Journal of Coastal Research	SI 39	880 - 883	ICS 2004 (Proceedings)	Brazil	ISSN 0749-0208

Erosion Protection of Pondicherry Coast, South East India

S. Neelamani† and R.Sundaravadivelu‡

†Research Scientist
Coastal Engineering and Air Pollution Dept
Environmental and Urban Development Division
Kuwait Institute for Scientific Research
P.O. Box : 24885, 13109 SAFAT, KUWAIT.
nsubram@kisr.edu.kw

‡Professor
Department of Ocean Engineering
Indian Institute of Technology Madras
600 036, Chennai, INDIA
rsun@iitm.ac.in

ABSTRACT

NEELAMANI,S. and SUNDARAVADIVELU,R., 2006. Investigation on the reasons for erosion of Pondicherry Coast, South East Coast of India; Solution for prevention of further erosion and to win back the beach. Journal of Coastal Research, SI 39 (Proccendigs of the 8th International Coastal Symposium), 880 - 883. Itajaí, SC, Brazil, ISSN 0749-0208.

One of the serious problems along the Pondicherry coast is the acceleration of erosion, due to the construction of an artificial fishing harbor in an active littoral transport zone in the Bay of Bengal. The annual net sediment transport is about 247000 m3 per year towards North in this coast. The formation of Pondicherry Harbor by a pair of breakwaters has interrupted the movement of alongshore sediment transport and resulted in erosion at Northern side and accretion at the Southern side of breakwaters. The stretch of the coast along the Northern side of fishing harbor is about 6 km (The main city is in this stretch) and was seriously affected resulting in damage of buildings along the shore. To combat erosion and to protect the Northern side of Pondicherry coast, a suitable groin field is contemplated as a possible coastal protective measure, taking into account of existing environment conditions. The scope of this project is to propose a suitable groin field with transition system and the estimation of sediments required to fill the groin field.

ADDITIONAL INDEX WORDS: *Beach erosion, groin field, artificial nourishment.*

INTRODUCTION

The union territory of Pondicherry is located on the East Coast of South India facing Bay of Bengal at latitude of 11°56' N and longitude of 79°50' E. Due to its geographical location along the Bay of Bengal, which is cyclone prone, it experiences an average of 2 to 3 cyclones annually. The normal wave climate in Bay of Bengal is mild (with significant wave height varies from 1.0 m to 1.5 m and peak period varies from 7.0 sec to 9.0 sec), but the wave climate is very severe during cyclone with significant wave heights ranging from 4.0 to 6.0 m and peak periods from 10.0 sec to 15.0 sec. The severe wave climate exists only for less than 1% of a year, but from erosion point of view, its effect need to be considered.

Pondicherry coast is facing the problem of shoreline erosion and the intensity is severe during the past 15 years. After construction of the Pondicherry Port and the breakwaters in the Southern part of the Pondicherry city, the coastal erosion on the Northern side has accelerated significantly and the entire beach area of Pondicherry is lost. The satellite imagery of Pondicherry is shown in Figure1.

Form this figure, it is clear that erosion is taking place on Northern side of the breakwater and deposition is taking place on the Southern side of breakwater. A restaurant called Le-Café on the beach was destroyed by the scour of its foundation (Figure 2).

The configuration of the breakwater and accretion at the Southern side of the breakwater is provided in Figure 3. For protection of shoreline erosion, the Pondicherry government has built seawalls using boulders of size 0.50 tons to 1.50 tons for a total length of about 6 to 7 km.

In many places along this seawall, the seabed below the seawall is eroded due to severe wave actions and ground settlement.

This situation made Pondicherry government to find a permanent solution for protecting the coast from further erosion and to win back the sandy beach for improving the tourism activities.

The construction of Pondicherry port using breakwaters encourages the progressive sediment deposition at the Southern side and the erosion at the Northern side of the breakwater since the net sediment drift is towards North in a year. After studying the merits and demerits of different types of coastal protective measures existing today, proposal for a groin field with artificial sand nourishment is finally given for this site. The objective of the present paper is to deliberate on why a groin field with artificial nourishment is the best option for this site.

