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Effect of Shore Protection Structures (Groins) on São Miguel Beach, Ilhéus Bahia Brazil

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ABSTRACT

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Measurements of beach profiles associated with granulometric analysis of beach sediments were made to determinate the morphological evolution of São Miguel beach (north coast of Ilhéus - Bahia - Brazil), the coastline state and its response to the construction of four transverse groins as shore-protection structures. The results showed that the beach continued quite susceptible to the erosion in most of the coastline except for the first sector of the beach, between the groins 1 and 2. The curvature in planview of the beach sectors results from the wave refraction at the groins, which generates a longshore sediment transport causing deposition at both extremes of the beach sectors; as well as the action of rip currents in the central part of the sector, which carries sand seaward from the beach. The groin spacing on São Miguel beach varies from around 500m to 770m and groin lengths from 57m to 190m. This variability can be the reason for the failure of the shore-protection structures because it doesn't respect the relation of 1:3 recommended for this case. The predominant sediment deposited on São Miguel beach is fine sand, except for profile 8, where the predominant sediment is medium sand, corresponding to the higher energy sector of the beach. The variation of energy level along the beach can be a consequence of the shade zone of the Port of Malhado breakwater that modifies the intensity of the incident waves in the south part of the study area.

ADDITIONAL INDEX WORDS: *Erosion, sedimentary transport, balance of sediment.*

INTRODUCTION

The beach is a transitional environment, which suffers seasonal morphological changes. The interaction between the coastal dynamics and other factors such as climate and anthropogenic action contributes to the establishment of the conditions of equilibrium, erosion or accretion of the coastline (MUEHE, 1994).

Shoreline erosional and depositional phenomena have been attributed mainly to three causes: variation in the hydrodynamic processes, sea level changes and anthropogenic interference, which act alone or in combination to each other (TESSLER and MAHIQUES, 1998). Nowadays most of sand beaches experiences some kind of change on its morphodynamic state, especially because the increasing on anthropogenic pressure. Urban expansion over coastal zones has contributed to the establishment of disequilibrium conditions.

Coastal erosion is a result from negative sediment budged (DOMINGUEZ and BITTENCOURT, 1996). In many cases the reduction in sediment delivery to the coast has resulted in shoreline erosion (KOMAR, 2000). Human interfering on coastal area, mainly through the construction of seawalls, groins and other engineering structures can contribute to changes on beach sediment supply (KOMAR, 1976), causing the establishment of erosional processes.

Beach Erosion

Beach erosion is a serious problem in urban areas representing a hazard for coastal infrastructure and reducing beach capacity for recreation. The increasing human pressure on the coastal zone has exacerbated this problem due to coastal improvements made ignoring dynamic coastal processes and exposing these developments to sea forces (APPENDINI and LIZZARAGA-ARCINIEGA, 1998 *apud* LIZZARAGA-ARCINIEGA, APPENDINI-ALBRETCHSEN and FISHER, 2001). Today, most of the 125 coastal countries around the world suffer erosion problems that result in considerable economic and social losses (UN, 1982).

Shoreline erosion results of a full range of processes, including sediment motion under waves, the behavior of the

