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PORT OF PECÉM
STUDIES OF PORT CONCEPTION

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ABSTRACT

This work describes the activities and hydraulic studies developed at the Instituto de Pesquisas Hidroviárias - INPH, for the implantation of a new open sea port in the State of Ceará, at the northeast littoral of Brazil. Physical and environmental conditions that led to the choice of an offshore-type breakwater are also stated. In January 1995, the Government of the State of Ceará authorized the execution of feasibility studies for the construction of an industrial port plant that would help to stimulate the development of the region where the port was intended to be settled. Information provided by the Navy's bathymetric charts (1:5000 scale) of the Pecém region, were used in the design of the port layout. These studies were carried out in strict collaboration with Vale do Rio Doce Company - CVRD.

BACKGROUND

In the early sixties when Instituto de Pesquisas Hidroviárias - INPH was starting its activities in the field of experimental hydraulics it had the opportunity to take part in the construction of a jetty at Futuro Beach which was intended to retain the beach sand. This work was one of the solutions presented by Sogreàh/Neyrpic, a famous french hydraulic laboratory, in order to recover the Port of Mucuripe. At that time, a great extension of earth road that linked the Fortaleza City down town to the port, corresponds to a significant part of the today's Littoral Avenue.

Three decades later, Brazil has grown and so did Ceará State. The Port of Mucuripe, respected its depths limitations, has grown and expanded its back area too. The sedimentation process around the port has increased and year after year the dredging volume grows despite today's 990m long jetty in Futuro Beach (INPH, 1985). Along those years the back area of the port was involved by the Fortaleza City as it spread over its old centre.

In the early eighties a new port was created in another northeastern Brazilian state - Port of Suape, in semi-deep waters, which was supposed to attract the commercial interchange not only to the world but to other parts of the country too.

In 1989, financiers and businessmen started to take a deep concern in the construction of a new maritime terminal and since then several preliminary analysis of possible sites for this engineering work have been conducted. The localities of Pecém and Paracuru, along the west coast, were appraised because of being considered in principle the places that are best suited to serve the purpose of the required depths (INPH, 1989).

Maritime conditions have been studied and preliminary analysis of the two topographic-hydrographic surveys led to chose Pecém as the most promising place for the new port.

NATURAL CONDITIONS

The port terminal is going to be built in Ponta do Pecém, a place some 53km straight from the northwest of Fortaleza City, at the following geographical coordinates: 03° 32' 48"S and 038° 48' 42"W as illustrated in Fig. 1. The sea bottom is sandy, and the littoral zone have some exposed sandstone forming points and great dunes.

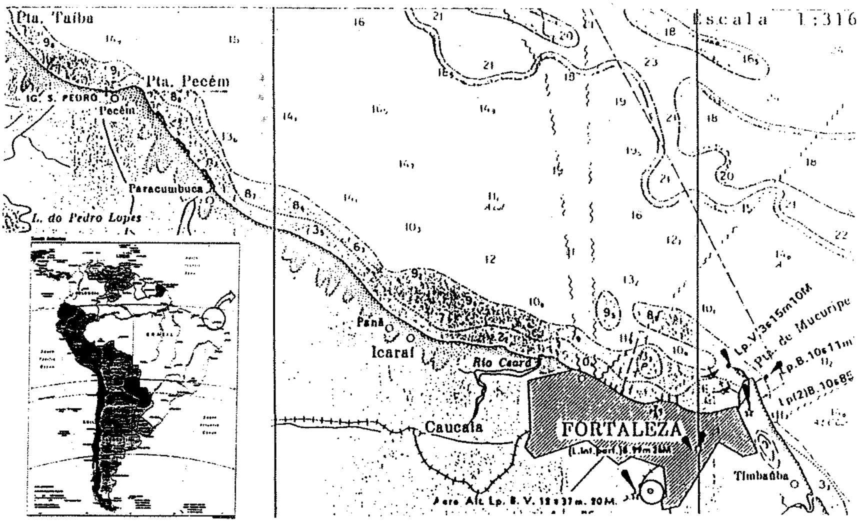

Fig. 1 Location of Port of Pecém

Winds

Winds have great influence over the northeast coast of Brazil and in special on the considered area. Its influence is confirmed by the extensive dunes formed in some places, where the shore alignment is normal to the predominant wind direction. In part the winds contribute to local erosion, since the sand grains thrown upon the continent hardly return to the sea.

