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A coastal conservation programme for the Chennai sea shore, India – A case study

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Abstract. The Chennai coast, an integral part of the east coast of India, extends over ca. 35 km. Over the past 120 yr the coastline has witnessed both man-made and natural disturbances which led to the destruction of the beach front. The construction of Madras harbour in 1876, was the prime cause of the degradation of this very sensitive coastal region. Continued growth of Madras harbour has helped in the natural formation of the wide 'Marina Beach', south of the harbour. But the shoreline north of the harbour suffered the consequences of harbour development activities. The north shore receded by ca. 500 m over the past 120 yr and received attention from the authorities in the past few decades because of the growing awareness of the conservation value of the coast. This paper highlights the effects of Madras harbour development on the adjoining coast and on the short-term mitigation measures planned and executed by the Government agencies to protect the fragile coastline. In spite of sincere efforts to protect the coastline, the destruction continues unabated due to various reasons. This paper analyses the facts and suggests a long-term solution to protect the coastline and to regain the past glory. Feasible and cost effective permanent measures are identified, construction methods suggested and the advantages that the community can derive from the long-term solutions are discussed.

Keywords: Coastal defence; Coastal erosion; Integrated approach; Reclamation.

Introduction

In recent years, the 11-km long Chennai coast, extending from the fishing port to the Ennore creek (Fig. 1), has witnessed an increase in industrial growth for (1) the exploration and exploitation of marine resources, and (2) the development of new harbour facilities to meet the demands of industries like thermal power stations, oil refineries etc. This industrial growth combined with harbour facilities has resulted in (a) migration of population towards coastal towns, (b) increased vehicular traffic along the coastal highway, and (c) changes in coastal dynamics.

The coastal stretch of interest experiences enormous sediment transport moved by the waves both during the northeast and the southeast monsoons and it is estimated that, in net, about 0.5 million m^3/yr of sediment is transported towards the north. Though the northeast monsoon lasts for a few months per year when compared to the southwest monsoon, the coastal deformations produced by the former are more damaging. For example, the coastal stretch of ca. 10 km north of the fishing port at Chennai, is repeatedly threatened during the northeast monsoon and as the process continues, the existence of a vital road link (the east coast highway) is challenged by the fury of the waves. It is estimated that an area of 260 ha of land has been lost between 1893 and 1955 and that an area of ca. 30 ha was destroyed by the sea between 1980 and 1989. Overall loss between 1893 and 1989 has been estimated to be in the order of 350 ha. The cost of land alone, lost to the sea, is of the order 40 million USD. The North Chennai coast has thus become volatile and is in need of immediate relief measures for the upkeep of the coastal region. In the recent past, reports on further recession of the shoreline have been received and in order to check the erosion, the Government of Tamil Nadu has spent a substantial sum for construction and implementation of short-term protective measure like a rubble mound seawall along short stretches. To highlight the effect of (1) environmental conditions, and (2) human activities by way of encroachment, a couple of examples is given to focus on the impact of the processes on the coastal zone and the conservation measures undertaken to protect the coast.

The necessity for an engineering solution

Although it is preferable to opt for a geomorphological or ecological solution for coastal conservation (Carter 1988), the Chennai coast has been taken-up as a case study where the need for an engineering solution is emphasized due to the following factors.

1. As non-uniform coastal protective measures adopted until now has deformed the shore characteristics, adopting a common geomorphological or ecological solution for the entire stretch of the coast is almost impossible.

2. Even if an attempt is made to adopt a geomorphological or ecological solution, it requires proper coordination amongst the implementing agencies followed by

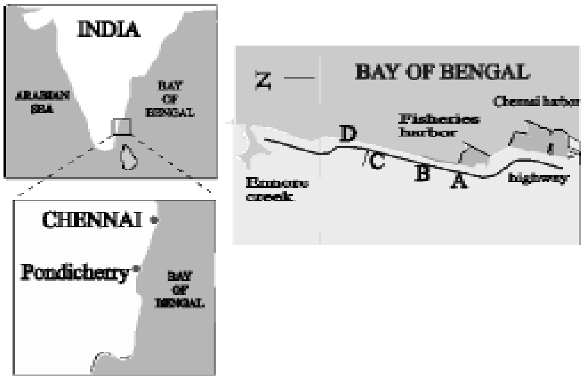

Fig. 1. The North Chennai coast.