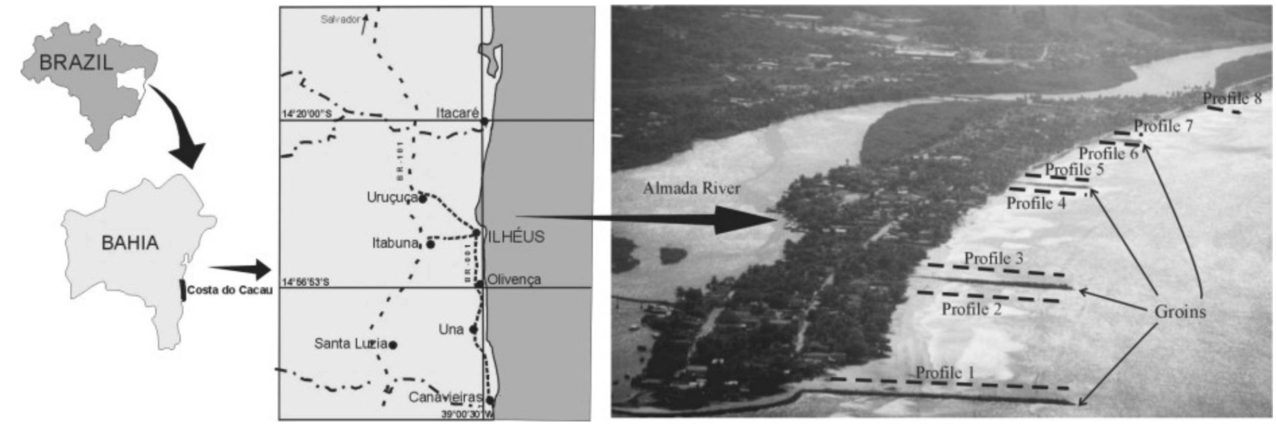

Figure 1. Location of the study area, groin positions and surveyed profiles.

beach within a littoral cell and even land-use practices within watersheds. Among the factor that beach erosion is the result of the sea level rise, sedimentary budged, wave incident conditions, input of sediments to the coast and anthropogenic influence, acting combined to each other. Relative sea level rises are responsible to erosive processes that act in a much longer time scale than other factors, including time scales that vary from decades, centuries even to thousands of years.

Sedimentary budged is directly affected by the rate of the input from continental drainage and by longshore transport of sediments into the area. The balance of sediments between inputs and outputs should be approximately equivalent to the local beach erosion or accretion (KOMAR, 1976). River transport contribution to the coast can be responsible to a positive sedimentary budged resulting in a state of equilibrium or accretion while a negative one can result in disequilibrium inducing to erosional state.

Incident wave conditions are important factors that can contribute to coastal erosion. The intensity and frequency of the winds and the way waves approach to the shoreline generate currents in the nearshore which affect the transport of sediments. Nearshore currents are important in controlling the morphology of the beach because they act combined with waves to transport beach sediments. According to AUBREY (1983, apud HOEFEL, 1998) and WRIGHT & SHORT (1984), offshore incident waves are the most important input of energy to beach systems, so that the morphological evolution of the beach is the result of the padron of incident wave conditions.

An oblique wave approaching to the shoreline generates longshore currents causing longshore movement of beach sediments; while a cell-circulation system consisting of rip currents associated to longshore current are the two wave-induced current systems acting in the nearshore.

Anthropogenic influence in the coastal zone is nowadays the main factor causing shoreline erosion. About 60% of world population is concentrated in coastal areas (BIRD, 1985), which generates demand for coastal infrastructure resulting on extreme changes on this stressed interface region. Urban expansion over the littoral, through the construction of houses, hotels and piers or stabilization structures like seawalls, groins and breakwaters, generally causes changes on sedimentary budged (KOMAR, 1976). Those constructions can even produce accelerated rates of shoreline retreat.

Usually, human response to coastal erosion includes five categories (POPE, 1997): 1) Use of coastal structures to protect infrastructure (armoring), 2) activities designed to reduce beach erosion rates (moderation), 3) beach nourishment (restoration), 4) acceptance of erosion hazard without taking action (abstention), and 5) regulations and policies for using the coastal system (adaptation). The use of any these strategies or a combination of them should be made in the context of the littoral cell.

Protection Structures (Groins)

Groins are narrow shore protection structures usually constructed perpendicular to the shoreline with the objective of trapping longshore movement of beach sediments (longshore drift) (CARTER, 1993).

The construction of this stabilization structures demands the knowledge of oceanographic conditions and longshore sedimentary transport in order to define a correct selection of the lengths of the groins and their longshore spacings. On reflective beaches, where sediments are transported rolling (bedload) on the swash zone, shorter groins can be rather effectives. On dissipative beaches otherwise, having a low-sloping profile and finer sediments, the construction of longer groins are necessary because the sedimentary transport occurs on the surf zone. On both beach types, however, the relation between groins' length and longshore spacing must be respected. For dissipative beaches it usually is 1:4 while on reflective ones is 1:2 (CARTER, 1993.).

