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A Study on Developing Structural Measure for the Prevention of Coastal Erosion

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ABSTRACT

The impact of coastal erosion has adversely affected the socioeconomic conditions of the coastal community worldwide. The coastal environment is experiencing a wide range of natural and anthropogenic pressure in India. The coastal zone has been receiving increased attention due to pressure of population growth, developmental activities, trade and transport and presence of vital and critical habitats. Severe coastal erosion, loss of marine ecosystem, industrial pollution, sedimentations in harbours and portsare some of the major concerns to the coastal zone managers. Thus, the presented study identifies the effects of existing methods and suggesting an inventive structural measure to prevent the coastal erosion. Further, the suggested measure supports the development of marine ecosystem as intact as an artificial coral reef which improves the coastal community'slivelihoodsand sustenance of coastal ecosystem.

Key words: *Coastal area, Coastal erosion, Concrete ring ssegment, Ecosystem*

Introduction

Coastal areas are the interface or transaction areas between the sea and land. The coastal zones are most dynamic, fragile and productive ecosystem and are very often stressed due to both natural processes and anthropogenic activities. These coastal zones support large amount of floral and faunal biodiversity. The total coastline of the world is 3,56,000 km and therefore the 10% of earth surface is covered by the coastal area. Within 100 km of the shore, around 40% of the world's population lives. India has a coastline of 7517 km. Around 35% of population reside within 100 km of the country's shoreline (Coastal Zones of India 2012). Sea erosion affects a large portion of the country's coast. Coastal erosion has resulted in the loss of lives, precious natural coastal ecosystems, property as well as the destruction of important beaches and nearby coastal land utilized for living, agriculture and tourism. Coastal erosion is mostly caused by natural factors. The coastal zones come under immense pressure in many portions of the country as a consequence of elevated population density and coastal engineering (CWC 2003). On the other side, the extremely high sensitivity of coral reefs to warming, ocean acidification, increasing storm severity as a result of climate change, including increased bioerosionemphasises the importance of management of the coastal ecosystems (Bindoff *et al.,* 2019). The present study aims to suggest a sustainable solution to coastal erosion and also to develop the marine ecosystem.

Effects on Coastal Ecosystem due to Climate Change

Regional patterns and local manifestations of global scale changes determine the impacts on ocean ecosystem and human societies. Temperature, acidification, nutrient, salinity and oxygen concentrations in ocean are also expected to exhibit changes at the basin and local scale (Bindoff *et al.,* 2019). The rise in Global Mean Sea Level (GMSL) persuaded by melting glaciers and ice sheets, thermal expansion, and changes in land water storage is predominantly dependent on which Representative Concentration Pathway (RCP) emission scenario is applied. By the year 2100, GMSL will have risen between 0.43m and 0.84 m compared to 1986-2005. Due to the expected GMSL rise, unusual extreme sea levels will become consistent by 2100 under all RCPs. By the year 2050, many low-lying cities and tiny islands at most latitudes will be subjected to such incidents on a yearly basis is represented in Figure 1 (Oppenheimer *et al.,* 2019). These inputs present an overview of depletion of marine ecosystem and rise in the global mean sea level which is considered on the new approach in coastal protection in order to recommend proper solution for the coastal problems.

Characteristics of Indian Coastline

India has a coastline that stretches for over 7500 km, with around 3000 km on the west coast, 2700 km on the east coast, and remains along with the coastlines of Lakshadweep and the Andaman group of islands. The west coast of India has a flatter slope (1:500 to 1:1000) than the east coast (1:100 to 1:150). Due to typical meteorological conditions in oceans, numerous storms occur on India's east and west coasts each year, mainly during April to June and October to January. The frequency of cyclones on the west coast is minimal (approximately 2 per year), but cyclones are more common on the east coast (about 5 per year) (Kudale, 2015). These characteristics are considered while planning for new structure. The following are some of the most notable characteristics of the Indian coast in Table 1.

Coastal Erosion

The beach is eroded when the amount of material removed by the breaking waves along its shore for deposition elsewhere exceeds rate of supply. As a result, the shoreline pushes landward. Only the magnitude and nature of erosion may vary from location to location (Shareef, 2007). The erosion observed throughout the majority of the Indian coast is seasonal in character, that is, the beach erodes during the monsoon season and returns to its previous profile during the fair-weather season. However, in certain areas, erosion is permanent (CWC, 2003). The erosion of the shoreline is mostly caused by the two factors, which are outlined below:

(i) Erosion caused by natural phenomena.

