Strategic Alternatives For Coastal Protection: Multipurpose Submerged Reefs

11th Meeting of the Coastal Protection and Development Advisory Committee (CPDAC)

Chennai, 4th January, 2010

Dr. Joseph Mathew, ADB Consultant  
jmathew200@gmail.com  Mob: 09446125731
Save India’s Beaches

In the News

**New coastal policy threatens beaches**
The livelihood of the fishermen and an entire stretch of coastline in Tamil Nadu is under threat.

**New Chennai bridge displeases ecologists**
If the Tamil Nadu government has its way, Chennai could have an elevated corridor from the Light House to the East Coast Road.

**India’s dying beaches**
A study conducted recently by the National Institute of Oceanography, Goa, says that 23 per cent of India’s shoreline is getting eroded.

**The death of India’s beaches**
It’s being called one of the biggest disasters India’s environment is facing. Our beautiful beaches are being killed.

**Gujarat’s mangroves under threat**
Gujarat, the state which has India’s longest coastline is home to one of the country’s largest ports and special economic zone.
Coastal erosion: Indian scenario

(National Coastal Protection Project Proposal)

• About 1380 km of Indian coastline (excluding Andaman and Nicobar Islands), faces serious impact, i.e. 25% of the 5,550 km

• Most of the impact zones are actively retreating, some of them in spite of coastal protection works.

• About 625 km of the coastline are protected by hard structures (seawall or groyne)

• Another 728 km is in need of protection

• Amount spent for coastal protection so far is over Rs. 400 crores

• Annual loss due to coastal erosion is estimated to be over Rs 575 crores

• Area lost or seriously impacted by erosion is estimated to be about 450 Ha per year
Coastal Erosion Status

- Andhra Pradesh
- Goa
- Gujarat
- Karnataka
- Kerala
- Maharashtra
- Orissa
- Tamil Nadu
- West Bengal
- Pondicherry
- Lakshadweep

Data source: Central Water Commission

Coastline length (km)
- Total length of the coastline
- Eroding coastline
- Artificially protected coastline
SAVE BEACHES
HELP PEOPLE
The List: Coastal Protection Options

‘Traditional’
- Seawalls
- Groynes
- Bulkheads
- Detached Breakwaters

‘Modern’
- Dune Restoration
- Submerged Breakwaters/Reefs
- Nourishment
- Bypassing/Circulation
- Hybrid Solutions

“What’s driving the changes in preference to coastal protection options?

Values
- Amenity
- Aesthetics
- Understanding
- Economics
- Sustainability
- Legislation
Figure 1.2 Progressive erosion scenario for defended coasts. As more defences are added to prevent erosion, so focus of that erosion is transferred along coast (After French 1997).
Figure 3.2 Typical end effects (terminal scour) associated with a sea wall. Note the scour which removes support from end of structure and leads to undermining at end of wall.
Groynes - Function

Are effective where alongshore sediment transport is dominant

Function by ‘trapping’ sediment moving along the coast – they mimic natural headlands
Groynes

Downcoast impacts can be reduced by continuous groyne-fields within a littoral cell or decreasing consecutive groyne length, ‘tapering’.

Poole Bay, England – 60 groynes in 19 miles

Can impact negatively on swimming safety, aesthetic and alongshore beach access

Are ineffective at preventing cross-shore sediment transport and can increase the loss of beach sand.
Loss offshore by rips

Overspill into next groyne compartment

Scour

Poor retention

Too small

Correct

Too large
Impacts of jetties on sediment budget

- Reduced accretion in estuary due to dredging and intertidal adjustment.
- Increased erosion down drift of jetty. Reworking of temporary stores (beach) and mobilisation down drift.
- Loss of estuarine sediment to offshore stores. Also, permanent loss of dredgings.
- Increased sediment accumulation. Sediments into temporary store due to interruption of longshore drift.
Erosion on the northern side of Chennai fishing harbour

Accretion on the southern side of Chennai port (Marina beach)

Source: ICMAM, Chennai
- An area of 350 hectares of land lost between 1893 and 1989

- The shoreline receded by about 100 m between 1978 and 1995.