The utilization of those hard structures for shore protection has been less effective than predicted. FRIHY (2001) studying the Mediterranean Coast of Egypt point out to environmental impacts as consequence of the construction of engineering structures. KOMAR (1998) mentions that a groin field shifts the zone of erosion out to the immediate area, transferring the erosion problem downcoast. PEREIRA (1996) verified on Casa Caiada beach and Doce River, north coast of Olinda (PE), that beaches lost their natural characteristics.

Study Area

The study area is located on the north margin of the outlet of Almada River, north coast of Ilhéus, on São Miguel beach, between coordinates 14º 46' 25" S / 14º 44' 24" S e 39º 03' 13" W / 39º 03' 49" W (Figure 1). The littoral zone has of approximately 4km of extension, constituted by a sequence of sand beaches deposited ahead of coastal terraces formed on Holocene. On this sector of the shoreline, Almada River flows parallel to the coast, demonstrating that the study area was formed by the migration alongshore of the outlet of the river, southward.

Geomorphologically, littoral of Ilhéus is characterized by Pre-Cambrian rock outcrops on the coast or near to the coastal zone. Quaternary deposits are little developed, exception made for the Almada sedimentary basin, where today the Itaípe lagoon is the last testimony of the presence of a bay during quaternary sea level rise. The south coast of Ilhéus is characterized by the resurging of Barreira Formation sediments, absent from Itacaré to the north sector of Ilhéus (MARTIN, 1980).

Incident Wave Conditions

The study area is located under the Divergence Zone of South Atlantic Semi-stationary Anticyclonic Cell. During summer time, the cell migrates to equator (13°S) and winds are predominantly from NE, which generates an incident wave from NE. On wintertime, when the cell moves southward (20°S) and the occurrence of storms is frequent, predominant incident waves are from SE. East wind are present all year.

This general padron can be modified when atmospheric events like El Niño block the SSE winds action in this area (BITTENCOURT, 2000).

Beach Erosion at Ilhéus

The north coast of Ilhéus is subject of intense process of erosion, mainly as a result of changes on incident waves after the construction of the International Port of Ilhéus (Malhado Port). The erosion on São Miguel beach, located north of Almada River, determined coastal retreat of around 140 meters in 30 years (APOLUCENO, 1998).

The construction of Malhado port and its subsequent amplification (200m of harbor area) changed wave energy distribution padron and caused the amplification of port shadow zone northward (APOLUCENO, 1998). The action of the shadow zone changed sediment dispersion padron at São Miguel beach, establishing a sediment divergent point near the north sector of the study area. Consequently, the budget of sediments became negative causing social and economic damage to the population. The destruction of 140 meters of urban structures; two streets and several houses, determined a devaluation of other coastal properties.

In order to mitigate the problem the Municipal City hall of Ilhéus built four transverse groins - varying between 190 and 57 meters in length and with spacing from 500 to 770 meters - in the beach sector more intensively affected by the process of erosion (Figure 1). The groins were designed to trap longshore drift for building a protective beach where an intense erosion process was in progress. The groins should nourish beach northward of each groin.

The objective of this paper is to evaluate the behavior of the morphology of the shoreline in response to construction of traverse groins.

METHODS

The measurement of morphological changes on beach topographic profile, were made through the establishment of 8 reference points along the study area where the beach profiles were surveyed.

The seven first profiles were established on the north and south sides of the groins, exception made for the first groin which was surveyed only on its north face. The eighth profile was surveyed away from the groins area, acting as a reference for natural conditions.

Field data acquisition occurred between November 2001 and November 2002, always during spring low tide period, each season. Beach profiles were measured through the method of Emery (1961), using two wooden apparatus, one and a half meters high, marked with graduated rulers and a measuring tape, 50 meters long, for the determination of horizontal interval along the profile. During the period were measured 8 cross-shore beach profiles from backshore to the limit of wave backwash.

Measuring of beach profiles elevations were determined by the vertical difference between the top of the seaward board and the horizon. There was used an arbitrary vertical reference level of 5 meters for each fixed reference point. Sediment samples were obtained surficially on the medium beach face, during summer time and winter time.

