Proceedings of the Ninth International Symposium on River Sedimentation
October 18 – 21, 2004, Yichang, China

SOLUTION TO THE PROBLEMS ON PONDICHERRY BEACH, INDIA

Wanzhan WANG and Zegong LI
Yellow River Institute of Hydraulic Research, Zhengzhou, 450003, China
E-mail: wanzhan@yahoo.com

Abstract: In the southeast coast of the Indian peninsula, the Pondicherry beach has been suffering from erosion since the completion of the breakwaters that were constructed in 1990 to a harbor. Resultant accretion in the approach channel to the harbor is another problem. One-line coastal model,Unibest, is run to simulate the morphological changes due to problems-orientated alternatives proposed by the present authors. Financial analysis leads to finalization of the most cost-economical alternative, which is capital nourishment plus sand by-passing.

Keywords: Podicherry, Beach erosion, Approach channel, One-line model, Morphology

1 INTRODUCTION

1.1 Problems

Located at Lat. 11°55′ N and Long. 79°50′ E, the town of Pondicherry is on the southeast coast of the Indian peninsula, approximately 150 km to the south of Madras. The Pondicherry coast has a natural wide sandy beach. A net littoral drift goes in the south-to-north direction, and it is roughly estimated to be around 75% of the total drift.

In 1986 construction of a harbor started in the Ariankuppam estuary to about 3.5 km south of the town of Pondicherry. The approach channel was planned to be 2 m deep and be kept open by two protective breakwaters constructed to the south and to the north of the river mouth. The breakwaters were completed in 1990. However, problems have appeared ever since the completion of the breakwaters, which are briefed as follows.

- Safety of the revetment: As expected, accretion, due to the construction of the breakwaters, has taken place to the south of the southern breakwater (the white colored part along the coast in Fig.1) and erosion to the north of the northern breakwater (the concaved coast to the north of the river mouth in Fig.1).

The wide beach (30m-50m) in front of Pondichery has disappeared due to the erosion. For the sake of safeguarding against the erosion, a stretch of revetment of large granite boulders has been, part by part, placed in place following the " feet " of the erosion. The eroded part has extended downdrift as long as 6 km in the past decade.

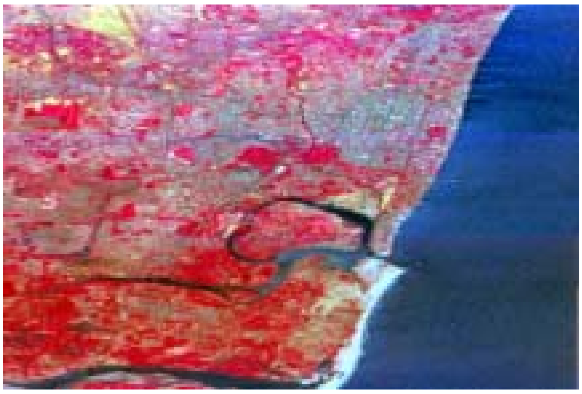

Fig.1 Coastal Area Near Pondicherry

To the disappointment of the designers for the revetment, construction of the revetment has led to another problem that the toe of the revetment has become undermined. Once the revetment collapses, the property and the people behind the revetment will suffer from flooding caused by the storms. That is what the local people worry about most, which must be solved.

- Downdrift erosion: The construction of the revetment has caused another problem, i.e., downdrift erosion. It has been found that erosion problem has not been halted, instead it has continuously moved downdrift to the area to the north of the end of the revetment. The erosion moving downdrift is one of the most painful worries of the local people and the neighboring people.
- Silting of the approach channel: Where waves dominate over a coast, an approach channel to a harbor tends to be silted up. It is true for the case of the approach channel to the harbor in the Pondicherry. So far the approach channel has been filled up with so heavy deposits that only the crafts used by fisherman, which are much smaller the design ships, can enter the harbor.

1.2 Objectives

The main objectives of this research are to find and evaluate the possible coastal engineering solutions for the three problems mentioned above, i.e., (1) to bring the lost beach back beach in front of the existing revetment, (2) to remove the deposits in the channel entrance to make it accessible for design ships, and (3) to stop continuing downdrift erosion at the end of the revetment.

2 EXISTING CONDITIONS

For the modeling of the morphological changes in the sandy Pondicherry beach with the mean particle size of 0.000,15 m, one-line coastal model, Unibest, is used. The main features of the data used in the model are briefed as follows.