(1) rigorous post monitoring of the coast to check the effectiveness of the solution, and (2) maintenance exercises.

This paper highlights the performance of the already implemented coastal protection measures and details on the need for an engineering solution towards an integrated long-term conservation programme. Further it is emphasized that the solution described in this paper is realistic as it is based on the success of a pilot scheme implemented by a private company (along its coastal front) on the advice of the author.

Coastal morphology and environmental parameters

The Chennai coast with an orientation of 15° to the north, is bestowed with a beautiful beach front on the southern side of the harbour. On the northern side, at a distance of ca. 50 km, the coastline has (1) a natural lake known as 'Pulicat Lake', and (2) widespread shoals in the nearshore region. The Chennai coast south of the above two exquisite features includes an inlet for a backwater, popularly known as 'Ennore creek'. The sea bed in the region had a gentle slope of 1:100 prior to the implementation of short-term protective measures and the introduction of a rubble seawall along the coast has caused considerable change in the sea-bed profile more specifically an increase in water depth along the seawall.

Monsoon regime and wave characteristics

The geographical position of the coast makes the region to experience the northeast monsoon between October and February and the southwest monsoon from May to September. The wind and wave conditions that prevail in deep water during the monsoons are summarized below.

Northeast monsoon:

Wind direction : 49-87°, relative to the North.
Wind speed: 5.8-7.5 m/s
Wave height: 2.5-3 m.
Wave direction: ca. 60° relative to the North.

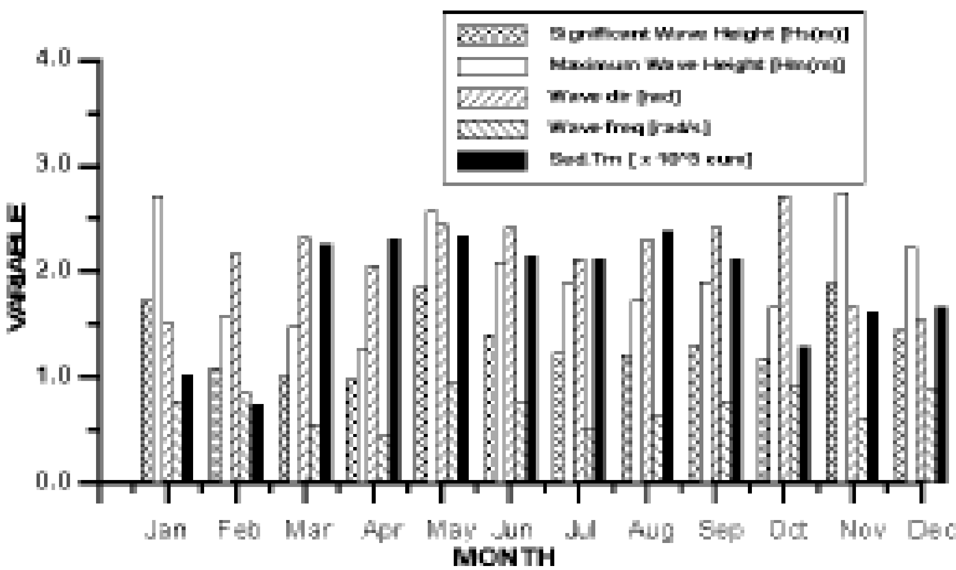

Fig. 2. Wave and sediment characteristics.

Southwest monsoon

Wind direction: 153 - 263 ° relative to the North.
Wind speed: 2 - 12 m/s
Wave height: 2 - 2.5 m.
Wave direction: about 135 ° relative to the North.

Typical monthly wave characteristics given in Fig. 2 indicate a maximum wave height of 2.5 m with a wave period of 6 sec during the southeast monsoon. These values are 3 m and 10 sec, respectively during the northeast monsoon.