Source: ICMAM, Chennai
Traditional Coastal Protection Methods:

Seawalls, Groynes, ..

- Address the **effects of erosion and not the cause**
- “Hold the line” approach
Common problems with coastal protection

- Interruption of sediment supply
- Interference with natural processes
- Lack of understanding of how coastal processes work – including processes relating to post-construction

Need to Consider:

- Benefit : Loss Approach (Sediment Budget)
- Habitat creation
- Integrating all aspects of coastal use into one management plan
Generalised coastal sediment budget (from French, 2001)
Nature’s way. Offshore reefs naturally protect the coast.
Natural Examples of Submerged Reefs

Maine, USA

Lots of land forward of the yellow line

Reef well offshore
Salients
Natural Examples of Submerged Reefs
Budgewoi, Australia

The beach is always the best beach protection.
Multi-Purpose Reefs:
A Technology Inspired by Nature

- Coastal Protection
- Ecology Enhancement
- Recreational Benefits
Multi-purpose Offshore Reefs

What is a multi-purpose reef?

- A multi-purpose mound on the seabed
- Constructed offshore
- Mimics nature
- Multiple benefits
One reef of 100 m protects 400-600 m of coast

If the principle was too complicated, there wouldn’t be 1000’s of natural salient examples
Wave rotated to stop longshore drift

Salient

600 m

One reef of 100 m protects 400-600 m of coast
Side view of the principle

- Sand retained on beach face.
- Reduced wave height inshore.
- Waves break on offshore reef.

REEF
Prediction of Shoreline Response

Black & Andrews (2001a,b)

\[
y = -0.052 + \left( \frac{1.317}{1 + \exp\left( \frac{\chi' - 0.356 \ln\left( \frac{1}{2^{0.356}} - 1\right) - 2.249}{0.356} \right)} \right)^{0.356}
\]
Reef design criteria

- Distance offshore
- Depth of the reef crest
- Placement around natural depths
- Reef length
- Reef width
- Length/width ratio
- Orientation
- Refraction/diffraction character
- Induced currents
Automated HydroCamel water samplers

Scientific measurements
Beach experiments
Site specific design
20,000 m³/yr of littoral drift sand heading east

Beach alignment changed to match the waves. Benefit felt in front of existing houses.

Waves out of alignment with existing beach. Sand pushed east.

20,000 m³/yr of littoral drift sand heading east
Case Study: Gold Coast Reef, Australia

- Major initiative in Queensland
- Won the prestigious State Environmental Award
- Monitoring of beach with Argus has confirmed that the reef has met the coastal protection expectations
- Designed to improve the surfing.
- Marine ecology is greatly enhanced
Gold Coast Reef goals

The specific sedimentation criteria for the Gold Coast Reef were:

- Provide a coastal control point to assist the maintenance of the widened beaches at Surfers Paradice
- No more than approximately 80,000 m$^3$yr$^{-1}$ of re-nourishment should be needed on the downstream (northern) side of the reef
- Beach adjustment should cause minimal impact on adjacent beaches.

Thus, the reef was designed to “leak sand” and was never meant to totally eliminate maintenance dredging at Surfer’s Paradise. As such, beach erosion at Surfers was anticipated to continue occurring but the reef was meant to slow the losses.
Shoreline response is evident.

Surfers use the reef on every swell.

Outcomes are very similar to predictions.

Diverse biology living on the reef.

Engineering and construction have gone really well.
Aerial view of Boscombe Reef (UK) under construction – June 2009

Boscombe Surf Reef (at low tide)  August 2009
Precedents

Gold Coast

Mt Maunganui

Dominican Republic
Multi-purpose offshore soft reefs: An option that actually improves the beach

- Beach protection
- Wider beach
- Reduced storm surge and flooding
- Improved ecology
- Improved property values
- Better economic returns for the community
- Healthy sporting activities
- Safer swimming
Set up in the lee of reefs

Wave height

Sea level

Storm surge much smaller
The ADB technical assistance (TA) project:

“Sustainable Coastal Protection and Management”

- Participating states:
  - Karnartaka, Goa, Maharashtra
ULLAL COASTAL EROSION AND INLET IMPROVEMENT PROJECT
The Proposed Project