(ii) Erosion caused by human intervention.

The coastline erodes as a result of different hydrodynamic effects of ocean phenomena such as, tides, ocean currents, waves, sediment deficit and deflation. This hydrodynamic action generates significant sediment movement, resulting in changes in morphology of the coast. The wave is one of the primary drivers of erosion and accretion along the coastline. Beach erosion occurs as a consequence of unplanned development of structures in the coastal zone. Ma-

Fig. 1. The Projected Sea Level Rise

rine resources are being depleted as a direct outcome of numerous services, tourism, and residences along the shore. The main causes of erosion generated by nature and human are outlined in Table 2.

Impact of Coastal erosion on Coastal Communities

Coastal erosion is accompanied by landward retreat of the shoreline and land area loss. It is a widespread alarming issue for all coastal communities. Rising mean and high sea levels endanger coastal communities including, (i) The persistent land submergence due to rising mean high tides or mean sea levels; (ii) Increase in the frequency or intensity of coastal flooding; (iii) Enhanced coastal flooding (iv) Coastal ecosystem loss and alteration; (v) Salination of groundwater, surface water and soils; (vi) Obstructed drainage (Diwakarnair 2005).

Existing Coastal Protection Measures

There are two types of coastal erosion protection measures: structural measures and non-structural measures (Cai *et al.*, 2009). These measures are intended for protecting the coast and beach from the forces of waves, storm surge, currents and flooding. Non-structural solutions include land-use restrictions, the establishment of warning lines such as the coastal setback line and the coastal construction control line to safeguard the shore from improper development and the banning of unreasonable sand mining and reclamation (Masria *et al.*, 2015). Coastal protection structures are categorised into four types: hard structures, soft structures, combination structures and new innovation structures. Shoreline erosion and retreat are reduced or prevented by hard-engineering structures (Cooper *et al.*, 2008). They are successful on small scale (Airoldi *et al*., 2005). There are various kinds of hard structures like as Seawalls, revetments, bulkhead, dikes and levees, groins, breakwaters, jetties and the soft measures includes beach fills, dredging or sand bypassing, sand dunes stabilizationand also the combined protection works may consists of submerged breakwaters, perched beaches and artificial headlands.

Impacts of Coastal Protection Structures

The major steps to conserve India's coastline is seawalls and groins. Due to heavy waves seawalls become unstable. Seawalls prevent erosion where they are built, but they do not prevent offshore erosion (Sannasiraj, 2006). Influence on neighbouring coastlines may become undesirable to some extent. Groins are constructed perpendicular or inclined to the pre-project shoreline as shown in Figure 2. The consequence of the single groin is beach material accumulation on updrift side and erosion on the downdrift side, both which occurs some distance from the structure. Groins does little to address the lack of sediment supply, which affects not only the surf zone but also the offshore region. As a result, erosion continues beyond these structures, and the bed deepens and steepens. The employment of single groin to protect the shore is frequently ineffi-

Table 1. Characteristics of the Indian coast

West Coast	East Coast
Arabian Sea	Bay of Bengal
Tidal range: 1 to 6m	Tidal range: 1 to 1.5m
Strong tidal currents	Weak tidal currents
Southwest monsoon: May to September	Two monsoons: Southwest (May to September) and Northwest (October to January)
Only two major rivers meet Arabian Sea	Almost all rivers meet the Bay of Bengal: high source of sediment
Littoral drift negligible	Large littoral drift
Bed material: Clay, Silty-Clay	Bed material: Fine sand

Table 2. The Main Causes of Beach Erosion

Natural Phenomena	Human Intervention
Tidal current	Unplanned reclamation
Rise in the sea level	Removal of sand from beaches
Action of breaking waves	Construction of unplanned structures
Deflation	Dredging of inlet channels

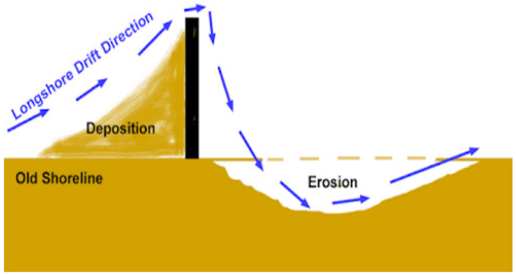

Fig. 2. Mechanism of Coastal Erosion

cient. Under the following conditions, groins may not perform well and should not be considered: (i) When a wide tidal range allows for excessive bypassing at low tide and overpassing at high tide. (ii) When the structure is excessively lengthy or impermeable, causing sand to be blown to sea. (iii) Where cross-shore sediment transport is major factor (CWC 2003). Groins can slow or stop coastal erosion, but not if offshore erosion persists. The impact on nearby coastlines is negative, and often terrible shown in Figure 3.

