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Gabions for the Protection of Caponga Beach, Ceará Brazil: Hazards and Management

J.O. Morais†, L.S. Pinheiro†, C. Medeiros‡ and E.S. Pitombeira∞

† Departamento de Geociências
Universidade Estadual do Ceará
60740-000, Fortaleza-CE,
jader@uece.br
lidriana@uece.br
CNPq fellow

‡ Departamento de Oceanografia
Universidade Federal de Pernambuco
50740-550, Recife-PE
brazilcarmen@ufpe.br
CNPq fellow

∞ Departamento de Engenharia
Hidráulica e Ambiental
Universidade Federal do Ceará,
60740-000,
erasmo@deha.ufc.br

ABSTRACT

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This paper attempts to the hazards assessment and how to manage the hydrodynamic sedimentary processes stemmed from the emplacement of a set of gabions located at the stretch of a beach in Cascavel municipality, Ceará State, Northeast Brazil. The present littoral morphodynamics related to the wave climate, swash and backwash processes and anthropic activities actually held in the area, has been also considered. Top-hydrographic profiles, sediment sampling, and textural analysis all over the year of 2001 have been performed. The results were compared to the previous ones aiming at achieving the state of the art of the coastal hydrodynamics processes and their relationship to the degeneration and/or regeneration of the coastline morphology together with its uses and occupation. The beach zonation have been worked out, different compartments and three cells were calculated which allowed the definition of vulnerability inside in each one of the sectors. The progradation and inverse beach shift have been assigned to be cyclic process, but it must be said that wave refraction and diffraction, offroad vehicles and vandalism on the rigid structures and the dwelling of sediment supplying areas are responsible for part of the process during 2001. At the same time the Caponga Roseira flooding runoff responds for most of these processes at cell 3. This has been also compared to the development carried out in 2003. This lead to prevent future inadequate occupation of backshore that is nowadays taking place.

ADDITIONAL INDEX WORDS: *Gabions, coastal rehabilitation, Caponga Beach.*

INTRODUCTION

The Coastal zones are under increasing environmental pressure and are exhibiting unacceptable environmental changes as the consequence of population growth, urbanization, tourism and other multiple and often conflicting resource usage trends. These facts are also occurring in segments of the Ceará State seashore, northeastern Brazil, which are eroding as a result of the anthropogenic processes. Caponga is located in the coastal district of Cascavel Municipality (Figure 1) on the east coast of Ceará State, 70 km south from Fortaleza, the State Capital, that is experiencing erosion as the result of unsuitable occupation of sediment sources that have disrupted the sedimentary balance on the beach.

These have resulted in beach degradation, backshore destruction and to a series of physographic damages causing economic loss to local community and tourism decline. The placement of six gabions at the right angle to the coastline and the longitudinal one attached to the backshore were built to rehabilitation of this area. This study commenced as soon as these structures had been implemented. This paper presents beach evolution with management proposal strategies and local responses analyzed.

METHODS

The methodology went through a literature survey, the account of previous meteorological and hydrodynamics data and photogrametry, as a first step. These have resulted in a design of three monitoring cells based on the morphologic delineation, the populational density and the area directed influenced by the gabion implementation. The fieldwork evaluated the effectiveness of the beach profiling monthly measured relating the wave direction, height, length and period. In addition to this, it has been sampled sediments transverse and at right angle to the coastline. The foundations of echodynamics were based on the main indicators such the winds, longshore currents, sedimentary deposit, estuarine flux, waves and tide oscillations. The present developments done during 2003, close to the Caponga Roseira River mouth and Village Hotel, have been observed for realizing the more rational and adequate position of jetties, bulkhead and artificial nourishment, in order to obtain the best use of this new development.

BACKGROUND

Beach erosion is a serious problem in urban areas representing a hazard for coastal development and reducing beach capacity for recreation. The increasing human pressure on the coastal zone has exacerbated erosion problems due to development ignoring dynamic coastal processes and exposing these developments to sea forces (BIRD, 1996).