A wind meter is maintained by INPH on Pecém since November/95. The rose of winds for the period of one year (of measurements) is given in Fig. 2 .

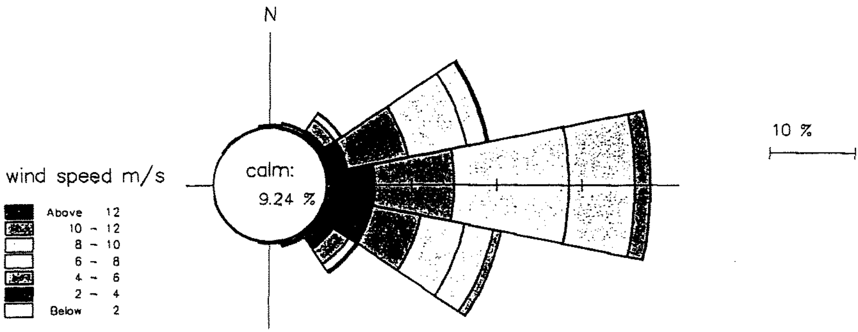

Fig. 2 Annual wind rose based on measurements between 9/11/95 and 1/2/97

Waves

To define the characteristics of the waves used in the study, INPH took the data measured with a *Waverider* buoy off the eastern side of the Futuro Beach jetty. The local depth was 16m and the coordinates of the measuring point were 03° 42' 14"S and 038° 27' 11"W. Results from this period of analysis is shown in Fig. 3.

The observed data have been obtained from 20 minute duration record, by sampling at fixed intervals 3 hours apart. The individual one year analysis were performed covering the period from February/91 to July/95. The wave propagation direction were estimated by visual observation. From this analysis it is found that the most frequent classes of significant wave height (H_s) is 1.10-1.20m with 17.20%, maximum wave height ($H_{máx}$) is 1.80-1.90m with 10.54%, mean period (T_z) is 5-6s with 47.91% and propagation direction is 90°-105° with 73.20% of the records.

Since March/97 a *Directional Waverider* was installed in front of Ponta do Pecém, at a depth of 17m on the coordinates 03° 29' 31"S and 038° 49' 03"W, in order to get a better accuracy of the wave climate.

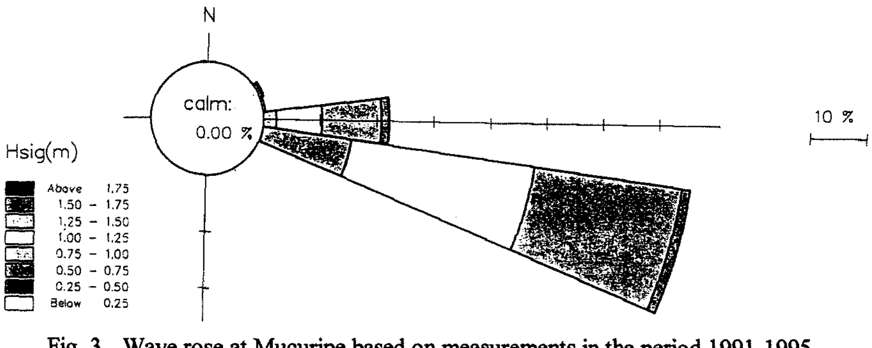

Fig. 3 Wave rose at Mucuripe based on measurements in the period 1991-1995

Tides

The hydraulic studies were undertaken using the levels based on tidal data from Port of Mucuripe (HW=3.20m, MSL=1.60m, LW=0.00m)

In order to define a reference level to give information for the construction, a tidal station was installed in Ponta do Pecém and after the determination of the reduction level, a statistical and harmonic analysis of the records from 14/March to 30/April/96, gave the following results:

High Water (HW)	3.0145m
Mean	1.493m
Low Water (LW)	- 0.0055m

PRELIMINARY STUDIES

Two basic premises have ruled the preliminary studies: to minimize the effects of the port on the morphology of Ceará's littoral zone and to provide the port with adequate infrastructure in order to lure more cargo. At a basic project level, 14 port layouts have been suggested, all of them taking into consideration the following items (INPH-21/95):

a) the bottom contours of the region next to Pecém,
b) to reach the desired design depth at a minimum distance from the coast,
c) to reduce the initial costs to a minimum,
d) to avoid investment dredging,
e) to avoid blasting,
f) to create a port basin in order to facilitate the approximation navigation and arranged according to the dominant direction of winds and waves.