- Ullal beach in southern Karnataka has suffered from serious erosion over several decades
- The local people are under severe attack from waves
- Many houses have been lost to the south of the breakwater of the old Mangalore port.
- Currently a large area is threatened by waves flooding year round and under severe threat during the monsoon.
• Northern beaches were vulnerable to erosion (1970s)

• Sedimentation in channels and boat capsizing

• Breakwater constructed (1991-94) to prevent sediment entering the estuary

• North breakwater : 375 m

• South breakwater : 580 m

• Entrance : 500 m

Navigation channel draft : 4 m
But Bar only 1-2 m deep
India West Coast

“Rock wall has led to deepening offshore also

On the side of good

On the side of evil
Monsoon Peak Ebb Velocity and Depth (ENTRANCE)

Currents decelerate rapidly beyond the ebb shield, dropping sand and forming the bar.
Understanding using models
Detailed investigations based on field and numerical model studies have revealed that Ullal Beach is eroding for two key reasons:

- The alignment of the beach is not in equilibrium with the wave climate, with extremely large amounts of sand being lost to the south each year.

- Insufficient sand is being provided from the northern beaches and the river, due to several factors including:
  - the northern bias in the alignment of the breakwater.
A 10 year record of waves from the NOAA WW3 wave model showing directionally binned significant wave height and directionally binned peak period.
Wave transformation studies: Significant wave height and peak wave direction

Monsoon
10-Jun-2005

Non-Monsoon
01-Oct-2005
Recommended solution

A hybrid solution was proposed to address the Ullal erosion problem:

- Altered north breakwater to ensure that sand coming from the river is driven south and that natural by-passing occurs more effectively.

- Re-alignment of the Ullal Beach to face more directly into the waves, and thereby stop the large quantity of sand moving south and being lost from the beaches.

- Nourishment of the beach to “catch up” on the long history of erosion and sediment loss.

- Construction of two offshore multi-purpose artificial submerged reefs (M-ASR’s) and four nearshore berms to hold the nourishment in place.
Erosion management options at Ullal

Natural Sediment bypassing

Offshore submerged reefs
Breakwater realignment:
Proposed changes to the breakwater. The north breakwater is extended across the channel by 200 m. The south breakwater is being shortened by 150 m.
BEACH NOURISHMENT

- To nourish the beach (450,000 m³) and fill the geotextile containers (70,000 m³) will be sourced from the shoals that exist in the Ullal Inlet and Netravati river bed.

- A layer of 1 m of sediment will be removed over the channels.
Ullal offshore reefs:
Two offshore reefs in combination with four nearshore berms constructed of sand filled geotextile containers to dissipate incoming wave energy and stabilise the beach nourishment placed on shore.
The volume of the reef is governed by several key factors:

**Cross-shore width of the reef:** If the reef is too narrow the waves don’t have sufficient time to shoal and properly break. If the reef is too wide, then volume is wasted unnecessarily.

**Longshore length of the reef:** The model tests have shown that the reef needs to have a minimum length of about 250 m to provide effective coastal protection.

**Crest elevation:** The crest height has been set to 1 m above Chart Datum which has been shown by laboratory tests and similar other projects and present modelling.

**Sinkage and pancake:** A geomat will be placed under the reef to prevent individual bags from sinking. It is essential to allow a minimum of 0.5 m for sinkage and “pancake” filling of the bags.

**Compression of sand:** Under the very high compression forces the grains are forced into each other.

To achieve the coastal protection goals, the optimum reef volume is selected.
Offshore reefs provide a high level of shoreline protection by:

- blocking the wave energy from a wide variety of directions, and
- re-orienting the waves and thereby minimize or negate the longshore currents.