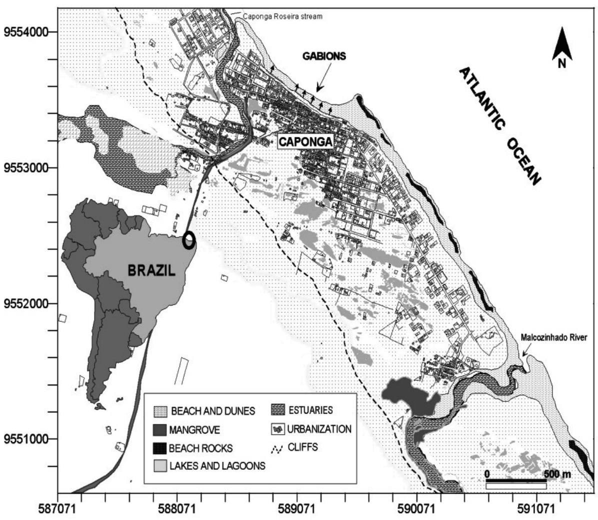

Figure 1. Study area.

The human response to coastal erosion includes five categories (POPE,1997): 1) use of coastal structures to protect urban infrastructures; 2) activities designed to reduce beach erosion rates, 3) beach nourishment (restoration), 4) acceptance of erosion hazards without taking action and 5) regulations and police for using the coastal system.

Caponga always had fishing as its main economical activity. The beauty of its natural geographic scenario gives another alternative for economic activities towards to industrial tourism and from the early seventies. This resulted in the rapid occupation of its seafront, appearing with the great number of constructions in short space of time. This urban growth has gone right into areas of dunes, terraces and in many parts of the backshore. In addition to this, the dune sands and rocky outcrops have been used for construction suppliers. These activities have negatively impacted on the coastal dynamics and the sedimentary balances resulting in progressive destruction of the streets, houses and trade sites.

The first attempt of softening the coastal erosion, a protection wall (sea wall) bordering the coastal avenue, towards NW was built in front of the urban core of Caponga. This wall did not stand with the wave energy, and the sand withdraws augmented in the foot of the wall, causing its failure making it ineffective for beach protection (PINHEIRO, MORAIS and PITOMBEIRA, 2000). The first work in the area was made by MORAIS and MEIRELES (1992) that considered the whole border of the beach of Caponga as an area of high geological risk. The intensity of the coastal erosion resulted in the reduction of the beach gradient, exhuming old mangrove deposits on the beach

STUDY AREA

The Caponga beach is characterized by Quaternary sedimentary deposits. It is worth mention the outstanding calcium carbonate beach rocks covering 55% of the coastline, submerged bars and sandy spits associated to the river mouth migration and beaches progradation. This fact confirms that current fluvial courses have little contribution on the beach and internal shelf sedimentation.

The annual rainfall mean is 1.500 mm, which 93% are concentrated in March, April and May. The relative humidity of the air presents a variation pattern similar to that of the precipitation with higher values in March and lower in September. Evaporation values are also quite high, reaching annually 1.800 mm, with maximum periods during the months of August to November, and minims from February to May. The medium temperature has monthly values varying since 240 C (February) up to 28°C (December).

The wind predominant direction is E-SE which associated to the alignment of the coast line (SW-NW) favors bypass of sediments for the formation of dunes and beaches. The area urbanization represents an impeditive factor concerning sediment transport, causing roads and houses siltation.

There is an increasing value of the wind speeds from July to November, reaching maxims in September and October (711 m/s), and gradually declining to May (3.5 m/s). Wind velocities varied from 3.2 to 10 m/s along the year, controlled by the migration of Convergence Intertropical Zone (ZCIT), presenting a very defined cycle with maxims in the drought periods and low in the rainy ones, being reflected in the recurrence of the coastal processes.

HYDRODINAMIC AND MORPHODYNAMIC PROCESS

The study coastal area shows semi diurnal tides with maximum widths of 3.3 m. The longitudinal currents predominant direction is SE-NW. The Ceara wave mean high is 1.54 m to the maximum and 0.70m to the minimum. The direction offshore varies 100th - 110th and 50th75th in the break zone. They are predominantly seas with periods between 4.5 and 13 seconds. The longshore current predominantly trends N-NW ranging around 0.30 cm/sec (dry season) and 0.16 cm/sec(rainy season). The annually sediment transported mean values in Caponga considering the minimum and maximum conditions of heights, period and wave incident angles were 888.09 m^3/year and 1530.00m^3/year respectively. During high waves period the zero m isobath reached the greatest recede 40 m being recovered afterwards.

The Malcozinhado mouth was considered the southeastern limit that is covered by dunes fields and beach rocks sequences, out of gabions influences. The average length beach profile is 150 m.