Proposed Conceptions

Analysis of the cost and benefit relationships of each one of the proposed layouts provided the required elements for decision making on which of the layouts best suited the port's needs and priorities. Short term expansion of the port is considered in the project.

Once defined the port arrangement, technical details of the project as well as layout optimization required complementary studies. Numerical and physical modelling have thus been employed in studies concerning wave penetration in port basin, ship motion, quay reflection characteristic and breakwater overtopping and stability. The planning of this development involved the coordination of all above activities and studies of various disciplines.

During the preparation of the project, different stages are dynamically related in such a way that permit one influences the others.

BREAKWATER DESIGN

The wind in Ceará is very persistent, blowing practically all year round from E quadrant; as a result, the wave climate is dominated by short period locally generated sea waves. Nevertheless, measurements performed in the area indicate that from December to March, long period, swell coming from a more northerly direction, due to extra-tropical storms in North Atlantic are frequently observed (Melo, 1995).

Unlike most of Brazilian ports where shelter works are structures connected to the coast, the shelter work adopted for the new port is a L-shaped, offshore breakwater. Since it has been constructed in such a way as to protect mooring areas from the two main directions of incident waves, its two branches develop in the SW and NE directions, each one with respective lengths of 900m and 800m.

Another important feature of this port conception is the large dispersion area to the lee of the shelter work, that almost eliminates the effects of wave reflection in the mooring areas. When conventional jetties are used, undesired wave reflection in the confined area is very usual. Smaller period oscillations (if compared to those that occur in an open basin) generated in the sheltered basin are also common (INPH-71/96).

It is necessary to remark that in this case, a superposition of the wave trains diffracted on both edges of the breakwater occurs in the lee zone, thus generating peculiar oscillation characteristics by addition and/or subtraction of the individual waves, as well as phase and period modifications. Depth variations on both sides of the breakwater is one important physical characteristic found and by reffraction it changes the characteristics of incident waves.

The Structural Conception

The main factors that help to determine the structural conception of a shelter work are the local maritime conditions (depths, tides currents and waves) and the financial and economic features that take into account the easiness of the construction (equipment) and the availability of unexpensive building material in the region where the work is going to be carried out.

Conventional rubblemound breakwater, berm breakwater, vertical breakwater (made of concrete cassions filled with sand or rock) and artificial blocks breakwater are the most usual maritime structures. Although in Brazil conventional rubblemound breakwater have been largely used and are found in almost all open sea ports over the country, it is a berm breakwater that protects the offshore Port of Sergipe.

Recently some countries have taken deep concern in developing and improving the concept of berm breakwater. This is somehow a return to the early days of the breakwaters when they used to be a simple mass of superimposed stones that acted as a barrier to the wave attack and offered some protection to port basins. At that time those structures were not long lasting due to the lack of an adequate knowledge for their design and construction.

The two main factors that led INPH to suggest a berm breakwater for the new port of Pecém were the good use of the stone quarry that will supply the structure and the easiness of construction implicit to this structural conception. In berm breakwaters the selection of quarry blocks is limited to two ranges of granulometry: the core, made of fine material and the berm, made of coarse material. Since they complement each other, the material from the stone quarry is used to advantage in the structure (INPH-70/96).

As a matter of fact the ideal utilization of quarry stone will depend on the granulometry curve obtained from the quarry blasting. The resulting material must distribute in the granulometry curve in such a way to fulfill the proportion design requirements for core and berm materials. Tests involving stone quarry blasting are thus very important for the evaluation of granulometry distribution. Berm breakwater's slopes requires no special operations to be formed. Stones are simply dumped and pushed to their places until the berm width defined in the design is reached.