Tides

Tides at Chennai are semi-diurnal with a maximum tidal range in the order of 1.4 m. Characteristics of the tide observed by the Chennai Port Trust suggested the following :

Highest High Water (H.H.W.)	1.50 m
Mean High Water Spring (M.H.W.S.)	1.10 m
Mean High Water Neap (M.H.W.N.)	0.80 m
Mean Sea Level (M.S.L.)	0.54 m
Mean Low Water Neap (M.L.W.N.)	0.40 m
Mean Low Water Spring (M.L.W.S.)	0.10 m

Littoral drift

A large quantity of sediments is supplied by the major rivers along the east coast and is constantly moved by the waves either towards the north or south depending on the angle of wave approach with respect to the coast. The rate of sediment transport varies from time to time along the coastal region. Analysis presented (Chandramohan et al. 1990) indicates that the transport is towards the north from March to October and towards the south from November to February. The transport rate during March-October varies between 0.5 and 1.5×10^5 m^3 per month. During November-February the rate varies from 0.5 to 2.5×10^5 m^3 per month. Northerly and southerly components of the annual sediment transport along the Chennai coast are estimated to be in the order of 0.89 and 0.60×10^6 m^3, respectively. This results in a net northerly drift of $0.3 \times 10^6 m^3$ per year. The volume of monthly sediment transport estimated on the basis of suspended load and bed load transport for the coastal region south of Madras harbour is given in Fig. 2.

Dredging at Chennai Harbour

Discussions with Chennai Port authorities revealed that at present, Chennai Port is undertaking maintenance dredging with two port dredgers viz. 'Pride' and 'Coleroon'. The working draft of Pride being 1.55 m with a hopper capacity of 300 m^3 is mainly assigned for the maintenance dredging of the inner harbour whereas the 'Coleroon' which has a hopper capacity of 650 m^3 and a loaded draft of 4.55 m is engaged for the maintenance dredging of the outer harbour since 1973. Both dredgers are capable of handling the dredging required to maintain the desired depths both at the berths and the approach channel. The quantity of material dredged from various parts of Chennai Harbour for the last 10 yr is given in Table 1. In addition, the table indicates the capital dredging carried out by the port over 1980-1991.

From the above information it is clear that the quantity of dredging by the afore-mentioned dredgers varied over the years with a peak value of ca. 2 million m^3 during 1987-1988. The quantity gradually got reduced and it stood at 0.48 million m^3 in the year 1994-1995 probably due to extension of the breakwater. The figures of dredging quantities provided by the Dredging Corporation of India indicate a variation between 0.27 million m^3 and 1.10 million m^3. It has been reported that the annual maintenance dredging at Chennai Port is in the order of 0.5 million m^3.

Madras harbour, North Chennai coast – a conflict

History reveals that in the year 1876 a jetty projecting into the sea was constructed at Chennai for the unloading of cargo. Later, breakwaters were constructed on either side of the jetty (with the harbour entrance located on the eastern side), to protect the facility from wave disturbance, without realising the effect of breakwater construction on sediment transport. Subsequently, the entrance to the harbour was shifted to the north and the harbour expanded further parallel to the coast for operational reasons.

Fig. 3 shows the present configuration of Madras Harbour and the growth of the beach on the southern side over the years. The North Chennai coast, extending from the fishing port (Fig. 1), is fragile and is very sensitive for change in the environmental conditions.

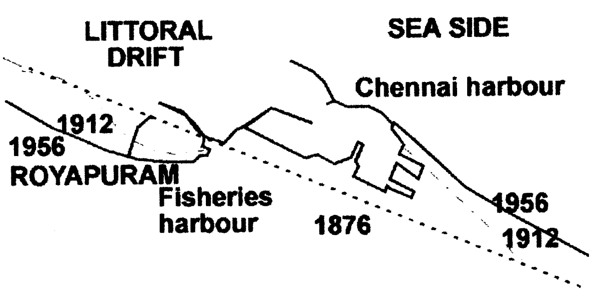

Fig. 3. Shoreline configuration at Chennai.

Table 1. Quantities of dredging at the Madras harbour.