That sector presents a 50 m backshore between the line of maximum high tide and the beginning of the urbanization. The sediment volume rate is 444.03 m^3/m, with maximum 584.15 m3/m in February/00 and minimum of 249.87m^3/m in May/01. The volume in 2001 is 30% below the necessary volume to the morphologic balance, calculated in June of 1999. Those values reflected the progress of the quota zero, breaks of the cyclically, outcrops the beach rocks packages and the increasing beach slope due to erosion and terraces and cliffs wave cutting. The coast line retreat rate verified between 1959 and 2001 was 0,5 m/year. In the areas sheltered by beach rocks the rates are smaller and they arrive close to 0,05 m/y showing the importance of those structures as natural protection to the erosion. In spite of that, risk in the installed structures is moderate, as the spacing between the line of maximum high tide and the construction is concerned.

The Caponga Point beach profile has 150 m of extension, that is going from the beginning of the urbanization to the line of rocks of beaches. The backshore zone is invaded by house dwelling, and displays seasonal berm zone lengthening around 6 to 7 m and height between 0,60 and 1 m with 267,03m^3/m. medium volume. The registered values in December/99 corresponded to an accentuated instability of the morphologic profile, with berm destruction and attack of the waves in the urban structures. Between August/99 and January/00 there was an erosion pick inverting the situation into depositional patterns in the period of March to April of 2000. In October of 2001 the volume of the profile was 40% below the expected value for the dynamic balance and 20,6% in relation to the average. In that period besides the transverse displacement of sediments, a lateral transport was verified in the intertidal zone that contributes in the formation of the banks in the extremity of the Caponga Point.

Starting from Fevereiro/00 there was a slow recovery of the intertidal zone due to the displacement of the sandbanks through the progressive reworking of the waves peculiar to that period. In the Caponga Point shaded area the progradation rate of the beach was +0.5 m/y between 1959 and 2001. The extension of the beach profile in the gabion vicinity is 250 m. In this context of the coastal erosion high susceptibility to impacts and intense dynamics, the sediment volume balance is practically stable through the alternate deposition and erosion periods. The beach rocks line position softens the energy of the incident waves seasonally preserves the profile.

The backshore located in front of the urban nucleus of Caponga is occupied by summerhouses and secondary roads accessing the coastline. This houses complex lies at just 16 meters from the intertidal zone. In this site, the material earnings and losses presented a cyclical character, characterizing the typical profiles of erosion and deposition. The medium volume of the profile is 641,34m^3/m. The largest modifications happen in the foreshore in direction to the deepest areas that are marked by the existence of extensive sandy banks that are transported monthly inside of that own zone, modifying the geomorphology of the submerged profile. The gabions acted in that area as indispensable element in the stabilization of the intertidal area, mainly in the periods of the largest tidal ranges.

This section presents a strong susceptibility to the retaking of the erosive processes, mainly because waves reach its beachface with angles up to 300, derived from the refraction produced by the sandbanks. That area receives little eolian contribution, because the supplying areas are completely stabilized. The succession of bars and throughs in December/99

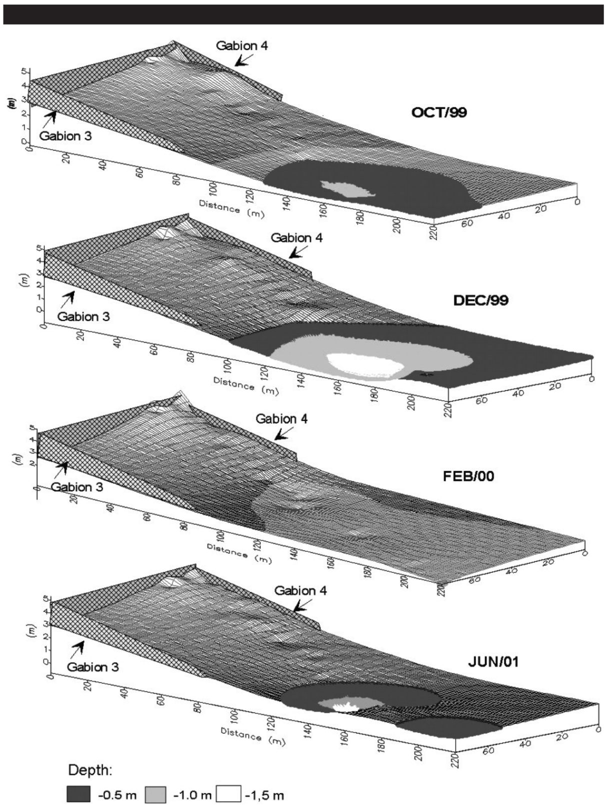

Figure 2. Seasonal variation of the beach gradient between gabions 3 and 4. Sediment displacement forming sand bars.

and Jun/99 generates rip current that increases the drowning risk and gives an intermediate characteristic to the profile.