Fig. 3. Impact of Coastal Protection Structures

Proposed Methodology-concrete Ring Segment

The present study has suggested the innovative approaches for effective coastal protection as an alternative to traditional structures like groins. The design is proposed by considering the characteristics of Indian coastline. The west coast of India is almost straight with an overall concavity towards the sea. So, this coastal region is experiencing erosion due to flow of current from west to east, east to west and south to north direction across the year. To stop these three directional currents a new structure named 'Concrete Ring Segment for Coastal Erosion' is developed as shown in Figure 4. Which may stop the erosion in the Indian shoreline. To develop this structure a required number of circular breakwaters are placed in a semi-circular pattern in 60 m away from the seashore with specific space between the breakwaters and it should be also provided with seawall in the coast for more protection. This new structure partially obstructs the high penetrating waves. So, the frequency of the waves should be reduced partially. Because of this partial obstruction the nearby coasts are not affected by erosion.

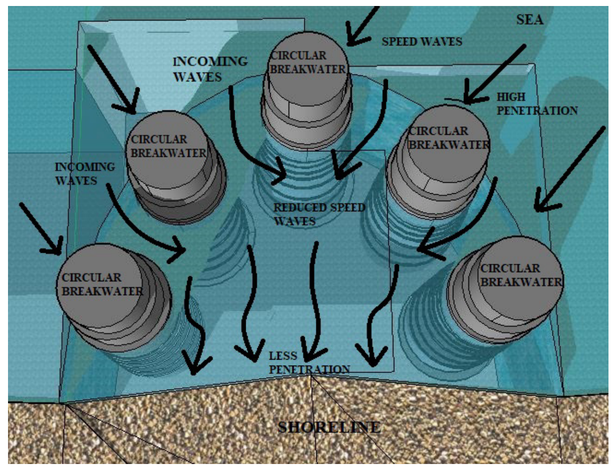

Fig. 4. The Proposed Concrete Ring Segment

Constructional Approach

For constructing the proposed design, utilizing the construction debris will prevent the usage of virgin construction material and redundant dumping which ensures the sustainable material management (Sampathkumar *et al.,* 2014). Concrete has proven high success rate as an artificial reef material in both marine and estuarine environments, whether in fabricated units specifically designed for artificial reefs or in imperfect concrete manufactured products such as rubble or culvert from demolished buildings, sidewalks, bridges, and roadways. The evident reason for this high success rate is the material's good compatibility with the environment in which it is placed for which it is deployed. In reef applications, concrete is often exceedingly robust and stable. Portland cement is mostly composed of lime, a component of limestone. Limestone is mostly composed of calcium carbonate, which is the component from which coral reefs are formed. Concrete materials are particularly suitable for use in the marine environment. Concrete is extremely long-lasting, stable and widely available.Concrete provides great surfaces and habitat for encrusting or fouling creatures, which in turn provide forage and refuge for other invertebrates and fish (Artificial Reef Subcommittee, 2004).

Conclusion

The proposed structure for coastal protection has been designedbased on the principle of diffusing wave energy and protecting the shoreline. This unique solution is developed by considering the site conditions andpotential environmental and economic constraints. The construction of proposed design is considered asan affordable and efficient, since it dissipates natural strong wave forceswhich aids in the nourishment or reclamation of fresh land, thereby reducing the rate of coastal erosion significantly. At the same time the developed structure will also act as artificial reef where the marine species occupy those spaces and starts its breeding. As a result, the concrete ring segments will act not only as an energy dissipaters but provide the protection for the onshore seawalls. Further, the proposed design concept can be put forward for experimental analysis by considering the real time environmental and economic constraints which will paves the way for safeguarding India's coastal profile and related ecosystem.

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