Year	Maintenance dredging (million cu.m.)	Capital dredging (million cu.m.)
980-81	–	0.53
1986-87	1.45	0.50
1987-88	1.83	–
1988-89	0.71	1.10
1989-90	1.58	–
1990-91	0.98	0.27
1991-92	0.69	–
1992-93	0.84	–
1993-94	0.60	–
1994-95	0.48	–

This figure shows the locations of importance viz. fishing port (A), old highway (B), Ennore junction (C) and the temple (D). One of the main reasons for this delicate response of the coastal stretch is the disruption in sediment supply induced by Madras Harbour. Of late, the coast exhibits unpredictable behaviour especially during the northeast monsoon. Wave overtopping and undermining of the coast due to unprecedented wave activity have caused substantial damage to the highway, leading to its closure and diversion of coastal traffic.

Several consequences of the construction of Madras harbour on the North Chennai coast can be mentioned.
1. Coastal erosion. The shoreline has receded by about 500 m with respect to the original shoreline in 1876. In order to protect the coastline, authorities resorted to construction of short-term protective structures (Institute of Hydraulics and Hydrology, 1989) from position A to B (Fig. 1). A photo taken in the year 1990 (Fig. 4a) shows the construction of a seawall and a row of huts adjacent to the fishing port. Part of this protected coastal stretch experiences undermining of the sea bed due to large-scale wave action. The erosion along this coast has reached an alarming stage requiring immediate attention. (Kaliasundram et al. 1991). During and after 1990 this stretch of coastline was threatened by severe waves and the authorities resorted to new techniques involving the erection of concrete columns to protect the shoreline near location 'C' (Fig. 4b). At location 'D' a temple existed on a wide beautiful beach until 1990 (Fig. 4c).

The photo in Fig. 4d, taken in 1994, shows the effect of lines of columns on the coastline and the extent of erosion that took place between 1990 and 1994. The severity of coastal erosion is visible from the slow disappearance of the temple. It is estimated that ca. 50 m beach must have been lost during this period. Devastating wave overtopping and severe erosion led to the destruction of the coastal highway and compulsory rehabilitation of fishermen (about 200 families) to safer places. The photo in Fig. 4e, taken in 1998, shows the present situation in which the lines of columns stand isolated from the beach. The temple that existed until 1990 perished due to erosion illustrating the coastline's vulnerability to wave threat. A study reported by Ramaiyan et al. (1997) indicates that the shoreline receded by ca. 100 m between 1978 and 1995.
2. Damage to the coastal aquifer: The coastal erosion has contributed to the landward shift of the coastal aquifer which in the past was located very close to the shoreline. This has resulted in shortage of potable water along the coastal belt.
3. Threat to the coastal highway: The highway running at the edge of this weak coastline, faces the following natural and man-made threats.

(a) Large size waves continuously attack the seaside slope of the road resulting in (1) severe wave overtopping, and (2) damage to the highway. Slow disintegration of the bitumen surface of the highway allows sea water to seep through, a sure sign of the decay of the highway.

(b) This highly sensitive road also experiences large-scale vehicular movement (especially trucks laden with containers) due to the mushrooming regional container depots in recent years.

Though government agencies have been providing short-term protection to the coastline by dumping stones, these measures have been found to be ineffective for reasons that (1) the near-shore coastal processes in the region have not been clearly understood, (2) inadequate funds usually restrict the required quantity of rubble for the protection and maintenance, and (3) lack of continuous monitoring.

As the above aspects indicate the need for a long-term conservation plan which can relieve North Chennai coast from the present-day problems involving nominal maintenance, a long-term conservation programme is suggested, the details of which are as follows.

Long- term integrated coastal conservation plan

The following long-term integrated coastal conservation programme is suggested to protect the coastline. A perspective view of the coastal conservation plan is shown in Fig. 5. Fig. 6 gives the sectional view of the proposal.

1. Stagewise construction of a seawall parallel to the coast in a water depth of 2.0 m at a distance of ca. 150 m from the coast.

2. This seawall would commence from the north breakwater of the fishing port and extend for a distance of ca. 11 km. Stagewise extension of the seawall would not cause disturbance to the present coastline as this wall is defended by short-term protective measures.