Conventional structures on the other hand requires three ranges of stone granulometry (for the core, filter and armour layers), which results in great waste of material from the quarry. Armour blocks are also heavier than those used in the berm of berm breakwater. Conventional breakwater slopes must be carefully arranged, their blocks being put one by one in the right place. As a result the slope formation must be monitored and powerful cranes with long beams must be used in order to reach the bottom of the slope.

Rock Quantities

The proposed sections seen in Fig. 4, will use blocks from 0.05 to 1.0t on the core, and from 1.0 to 4.0t on the berm that consists in two different layers, one with 75% of the blocks over the mean weight (ϖ =2,5t) and other with 50% of the blocks over. The total volume of the breakwater is round 2.0 millions of m^3 as shown on Table 1.

Table 1. Detailed volume of the breakwater

	L (m)	DEPTH (m)	ROCK (kg)			TOTAL (m^3)
			50 to 1000	1000 to 4000 (50% > ϖ)	1000 to 4000 (75% > ϖ)	
branch NW						
Head		-17.5	10,610.95	37,499.67	186.86	48,297.48
Section AA	150	-17.5	102,796.50	135,450.00	4,875.00	243,121.50
Transition	100		69,421.75	62,015.50	3,883.00	135,320.25
Section BB	480	-17.0	337,500.00	161,908.80	21,676.80	521,085.60
branch SW						
Head		-13.5	6,059.74	27,636.68	186.86	33,883.28
Section AA	150	-14.0	74,250.00	113,400.00	4,875.00	192,525.00
Transition	100		54,093.75	55,850.00	3,883.00	113,826.75
Section BB	580	-15.0	340,387.50	209,380.00	26,192.80	575,960.30
Curve	110	-16.5	58,151.70	67,622.94	4,965.79	130,740.43
	TOTAL	(m^3)	1,053,271.89	870,763.59	70,725.11	1,994,760.59