Local tidal range is 0.8 m and the mean maximum tidal current near Pondicherry is $0.15 m \cdot s^{-1}$. The data of the waves at Madras, 140 km to the North of Pondicherry, is available for the research. The wave height rose offshore indicates that the prevailing waves come from the southeast. Bathymetrical data in the research area is obtained from local nautical charts and from the measurements done by TU Delft students in 2000.

3 DESCRIPTIONS OF ONE-LINE MODEL AND ITS SETUP

3.1 Brief Description of the Model

One-line model of Unibest is applicable in the calculating of sediment transport and resultant morphological changes along the uniform beach with and without the presence of coastal engineering. For the details of Unibest reference can be made to its brochure.

3.2 Model Setup

Prior to the construction of the breakwater on the Pondicherry coast, the local contour lines are quite straight and parallel, so it can be taken as a uniform one. In the modeling, a total 20 km-long shore is modeled and schematized as a straight and uniform one, about 12 km-long shore to the north of the breakwater and about 8 km to the south. Considering there is small amount of sand coming from the river to the sea, it is decided not to consider the influence of the river on the morphological change. The two breakwaters are schematized as a single one perpendicular to the shoreline. With this the longshore sediment transport at the two end of the stretch of the beach can maintain fixed for a quite long term, which can be taken as upper and lower boundaries. The coastal orientation is found to be 101° (an angel clockwise between the north and the normal to the beach).

4 CALIBRATION

Wave breaking index is 0.78 and the bottom roughness is found 0.1 in the calibration. Calibration is done in comparing the calculated and the measured in 1990-2002 in terms of longshore sediment transport, total volume eroded from the Pondicherry beach, and the length of the eroded breach.

(1) Longshore sediment transport: Where it is not influenced by breakwaters, longshore sediment transport (LT) is estimated as 232,000 $m^3 \cdot yr^{-1}$, 115,000 $m^3 \cdot yr^{-1}$, and 185,000 $m^3 \cdot yr^{-1}$ with CERC, Van Rijn and Bijker formulas, respectively, all in the direction from the south to the north. Considering the measured LT of 185,000 $m^3 \cdot yr^{-1}$, it is concluded that Bijker formula gives the best results, so it is chosen in the research.

(2) Total volume of the eroded or deposited: In 1990-2002, there was 2.50 million m^3 sand accumulated in the area to the south of the breakwater while there was the same amount of sand eroded from the beach to the north of the breakwater. The value of the eroded or the deposited sand is close to the measured value of about 2.3 million m^3.

(3) The eroded beach length: Calculated results of the shoreline retreat in 1990-2002 indicates that the beach eroded to the north of the breakwater is about 6 km long, which is the same as real value.

Good agreement between the calculated and the measured in the above indicators signifies the robust applicability of the model in the modelling of the shoreline change around Pondicherry.

5 SIMULATION OF SCENARIOS (4 ALTERNATIVES)

There are four alternatives to realize the objectives mentioned in section 1.2, namely, (1) to te a new beach, (2) to remove the deposits in the channel entrance, and (3) to stop continuing downdrift erosion. The one-line model of Unibest is applied to evaluate the morphological changes incurred by the alternatives. With that, financial analysis is done to evaluate the alternatives and finalize the cheapest alternative in cost.

5.1 Morphological Changes

5.1.1 Alternative 1: Capital Nourishment Plus Re-nourishment

Capital nourishment: It means first dredging both the deposits (2.5 millions m^3) accumulated in the area to the south of the breakwater and the sand in the other sources including the deposits in the approach channel, and then dumping it to the eroded area to the north of the breakwater so that the eroded beach could be reversed into the one before construction of the breakwaters.

Re-nourishment: After capital nourishment done, the model of Unibest is applied to the newly recovered uniform beach and run to find morphological changes in the five years to come (Fig.2). Fig. 2 shows that the Pondicherry beach, which is to the north of the breakwater and with the horizontal coordinates ranging between 0 and 12,000 m in Fig.2. It is found that there is a progressive erosion to the Pondicherry beach in the first years after the completion of the capital nourishment, and that the eroded volume is 887,000 m^3 while there is 887,000 m^3 sediment deposited to the south of the breakwater. So re-nourishment will be done every 5 years by dredging all the deposited sediment (including the sediment deposited in the approach channel and in the other sources considering the sand loss during the nourishing) and distributing it along the beach lost.