3. For every 1 km length of the seawall, a 50 m long landing beach would be provided to enable fishermen

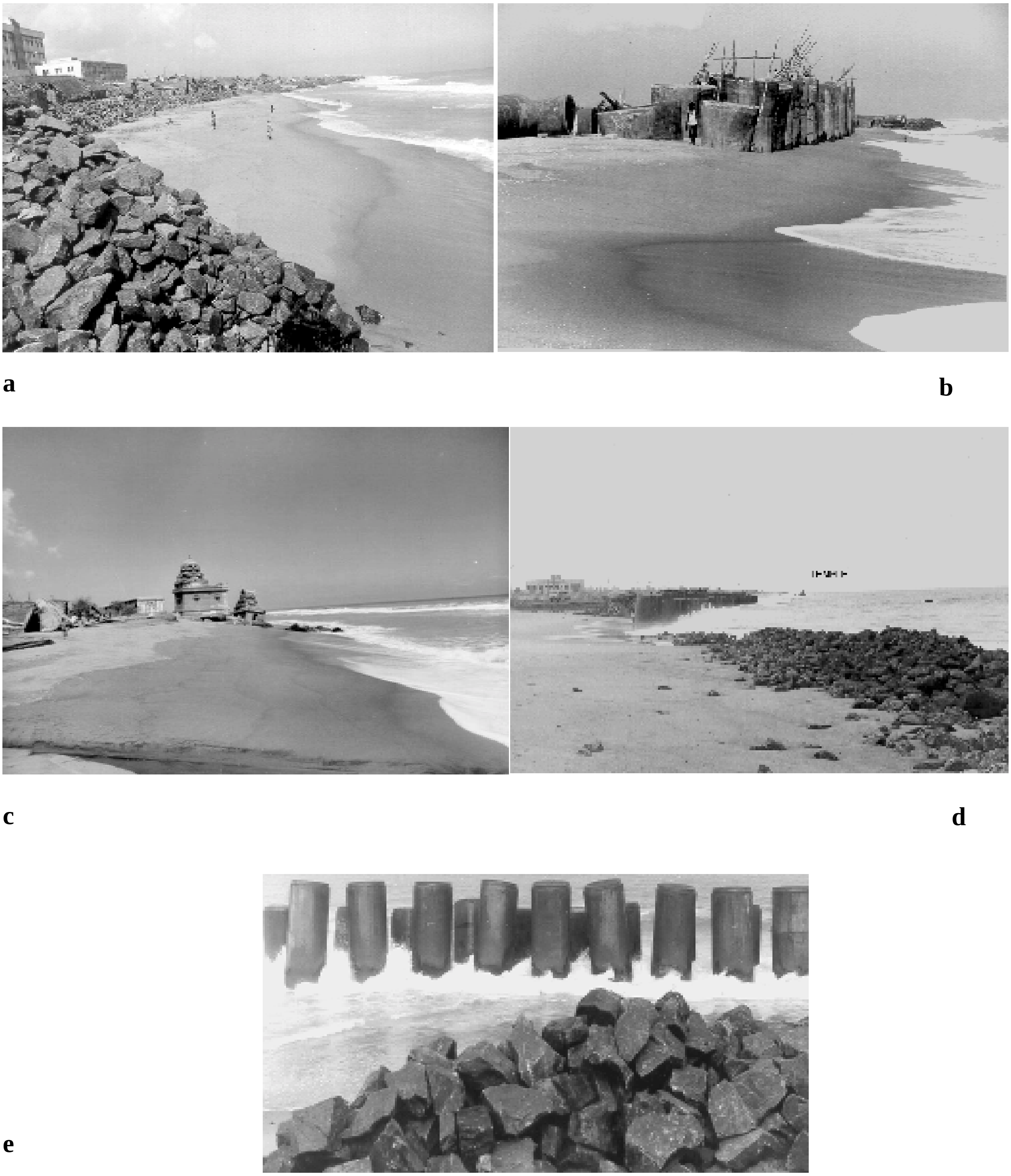

Fig. 4. Five pictures of Chennai Beach. **a.** Sea-wall construction prior to 1990. **b.** Erection of concrete pipes (1990). **c.** Temple and wide beach (1990). **d.** Extent of damage to the coast (1994). **e.** Concrete pipes isolated from the beach (1998).