SHORE PROTECTION MEASURES AND ITS SELECTION CRITERIA

There are large numbers of engineering solutions possible for protection of Pondicherry coast from erosion and to control the littoral drift. The coastal protection measures can be of HARD form or SOFT forms. The HARD solution includes

a. Sea walls
b. Groins
c. Offshore breakwaters (Either submerged or surface piercing)

The SOFT solution is basically artificial beach nourishment using the suitable sand from a borrow pit.

The selection of suitable type depends on a number of parameters, like the environmental conditions, cost of the project, availability of material and suitable machinery for the construction, environmental impact of he proposed solution,

Figure 1. Satellite Imagery of Pondicherry Coast.

Figure 2. Damage of LeCafe Restaurant due to the Coastal Erosion.

Figure3. View of the Pondicherry Harbor (See the accretion of sand at the far end of the photo.

Aesthetics etc. The merits and demerits of these solutions with respect to the present project are given below:

SEA WALLS

These are structures, which are placed parallel or nearly parallel to the shoreline to separate an eroding land area from water area. The primary purpose of these structures is to protect the land and upland areas from further erosion by waves with an incidental function as retaining wall or bulkhead. The limitations of these structures are that they can only protect the land behind them and none adjacent to the up coast or down coast. When built on a receding shoreline, the recession on the adjacent shore will continue and may be accelerated. The erosion of the seabed material in front of the seawall normally gets accelerated. The seawall will not interrupt the alongshore sediment movement. Pondicherry Government has already tried this option and they have lost the existing beach totally. For the past 10 to 15 years, the seawall is sinking and was replenished from time to time. Now they wanted to get back the beach. Hence the sea wall option is not suitable for this particular problem.

Offshore Breakwaters

Offshore breakwaters are usually shore parallel structures. It is a structure designed to provide protection from wave action to an area located on the leeside of the structure. It dissipates a significant part of incident wave energy and only the remaining energy is available at its lee side. Offshore breakwater is not only used for shore protection but also to provide Harbor protection, acting as a littoral barrier. It also serves as littoral barrier-sediment trap to some extent. The shore starts building up towards the breakwater and the formation is called 'salient' if the advanced shoreline does not reach the breakwater. If it reaches the breakwater, the formation is known as 'tombolo'. Detached breakwater works efficiently, when the waves are coming in the direction normal to the shore. But in Pondicherry coastal region waves are approaching at different angles to the shore depends upon the seasons over the year. Moreover this option will be expensive, since the quantity of rock required for the offshore breakwater construction is more when compared to Groin, since it is constructed in relatively deeper waters (say 3 to 5 m water depth). It also needs sophisticated equipment like floating barges, cranes and a working harbor when compared to groin construction. Hence the offshore-detached breakwater option is also not well suited for the present problem.

GROINS

Groin is usually built perpendicular to the shore, extending from a point landward of possible shoreline recession in to the water, a sufficient distance which helps in stabilizing the shoreline at a desirable location.

Groin may be classified as permeable or impermeable, high or low, fixed or adjustable. Groins are built in order to halt or reduce shoreline erosion by intercepting the littoral drift. In Pondicherry, about 1.0 million cubic m of sand is drifting from South to North and about 0.4 million cubic m is drifting from North to South over a year. Functional design of Groin field involves the determination of length of each groin, spacing between Groins, height and type of groin and weight of amour stones and inner layers including the core.

The following few basic principles can be applied in the design of groin fields:

a. Groins can be used to interrupt the long shore sediment transport.

b. The beach adjustment near the groins depends on the magnitude and direction of the alongshore transport.

c. Water pushed by waves into a groin compartment (the space between two adjacent groins) will sometimes return offshore in the form of rip currents along the sides of groin.

d. The percentage of the alongshore transport, which bypasses a groin will, depends on the groin dimensions, fillet dimensions, water level and wave climate.

e. The alongshore drift that is collected in the up drift fillet is prevented from reaching down drift area, where the sand balance is upset.

These general guidelines must be given due attention while selection the Groin solution for shore protection.

FILLING GROINS

Since the groin intercepts the sediment transport, the down drift side of a groin attracts erosion.