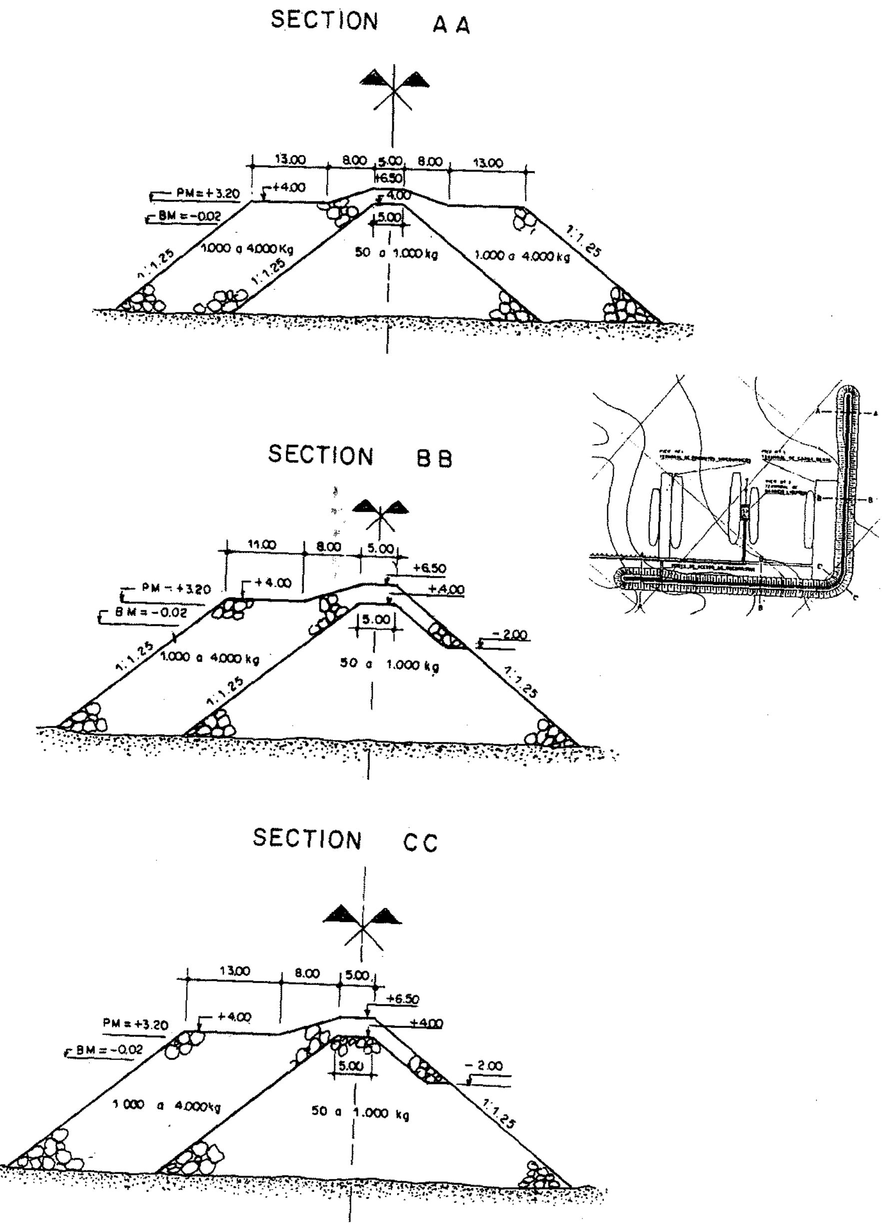

Fig. 4 Cross sections of the breakwater

SOCIO-ECONOMIC CONDITIONS

The Brazilian port scene, after the Port Modernization Law has been promulgated in February of 1993, is passing through a transition period. With the entrance of the deregulation on portuary operations and its possible reflections over the Brazilian cabotage navigation, it may foresee the concept feeder port working (INPH-15/95 A). The northeast littoral zone present adequate geographical conditions for the implantation of a feeder port by its proximity with important commercial partners as United States (east coast) and Europe, also by Panama channel, permitting the navigation to the North American west coast and Asia. Under this point of view a third berth has already been concepted and is intended to be built in a mean term. The development of economic activities in Pecém has the advantage of being a site not constrained by existing structures (Fig. 5).

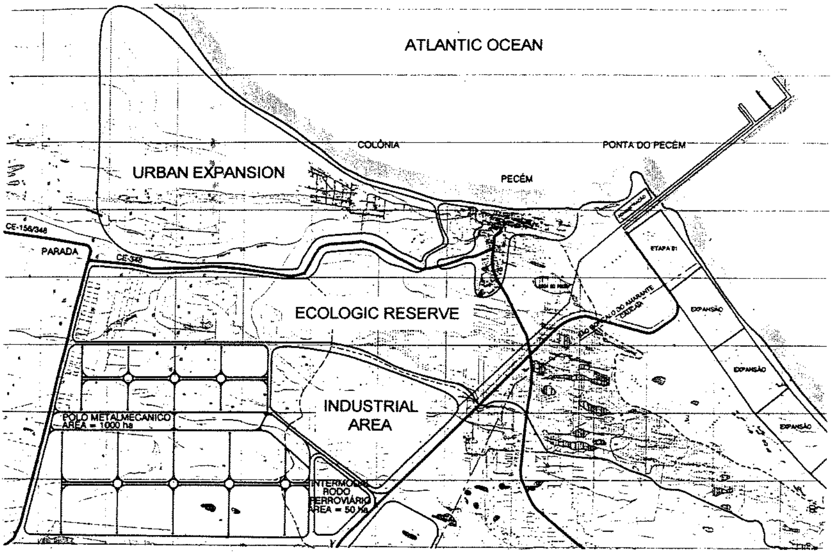

Fig. 5 Development planning for Pecém region

MORPHOLOGY

Information gathered during the construction of Port of Mucuripe as well as the resulting environmental influences along the coast, mainly in terms of the southeast to northwest littoral drift, of about 800.000 m^3/year (estimated value) has been used.