The monitoring studies have displayed that the area of direct gabions influence is under an intermediate phase of rehabilitation with positive tendency but needing severe and adequately management. Using the Dean estimate related to the hydrodynamics and morphodynamics beach conditions, it has been reached 75% to intermediary stages and 15% to dissipative stages. This means present stable morphologic conditions, with sediment input and output being controlled by cyclic wave high variations. However, starting from 2001 the beach strip located downstream of the ridges presented constant erosive process with destruction of walls and sidewalks. In that section, there is the intense occupation of the backshore zone and along the Caponga Roseira stream.

The fluvial discharges tend to maintain the open outlet, while the regime of waves incident tends to conserve the beach suitable to the closing sandy bar. The result of this process leads to the migration of the estuary fitted to the longitudinal current and of the dominant coastal transport. In Caponga, the westward migration creates problems for edification stability.

The largest constructions vulnerability downstream in this beach segment of Caponga Roseira is observed during sizigia tides. This situation becomes more complicated when that process coincides with the November-February period, added to the swell wave regime (PINHEIRO, MORAIS and MEDEIROS, 2001). In August 2003, two jetties have been constructed to avoid the severe erosion at the surrounding area of the Caponga Village Hotel, and to give birth a new area for marina, but the resulting processes are under observation.

The eolian contribution for the stabilization of the bar is hindered by the backshore dwelling that works as a barrier of sediments. The result of that is the formation of dunes which invade that establishment and the adjoining roads. The erosive processes are expanded according to the movement of the channel that cuts the shoreface, therefore, there is no evidence of the gabions influence in those processes. The inadequate use and maintenance of the beach and gabions put at risk the functionality of the structures, making the erosion recurrent in the area of larger urban settlement.

THE EROSION VULNERABILITY

The vulnerability to erosion indicates the susceptibility of the beach segment to experience damage. The following criteria were used to defines vulnerability: the morphology and sedimentology characteristics , population density, presence of coastal structure and beach profile annual average extension. The vulnerability to erosion degree was defined as low, medium and high, according to the following characteristics: Low