Sedimentary samples (around 50g) were analyzed by sieving at 0,5 phi intervals. Statistical analyses of grain size data were accomplished by the utilization of SAG program (Sistema de Análise Granulometrica) developed by Fluminense Federal University (UFF) of Rio de Janeiro. The morphological variability of beach profiles was represented by graphical treatment in *Excell for Windows* program.

RESULTS AND DISCUSSION

The analyze of the evolution of São Miguel beach profiles demonstrated that they reflect the variability of coastal dynamic processes, and registered depositional and erosional events with time.

Beach Morphological Changes

The analysis of the morphological evolution of São Miguel beach profiles revealed that they are subject to the seasonal variability of coastal dynamic parameters, presenting registration of depositional and erosional events along time.

The profile 1, experienced a retreat of the beach berm of approximately 30m from November 2001 to February of 2002, probably caused by severe climatic events associated with syzygy tide that happened in the summer of 2002. In the following periods, profile 1 was gradually recomposed, reaching practically the same level of deposition of the beginning of the survey. It was possible to identify a progradation of approximately 80m since the construction of the first groin, what seemingly demonstrate the efficiency of the structure implanted next to the outlet of Almada River.

In the profile two, unlike the profile 1, the berm progradated in approximately 15m from Novembro2001 to May of 2002 and in the following periods a retreat occurred in the same proportions. As in the profile 1, the beach seams to maintain an equilibrium beach profile of about 20m since the construction of the second groin.

Profiles 3, 4, 5, 6 and 7 presented little variation during the surveyed period, staying practically in equilibrium along time. In those profiles, it was not identified a retreat of the shoreline nor even the process of progradation that would confirm the efficiency of the structures built up for such purpose. The only morphological change was result of seasonal movement of sediment in the beach face. However, the arch morphology of the sectors between the groins demonstrated that the action of rip currents contribute to the erosion at the central part of the beach sectors.

Profile number 8, positioned out of the influence of shadow zone of Malhado port and away from the groin field, demonstrated an unstable equilibrium state, been an example of beach face seasonal variability which could result, in a long term, in retreat of the shoreline.

The results of groin construction were not totally satisfactory so that the stabilization of São Miguel beach was not achieved so far. An evidence of this fact is that during syzygy high tides, waves still reach the houses.

Grain Size Parameters

Grain size parameters have been widely used to identify environments of deposition and sediment transport patterns (Le Roux, 1993). Grain size analyses of beach sediments are good indicators of beach dynamics and imply information on longshore sediment transport and the energy level of the environment (Ponzi, 1995).

On São Miguel beach, 16 surficial sediment samples were collected at beachface, 8 during summertime and another 8 during wintertime. The samples were analyzed by sieving and sediment size parameters were determined: mean grain size, sorting and skewness.

During summer time (Table 1), samples were predominantly constituted by fine sand, well sorted and coarse skewed, while for profile 8, sediment were constituted by medium sand, well sorted and near symmetrical.

During winter time (Table 2), samples from profiles 1 to 7 presented mean size of fine sand with sorting varying from moderately sorted to well sorted and skewness from near symmetrical to coarse skewed. Profile 8 was constituted of medium sand, moderately sorted and near symmetrical.

Sediments collected on this sector of São Miguel beach indicated an improvement of energy level northward. Beach sediments on profile 8 demonstrate the highest energy level of the sector. This observation is compatible with the steeper beach profile associated to coarser sediments present all over the year on profile 8.

The association between beach profile slope and grain size analyses also indicates a lower level of energy for the first sector of the beach, near to outlet of Almada River.

The energy level variation at São Miguel beach is probably related to the shadow zone generated by Malhado Port (Apoluceno, 1998) which causes dissipation of wave energy,

Table 1. *Grain Size Parameters of summer time samples. D_{50} = median size; Sorting; Mean size (phi) e Skewness.*

Sample	D_{50} (phi)	Sorting	Mean size (phi)	Skewness
P01	Fine sand	Well sorted	2.484	Coarse skewed
P02	Fine sand	Moderately sorted	2.425	Coarse skewed
P03	Fine sand	Well sorted	2.464	Coarse skewed
P04	Fine sand	Well sorted	2.857	Coarse skewed
P05	Fine sand	Well sorted	2.439	Coarse skewed
P06	Fine sand	Moderately sorted	2.263	Near symmetrical
P07	Fine sand	Well sorted	2.548	Coarse skewed
P08	Medium sand	Well sorted	1.69	Near symmetrical

