


**Figure 10 - Section 2: South  
“Vecchia Pineta” 10 days after  
BMS restoration**





**Figure 11 - Section 3 “Nuova Pineta” before BMS construction**



**Figure 12 - Section 3 “Nuova Pineta” 8 months after BMS construction**

Figures 11 and 12 show the third section respectively before the BMS construction and eight months after its start up.

It is interesting to observe that in the same period in which the protected beach was growing up the shoreline of the neighbouring beach was withdrawing (see the upper part of the figure 12) in spite of some nourishment made before the summer in that area. This observation could show that the BMS produced a nourishing effect during the first months, even if in natural erosion conditions.

Further observations in the first months of 2002 show that the shoreline did not advance any more and in many points it is withdrawing even if it is still more advanced with respect to the original position (before BMS construction).

## **6. Monitoring Plan during the Testing Phase:**

Due to the experimental nature of the Ostia plant, Regione Lazio asked to Impresub a monitoring plan during the first year of BMS working. The activities planned within the testing phase have the two main goals:

- To assure the efficiency of system
- To define the most suitable procedure to evaluate its performances

The monitoring system planned within the testing phase involved the periodic inspection of the bathymetry and bottom morphology in the testing area (2 months after start up of the system, 6 months after start up of the system and 1 year after start up of the system). The survey has been performed as described for the feasibility phase. Moreover, the drain flow and the sea state were evaluated continuously during the monitoring period.

The previous monitoring activities were already performed and the results were delivered to Regione Lazio. Nevertheless, the obtained results have to be still processed in order to understand the real behaviour of the beach during the monitoring period. Above all it is interesting to understand the BMS limits and why in the last months the shoreline tends to withdraw.

In the next future a new independent monitoring plan will be run. This new program includes also measures of the water table oscillation, in order to understand the run up and drain effect on underground circulation.

## **7. Conclusions:**

The preliminary data on Ostia BMS experimental installation are quite encouraging. However, as already outlined, the success and widespread use of BMS is not yet sure, although the advantages of such an approach can be significant, taking into account the low installation costs and the negligible environmental impact.

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