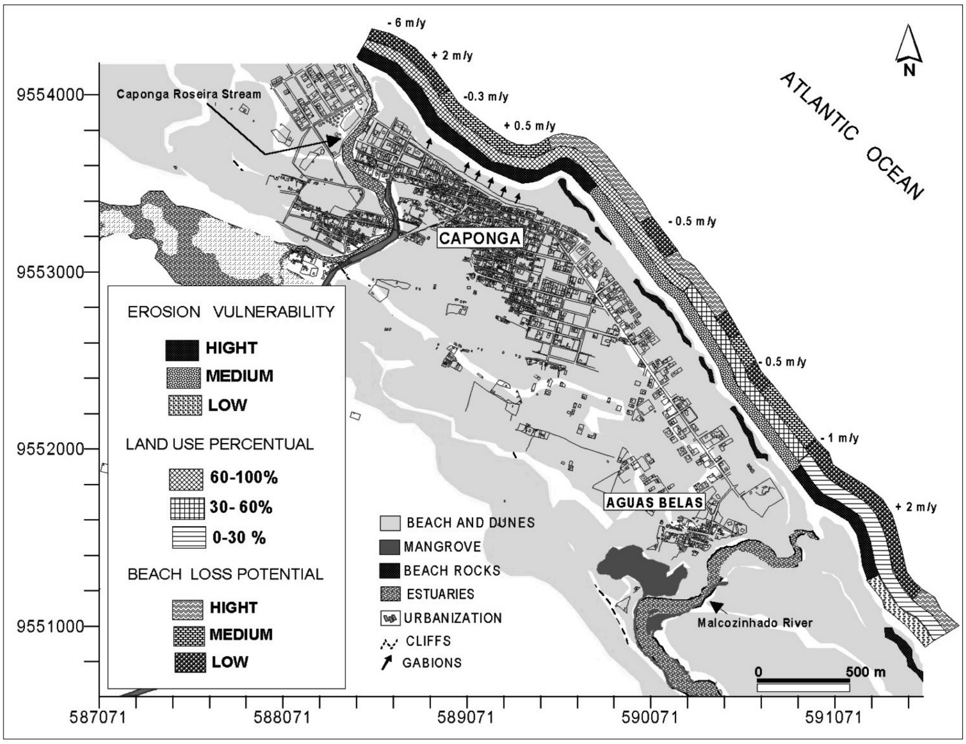

Figure 3. Indicators of the vulnerability to the coastal erosion in the beach of Caponga. The rates progradation/ degradation regard the period between 1959 and 2001 (PINHEIRO, 2003).

vulnerability is concerned to that one displaying well developed backshore and intertidal zone; natural protection to erosion and low population density; absence of contention tools and local stream mouth at the beach. Medium vulnerability responds for fragile stability, reduced backshore and implementation of contention development, intermediate morphodynamics profiling and population density varying from 30 to 60%. High vulnerability means lack of backshore and reduced and sloped intertidal zone, and intermediate to reflectives morphodynamic profiling, presence of coastal drainage outflows at the beach strip, population density ranging from 60 to 100% and strong presence of protecting structures.

The majority of the studied area presents high vulnerability to the coastal erosion. That is due to the ever increasing urban settlement and its low natural protection that includes the deficit of sedimentary beds and the entrance of difracted waves in the gabion protected sites. The medium rate of the gabion sites coastline was - 0,1 to -3 m/y from 1959 to 2001 (PINHEIRO,2003).

However, after the implantation of the protection system those values were close to zero. The variations depends on the cyclical events related to wave potency, tidal range, urban expansion and foredunes and backshore occupation (Figure 3).

The National Plan of Coastal Management, established by Law 7661/88 expresses the Brazilian Government's commitment, at all instances, with the coastal zone sustainable development, considered as national patrimony. Then, it does have, as fundamental principles, the preservation, conservation and control of coastal zone ecosystem representative areas, recovering and rehabilitating those undertaking processes of degradation.

In Caponga beach the gabions were efficient in minimizing the erosive process of high magnitude and gave sustainability to the project of urban rebuilding, such as the new avenue replacing areas totally degraded.

Barracks have a spread distribution all over this area, and in spite of the hazards it may create to the area, they remain there, making difficult the sediment movement by eolian deflation. At low tide, the vandalism practice is frequent as local people destroy the gabion structures for uusing pieces of it to inadequate purposes, in this case, barbecue. On the other hand, oil derived residues are thrown and garbages accumulates over the gabions. There is sometimes intense traffic using off road vehicles which opens its proper way through the gabions. Therefore, it is necessary a more effective performance by the municipality environmental authorities in order to mitigate this situation.

They agree in approving licences for constructions in the areas of high risk putting at risk the stability of the beach. The stabilization of the channel as well as the embankment for hotel enterprising in areas of domain of the tides will lead to the access limitation nearby the Caponga Roseira river mouth.

CONCLUSIONS

The emplacement of six gabions at right angle to the coastline and a longitunal one attached to the bachshore gave rise to local responses, which pointed out for a shifting for accretion as soon as the gabions have been placed and artificial nourishment provided. Then, the gabions rehabilitated the area previously degraded.

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The gabions deterioration is predominantly related to an almost maintenance absence which induces to vandalism in wiring cutting and accumulation of oil derived yielding.

In spite of the high susceptibility to coastal erosion, intense dynamics and impacts, the sediment budget is practically stable. The beach rocks line position softens the energy of the incident waves seasonally preserves the profile between Malcozinhado river and Caponga Point. It has been worked out from these observations that the main dynamic agents were the winds, waves and currents.

The longshore current predominantly trends N-NW ranging around 0.30 cm/sec (dry season) and 0.16 cm/sec (rainy season). The annually sediment transported mean values in Caponga considering the minimum and maximum conditions of heights, period and wave incident angles were 888.09 m3/year and 1530.00m^3/year respectively. During high waves period the zero m isobath reached the greatest recede 40 m being recovered afterwards. The volume in 2001 is 30% below the necessary volume to the morphologic balance, calculated in June of 1999.

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