Table 2. *Grain Size Parameters of wintertime samples. D_{50} = median size; Sorting; Mean size (phi) e Skewness.*

Sample	D_{50} (phi)	Sorting	Mean size (phi)	Skewness
P01	Fine sand	Well sorted	2.587	Coarse skewed
P02	Fine sand	Well sorted	2.785	Near symmetrical
P03	Fine sand	Moderately well sorted	2.778	Near symmetrical
P04	Fine sand	Well sorted	2.678	Near symmetrical
P05	Fine sand	Well sorted	2.809	Near symmetrical
P06	Fine sand	Well sorted	2.256	Near symmetrical
P07	Fine sand	Well sorted	2.467	Coarse skewed
P08	Medium sand	Moderately sorted	1.63	Near symmetrical

resulting in the arrival of lower waves with shorter periods, consequently with lower energy levels. Because profile 8 is away from the shadow zone of the port, approximately 4 km northward from the outlet of Almada River, it results in a higher energy level on this part of the beach.

CONCLUSIONS

The measurement of morphodynamic changes on São Miguel beach evidenced the great fragility of the north coast of Ilhéus, even after the installation of the groins. In agreement with previous studies (APOLUCENO, 1998), that type of construction usually minimizes coastal hazards, but the results showed that, until the present moment, most of the beach continues suffering with the transgression of the sea.

The determination of shoreline evolution showed stability in the beach between the groins 1 and 2, closer to the outlet of the Almada river (profile 1 and 2), with consistent deposition in its extremities, in spite of the occurrence of erosion periods along the year. In that area, the beach presented smaller energy than on its north limit, with predominant sediment in the class of fine sands during summer and winter periods. Those evidences indicate that even in more severe climatic events, the possibility of the progress of the sea on the houses is much smaller than the other monitored sections.

Other sectors of São Miguel beach presented retreat of the shoreline during the surveyed period. The curvature in planview of the beach sectors resulted from the wave refraction at the groins, which generates a longshore sediment transport causing deposition at both extremes of the beach sectors; as well as the action of rip currents in the central part of the sector, which carries sand seaward from the beach.

The action of strong rip currents and the irregular longshore spacing can be the reasons of the continuity of erosional processes. Groin longshore spacing at São Miguel beach is about 770 meters between second and third groins where according to APOLUCENO and SATO (1998) the distance should be of 600 meters. The failure of designed groins to meet their objective of trapping sand and to create a protected beach often results from the presence of nearshore currents (KOMAR, 1998).

Furthermore, the seasonal reversion of sedimentary transport determines the deposit at both sides of the groins so that the form taken by the beach after the construction of that structure type is usually the one of handsaw teeth, with sediment accumulation in one on the sides of the structure. The little deposition in the north face of the groins showed that the sedimentary transport N-S generated by the refraction of the waves in the port harbor and for the performance of northeast winds generate waves of the same quadrant which are insufficient for the reconstruction of São Miguel's beach.

Wind direction is preponderant for the sediment transport along the coast (DUPONT and ADDAD, 1997). The performance of the northeast winds in that sector of the coast is constant in summer period and autumn (BITTENCOURT, 2000); even so for the sediment transport along the coast what prevails is not only the period of time that the wind acts, but also its intensity. During winter time the incident winds are from south-southeast and southeast, with intensities very superiors of northeast and east ones, which are predominant in most of the year. That fact can have been preventing sediment deposition in the north face of the groins.

After one year of measurement of morphological evolution of São Miguel beach became evident the disequilibrium on sedimentary budged which caused coastline retreat, especially on the central part of beach sectors confined between groins and on the north limit of the study area, where the erosion is evident.

The high rate of human occupation on São Miguel beach associated to a constant process of coastal erosion caused damage to coastal properties and the continuity of erosional process will demand new effort to contain the progress of the sea over urban developments.

For that reason, it is necessary to avoid new constructions in the sectors more affected by the process of erosion and if possible relocate some away of the coastal zone.

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