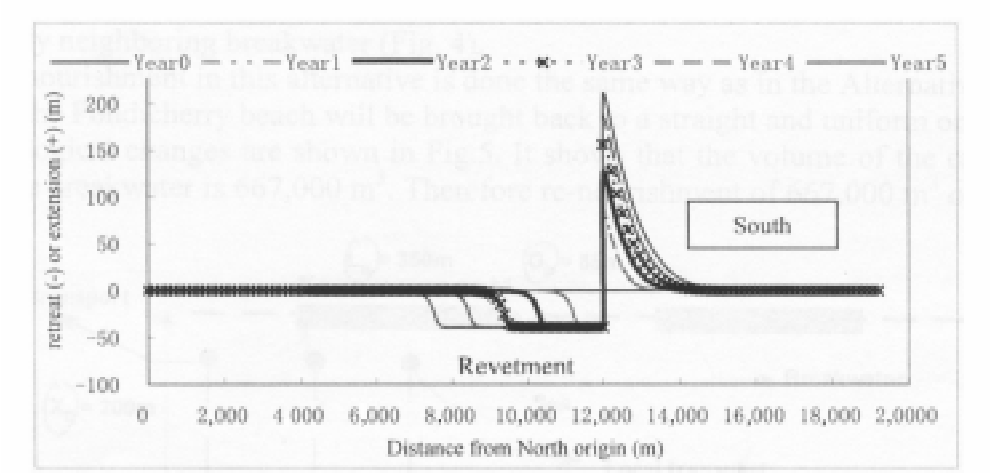

Fig. 2 Morphological Changes in the First Years (Alternative 1)

5.1.2 Alternative 2: Nourishment plus Groins plus Re-nourishment

Totally 12 groins, 150 m long each and 450 m in the spacing are constructed along the Pondicherry beach according to the alternative 2. Each groin has its cross section like this: 6m wide in crest, 1:2 in slope and 0 m-3 m in height (averagely, 1.5m).

Capital nourishment in the Alternative 2 is done the same way as in the Alternative 1. After the completion of the capital nourishment, Unibest is used to simulate the morphological changes in the next five years (Fig.3). From Fig.3, it is found out that the beaches in the groin fields change their orientations, and that the downdrift erosion (784,000 m^3 in volume) occurs at the end of the existing revetment. That leads to the necessity of every-five-year **re-nourishing** of 784,000 m^3 of sediment deposited to the south of the breakwater (including the sediment in the approach channel) and distributing the sediment along the beach to the north of the revetment.

5.1.3 Alternative 3: Capital Nourishment plus Sand Bypassing

Capital nourishment in this alternative is done the same way as in the Alternative 1. After this done, the Pondicherry beach will be brought back to a straight and uniform one as before 1989. Then sand bypassing will done every year. The volume of the sediment in the bypassing is the same as the longshore sediment transport without breakwaters, i.e., 185,000 m^3 per year, which can be seen from the calibration part.

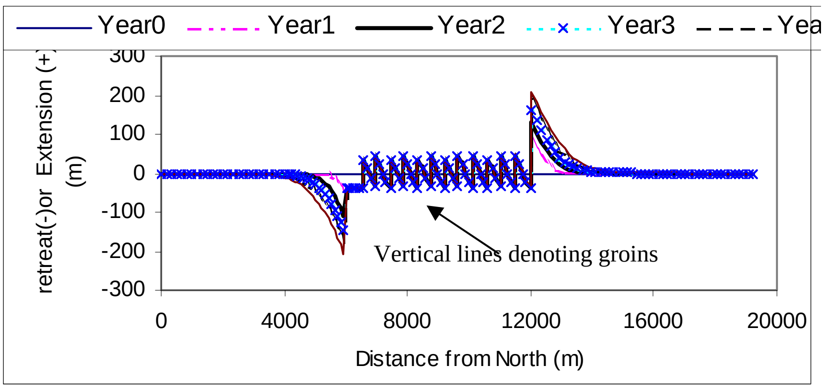

Fig.3 Shoreline Extension or Retreat (Alternative 2)

5.1.4 Alternative 4: Capital Nourishment plus Offshore Breakwaters

It is proposed to place 13 offshore breakwaters at the depth of 5m below MSL, 200m seawards of the coastline each. Each offshore breakwater is 350m long, and 85 m from its immediately neighboring breakwater (Fig. 4).

Capital nourishment in this alternative is done the same way as in the Alternative 1. After this done, the Pondicherry beach will be brought back to a straight and uniform one.

Morphological changes are shown in Fig.5. It shows that the volume of the erosion to the north of the breakwater is 667,000 m^3. Therefore re-nourishment of 667,000 m^3 of sand has to done.