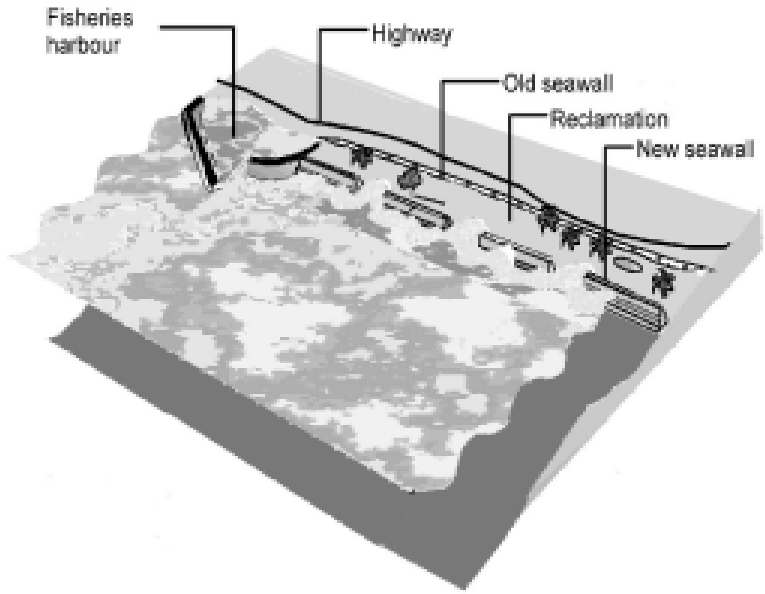

Fig. 5. Suggested land reclamation at Chennai coast.

and other users of the beach to have access to the sea.

4. The area between the new seawall and the present coast would be filled with the material dredged from the Madras Harbour during the annual maintenance to keep the channel and harbour basin open. If the dredge material is not found suitable for reclamation, the sediment trapped by the south breakwater of the satellite port located at ca. 15 km north of Madras Harbour can be utilized.

5. Special attention should be given to align the seawall on both sides of the landing beaches. This technique has been successfully implemented at the beach in front of a chemical industry at Chennai. Fig. 7 shows the details of the alignment of the seawall. This feature would enable

(a) partial arrest of littoral transport when waves approach the coast from northeastern and southeastern directions;

(b) reduction of the loss of reclamation material to the sea through the landing beaches.

6. Construction of the seawall and reclamation would be simultaneous and the procedure would be as follows.

(a) construct a seawall with natural rock for a length of 500 m and fill the backyard with dredge material to cover a length of about 250 m; a bottom opening barge can be employed for discharging the dredge spoil in the reclamation zone;

(b) extend the seawall to the site for the landing beach;

(c) ensure that the landward curvature for the seawall is provided at the commencement of the landing beach;

(d) for the proposed length of the landing beach, use sand bags as a temporary seawall to allow uninterrupted land reclamation activity;

(e) continue the construction of the rock-fill seawall beyond the sand bag seawall;

(f) once the construction of the seawall extends for a length of 1 km, the sand bags can be removed or punctured so as to facilitate wave action and to allow the natural formation of a bay;

(g) telescopic extension of the seawall and the reclamation until a total length of 11 km is covered;

(h) the dredge sand would be filled up to 2 m high.

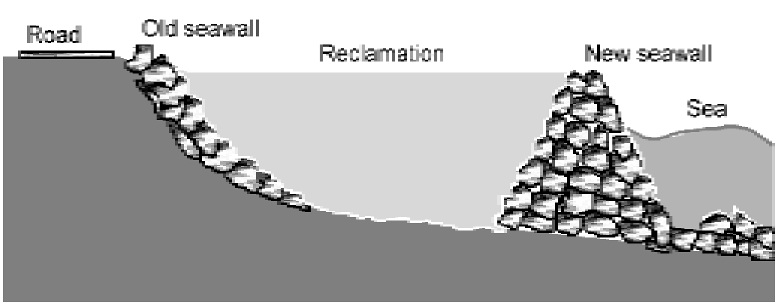

Fig. 6. Proposed seawall and reclamation.

Design and cost aspects

Fig. 8 shows the detailed dimensions of the seawall designed to withstand a wave height of 2.4 m with a period of 10 sec. Characteristic dimensions of the seawall, size of stone, fill material requirement, toe protection etc. are given below.