Comparisions of aerial photographs taken in 1968 and in 1996 show that during the last 30 years the shoreline in front of Pecém has retroceded some 4 to 6 meters per year, as a result of an erosion process that occurs as function of two main factors:

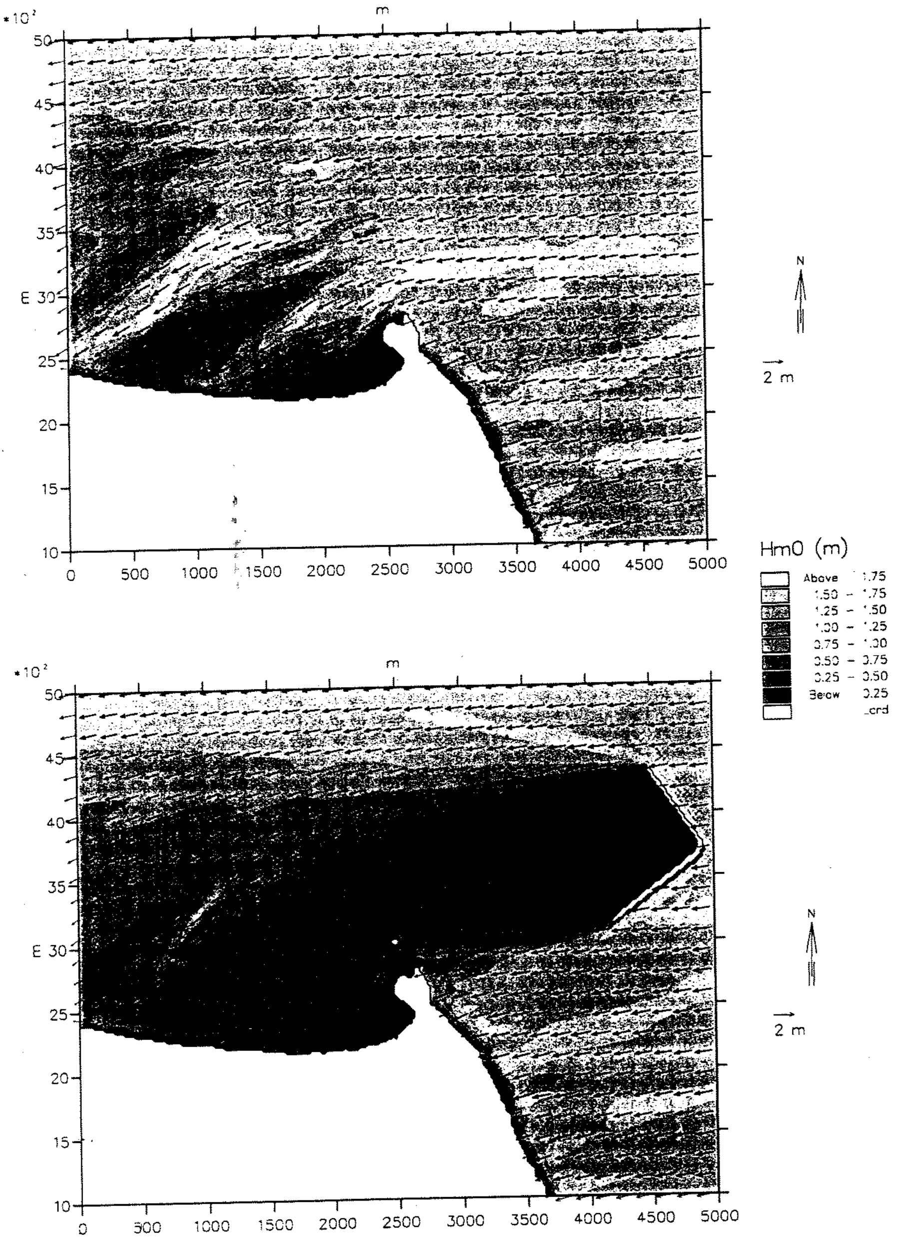

Fig. 6 Comparision of 2D wave field

- the disordered occupation of the ground, specially in the region of dunes, which reduces the wind driven sediment supply to the sea;
- the presence of Ponta do Pecém and the refraction-diffraction phenomenon makes erosion in the neighborhood of the city easier.

Simulations carried out so far have led to the conclusions that the construction of the Pecém port facilities will be good to the littoral zone of the city of Pecém since the shadow created by the offshore breakwaters tends to protect the shoreline from the existing erosion process. The Fig. 6 shows a simulation for Hm0=1.75m, Tp=7s and MWD=82.5deg.

The same simulations have not revealed any repercussion on the littoral zone to the east of Ponta do Pecém (Ponta Taíba). In that region the beach strip where the littoral drift is more intense is covered by beach rocks forming consolidated beaches that are not subject to erosion.

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