The importance of minimizing down drift erosion after construction of a groin system cannot be overemphasized.

Unless the natural alongshore transport is of sufficient magnitude to quickly fill the up drift side of the groin and the groin compartments or unless erosion of the down drift area is inconsequential, artificial filling of the groin compartment will be necessary. At sites, where a groin system is under consideration, two possibilities arise. Either the groin system is filled artificially or to depend on the alongshore transport to produce the fill.

With artificial fill, the only interruption of alongshore transport will be the period between the time the groin system is constructed and the time the artificial fill is made. For economical reasons, the fill is normally placed in one continuous operation, especially if it is being accomplished by hydraulic dredge. For Pondicherry, the groin construction and artificial nourishment of the compartments using the accreted sand at the Southern side of the Pondicherry Port is recommended.

WAVE CLIMATE OF PONDICHERRY COAST

The wave is the main driving factor for the littoral transport of Pondicherry coast. Pondicherry coast is affected by two monsoon wave actions.

During the North-East monsoon (October, November and December) the waves approach the coast from N-E direction. During the South-West monsoon (April to August) the diffracted waves approach the coast mostly from S-E direction.

Since almost 75% of year, the waves are driving the sediments from South to North, the net annual sediment transport is towards North only.

DESIGN METHODOLOGY

General

The design of the cross section of groin is similar to the design of rubble mound breakwater. HUDSON (1961) formula can be used to estimate the weight of the amour unit. The groin will be acted upon by waves on both the sides during different monsoon conditions. Hence, both the sides of the groins should be designed for direct wave action.

The proposed groin field consists of a number of groins. The length, spacing, alignment of each groin has to be designed. The cross section of each groin consists of the following items.

a. Primary amour layer
b. Secondary cover layer
c. Filter layer
d. Core Layer
e. Bedding layer

The design guidelines provided by SHORE PROTECTION MANUAL (1984) are used to estimate the weight of amour units and thickness of different layers. Pondicherry has a peculiar problem. They do not have amour stones of size 1.0 to 2.0 tones. It is to be obtained from Tamilnadu. PWD in Podicherry has expressed its difficulties in getting such units from TN. Hence, artificial units (Perforated cubes) are designed for the groins.

Amour Layer Design

The cover layer of a Groin is the outermost layer and is always exposed to wave action. Empirical formula developed by HUDSON (1961), expressed in terms of weight of the amour unit required to withstand the design wave loads without any significant displacement.

The HUDSON formula (1961) to determine the weight of individual amour unit is given as

$$W = w_r H_S^3 / K_D (S_r - 1) \cot \theta \quad (1)$$

Where
w_r = Unit weight of armor unit
H_s = Design significant wave height
K_D = Stability coefficient
S_r = Specific gravity of the armor unit, relative to the water at the Structure (wr/ww)
w_w = Unit weight of sea water
tan θ = Slope of the existing rubble mound sea wall with horizontal

Weight of Individual Units for Different Layers

According to the recommendation of SHORE PROTECTION MANUAL (1984), the weight of stone for different layers as given below:

Weight of units in secondary layer is W/10 to W/15
Weight of units in core layer is W/200 to W/4000
Weight of toe mound units is W/2

Thickness of Primary and Under Layer

The thickness of primary cover layer should be chosen such that thickness comprising the two amour units.

$$r = n K_v (w/w_r)^{1/3} \quad (2)$$

Where,
r = Average layer thickness in 'm'
n = Number of units in thickness comprising the cover layer
K_v = Layer coefficient
W = Weight of individual amour units in tones

Crest Width

The width of the crest greatly depends upon the degree of allowable overtopping and it is not critical when there is no overtopping. The minimum crest width should be equal the combined width of three amour units (n=3). Crest width may be obtained from the following equation,

$$B = n K_v (w/w_r)^{1/3} \quad (3)$$

Where,
B = Crest width in meters
n = Number of units (3 is recommended)
K_v = Layer coefficient
W = Weight of individual amour units in tones

The crest width must be wide enough for construction and maintenance equipment operated from the structure.