(1) diameter of the stone:	1.4 m
(2) weight of the armour stone:	3.5 t
(3) seaward slope of the seawall:	1 : 1.5
(4) leeward slope of the seawall:	1 : 1
(5) top width of the seawall:	1.5 m
(6) bottom width of the seawall:	11.5 m
(7) width of toe protection:	1 m
(8) size of geotextile	
(a) minimum pore size:	1.5 mm
(b) tensile strength:	> 3 t /m
(9) volume of sand:	4.4 million cu.m.
(10) volume of rubble:	0.264 million cu.m.
(11) sand gradation:	D_{85} = 0.4 mm
(12) reclamation area:	11 km × 150 m (1.65 million m^2)
(13) cost	
(a) seawall:	US $ 5 million
(b) sand:	US $ 5 million
(14) cost of reclaimed land:	6.06 USD/m^2.

Financial aspects

The project is expected to cost 10 million USD and the concept of ‘build, own and transfer’ can be adopted for successful completion of the project.

1. Foreign and local investors can be requested to invest in this development activity with an assurance from the Government body that a part of the land reclaimed would be given on lease to them for a period of ca. 30 yr.

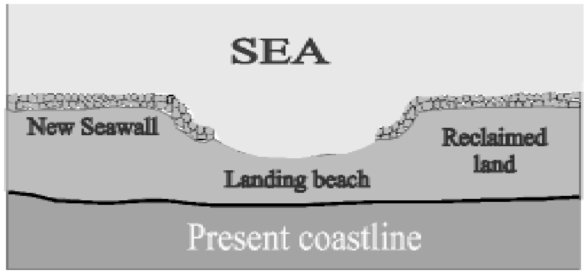

Fig. 7. Landing beach and seawall alignment.

2. The owner would be given permission to develop the reclaimed land as a tourist development area and other related activities which would fit in the coastal environment.

3. It would be ensured by the Government that except for the part of the land they own, the remaining area earmarked for fishermen and public would never be encroached.

Advantages

Advantages of the proposed conservation plan are as follows.

1. A minimum of 150 m wide coastal front can be retrieved.

2. A precious coastal highway would be saved from further deterioration.

3. The seawater ingression front would be pushed seaward enabling the coastal sweet water aquifer to recharge and provide drinking water to coastal inhabitants.

4. Increase in influx of tourists would generate additional revenue to the state.

5. Rehabilitation of native fishermen.

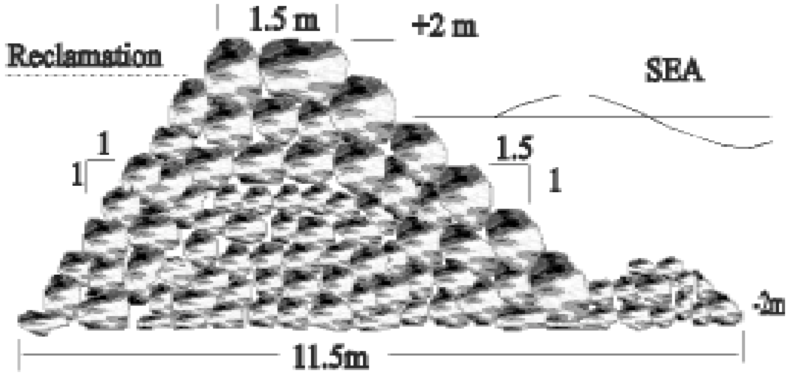

Fig. 8. Sectional details of the seawall.

Conclusions

1. An integrated coastal conservation programme would be a boon to the city of Chennai in terms of (1) additional land availability, (3) protection to the coast and the highway, (4) building of a new fishermen colony, (4) improvement to the ground water quality, (5) increase in revenue due to the inflow of tourists, and (6) low maintenance requirements.

2. The cost of reclaiming an area of 1.65 million m^2 would be ca. 10 million USD, implying that land development cost would be 6.06 USD/m^2.

3. The funds required for the proposal can be generated from promising foreign and local investors under the concept of 'build, own and transfer' of the reclaimed land.

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