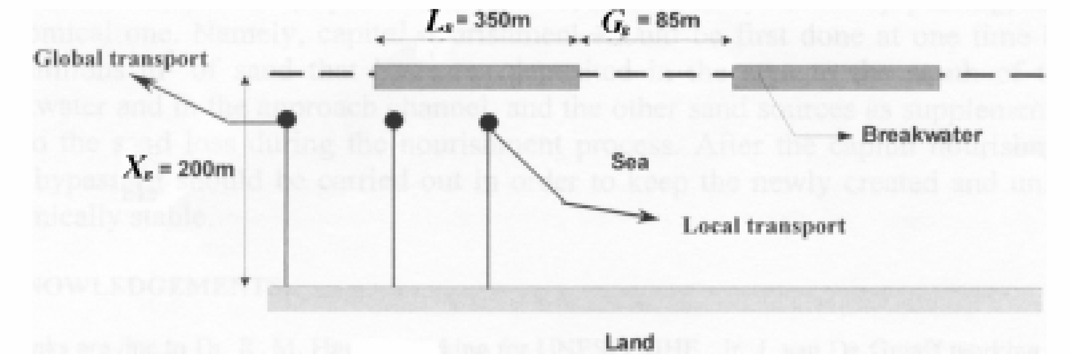

Fig. 4 Layout of Offshore Breakwaters (Part)

5.2 Financial Analysis

Unit Cost: according to the Indian markets, nourishment cost is assumed 3 US$·$m^{-3}$ for a total volume bigger than 1 million m^3 and 5 US$·$m^{-3}$ for the total volume less than 1 million m^3. Cost for construction of groins is estimated as 10 US$ ·m^{-3} .The local Indian unit price for sand bypassing is estimated 1 US$·$m^{-3}$ and the unit cost for construction of offshore breakwater is 7,00.0 US$·$m^{-1}$.

Total cost: It is assumed that the harbour has a lifetime of 50 years. It means that re-nourishment every 5 years will be repeated 10 times and that the sand bypassing will be carried out for 50 years. Considering future value of cost =present value × $(1+i)^n$, present value of cost can be obtained where local annual interest (i) is taken as 6%.The present values of the four alternatives are summarized in Table 1.

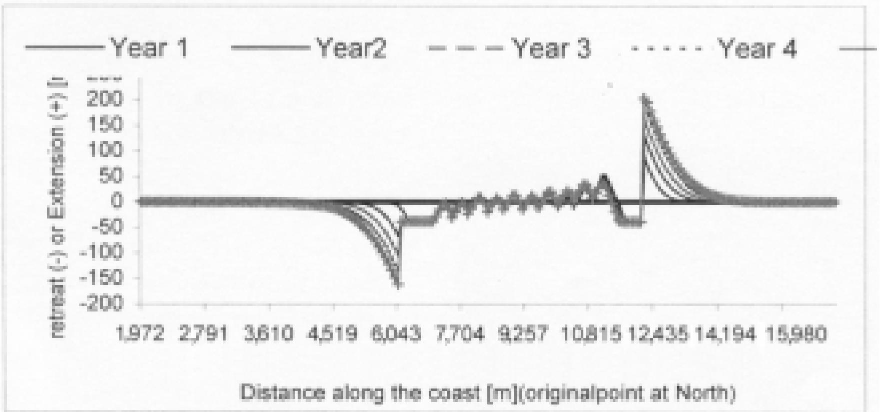

Fig. 5 Coastline changes after 5 years

Table 1 Present Values of Total Cost with the Four Alternatives (in US$)

Alternative	Present value
1 (capital nourishment + re-nourishment)	19,900,692
2 (capital nourishment + groins + re-nourishment)	18,703,702
3 (capital nourishment + sand by-passing)	10,415,944
4 (capital nourishment +offshore breakwater+ re-nourishment)	79,338,885

In conclusion, alternative 3 (capital nourishment followed by sand by-passing) is the most economical in cost.

6 CONCLUSIONS

By a one-line model, Unibest, the morphological changes in the Podicherry coast due to coastal engineering alternatives were simulated. Financial analysis has led to the conclusion that the alternative 3 (capital nourishment followed by sand by-passing) is the most economical one. Namely, capital nourishment should be first done at one time by dredging 2.5 millions m^3 of sand that has been deposited in the area to the south of the southern breakwater and in the approach channel, and the other sand sources as supplementary support due to the sand loss during the nourishment process. After the capital nourishment, 100 % sand bypassing should be carried out in order to keep the newly created and uniform beach dynamically stable.

ACKNOWLEDGEMENTS:

Thanks are due to Dr. R. M. Hassan working for UNESCO-IHE , Ir. J. van De Graaff working for TU Delft , and Ir. J. van Overeem working for Alkyon Hydraulic Consultancy & Research, the Netherlands for their valuable advice and help.