Functional Design of Groin

For functional design purposes, a groin may be considered to be consists of three different section. They are

a. Horizontal shore section (HSS)
b. Intermediate sloped section (ISS)
c. Outer section (OS)

Horizontal Shore Section (HSS)

This section extends far enough landward to anchor the groin and prevent the flanking. The height of the HSS depends on the degree desirable for sand to overtop the groin and nourish the down drift beach. The standard height is the height of natural berm, which is usually the height of maximum high water, plus the height of normal wave up rush. The maximum height of a groin to retain all sand reaching the area (a high groin) is the height of maximum high water and maximum up rush during all but most severe storms. Conversely, this section or part of it can be built lower than the berm to permit over passing of sediment during periods of high tide. The length of HSS depends on the area of the eroded land intended to be regained. It is always better to start with a short length at the beginning, nourish them, extend the HSS further in the future, if some more lands need to be regained.

Intermediate Sloped Section (ISS)

The ISS extends between the HSS and OS. It should approximately parallel to the slope of the natural foreshore. The elevation at the lower end of the slope is determined by the construction method used, the degree to which it is desirable to obstruct the movement of littoral material.

Outer Section (OS)

The OS is the outer part of the groin which extends the seaward of the ISS. This section is normally horizontal. The elevation is selected based on the economy and safety.

Other Design Details of the Groin Field

The length of each main groin : 50 m
Spacing between the groins : 150 m

Type of amour unit : Hollow cube of 0.6 m X 0.6 m X 0.6 m with 0.2 m dia hole in all six faces of the cube.
Weight of each unit : 0.4 tons
Side slope of each groin : 1 V : 1.5 H
Grade of concrete for the armor : M30
Weight of core material : 40 kg to 100 kg stones
Weight of filter material : 1 kg to 40 kg stones
Weight of toe mound : 100 kg to 200 kg stones
The crest level of the groin near the seaward side of the groin : + 2.0 m
The crest level of the groin near the shoreward side of the groin : + 3.0 m

End on method of construction is recommended. It is proposed to lay pipelines from the port to the northern most point of the groin for pumping the slurry from the dredging area of the port. The pipeline should have controllable outlet facilities in each groin compartment for the purpose of filling the compartments with sand.

Groin System Transition

To avoid an abrupt change in the shore alignment that may result in erosion of the down drift beach, the use of transitional groins (groins of reduced lengths) is recommended. Where there are reversals in the direction of alongshore littoral transport, transitions would be appropriate for both ends of the system. It is reported that only three or four groins need to be shortened at the down drift end of the system. The transition is more effective if a line connecting the seaward ends of the shortened groins and the last full length groin meets the natural shore alignment at an angle of about 60.

Proposal for Nourishment

Till the groin field construction is over, a temporary nourishment plan is provided to prevent further erosion of coast in the Northern side of Pondicherry Port. It is proposed to bypass the sand from the harbor side during South-West monsoon, since the wave direction in Pondicherry is from S-E. The sediments are expected to move towards North. It is proposed to stop sand bypassing during N-E monsoon since the sediments move towards South and hence the bypassed materials are expected to reach back the source point. This will result in wastage of money.

CONCLUSIONS

Pondicherry coast is undergoing erosion. It is accelerated due to the construction of Pondicherry Harbor. To protect the Northern coast from erosion, rubble mound seawalls were built by the PWD, Govt. of Pondicherry. The Government wanted to win back the beach in order to improve the tourism activities. IIT Madras has carried out a critical study on the merits and demerits of different schemes and finally recommended for a groin field with artificial nourishment of the groin compartments. It is sincerely hoped that Pondicherry will get back the beach, if the project is executed as recommended.

LITERATURE CITED

HUDSON, R.Y., 1961. Wave forces on rubble mound breakwaters and Jetties, Miscellaneous paper 2-453. *U.S.Army Engineer*, Waterways Experiments station, Vicksburg, Mississippi.

SHORE PROTECTION MANUAL, 1984. Volume I & II Coastal Engg. *Research Center, Department of the Army, U.S Army Crops of Engineers, Vicksberg, USA*.

VAN DEER MEER, J.W., 1993. Conceptual Design of Rubble mound Breakwaters. Delft Hydraulics, Publication No.483.