The reefs are placed well offshore to get maximum benefit by creating wide shadow zones.
Local Example
Shipwreck salient
North of Ullal entrance

Ship = 192 m
Salient = 1100 m
Ratio of reef/protection = 5.2
Distance offshore = 360 m
Salient amplitude = 115 m
Ullal South Geotextile Reef, Karnataka

Reef Bag Layout

Bag Layout - South Reef

<table>
<thead>
<tr>
<th>Fig. No.</th>
<th>Reef Layout</th>
<th>Date</th>
<th>Designed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>06/10/2009</td>
<td></td>
</tr>
</tbody>
</table>
Cross-Section B-A

Ullal South Geotextile Reef, Karnataka

Reef Cross-Section A-B
Maharashtra sub-project site: Mirya Bay
Mirya Bay - Present Problem

The prime causes of erosion include:

• Sand is being trapped in the fishing port

• Dredged sand from the port is being placed on land, rather than being put back to the bay.

• The beach which originally provided coastal protection is now degraded due to the lack of sand supply and offers virtually no protection.
Mirkarwada Fishing Harbour - Mirya Bay

TRAPPING OF SAND IN THE HARBOUR

Western Breakwater

Sediment trap

Northern breakwater

Dredged material
Mirya Bay  Fishery Harbour : Stage II Expansion
Mirya Bay: Wind driven currents

Monsoon

Non-Monsoon
Mirya: Recommended management options
Coco Beach, Goa
Coco Beach
Colva Beach M-ASR
No impact on adjacent beaches

Submerged reef
Solving Problems by Restoring Dunes
Motiti Road, Papamoa East

June 1997
Dune front erosion had been problematic for decades. In 1978 the BOP Catchment Commission advised residents there were no simple or cheap answers to address their erosion concerns at Papamoa East. Photo: Elco Solutions Pvt Ltd.

March 2004
Inexpensive planting of native dune species has re-created an accreting front dune, by Papamoa Coast Care helping to solve the erosion problems. This photo was taken the day after the impact of 10m waves from Cyclone Ivy.
majorda plan

Nalla Training using Geotextile bags see cross section
Kovalam Multi-purpose Reef

Kovalam – Wave climate.
Two swell directions at all times
Beach much narrower at the north in monsoon. Bay eroded.
Kovalam – 2DBEACH

Erodes in monsoon in the north

Accretes in monsoon in the south

Need to know what are the processes
Kovalam – 2DBEACH

2DBEACH explains the beach dynamics

Erosion North

Accretion South
Kovalam – 2DBEACH
Kovalam – The reason for erosion

Sand lost from beach
Kovalam Reef – site specific solution

3-D representation of the geocontainers layout to be used

Preferred reef option

Light House

38 m

110 m

y (m)
x (m)
Kovalam – Currents reversed
The reef consists of 4 sections
Reef Construction
Reef construction using geotextile

Important considerations when designing with geosynthetics in coastal applications include:

- UV Resistance
- Abrasion Resistance
- Damage Resistance
- Fines Retention
- Permeability
- Seam Strength

Selected material: Nonwoven, Staple Fibre Geotextile
Woven and non-woven geotextiles

(A) Thermally-bonded nonwovens
(B) Mechanically-bonded nonwovens
(C) Specialist wovens/monofilaments
(D) Meshes
(E) Woven polypropylene
(F) Woven polyester
Relative sizes of submerged reefs built from geotextile containers

A Pratte’s Reef bag.

A VW Kombi and driver.

A typical city bus.

A sand-filled ‘megacontainer’.
When applying geosystems, the major design considerations/problems are related to the integrity of the units during release and impact (impact resistance, seam strength, burst, abrasion, durability etc.), the accuracy of placement on the bottom and the stability.

When applying this technology the manufacturer's specifications should be followed. The installation needs an experienced contractor or an experienced supervision.
MEGA SANDBAG FILLING PROCEDURE FOR ARTIFICIAL REEFS

1. PUMPING SAND INTO TERRAFIX MEGA BAG
   - Typical bag: 20m x 20m x 2m deep, approximately 500 tonnes at
   - Terrafix action

2. BAG FULL OF SAND

3. OPEN HOPPER TO DROP BAG

4. BAG DROPPED

INTERNATIONAL COASTAL MANAGEMENT

SPLIT HULL HOPPER DREDGE FILLING SANDBAG
RAD Method, Mount Reef, New Zealand
In-situ Sand-filling Containers

- From dredge
- Inlet sleeve
- Fill material
- ~ 15m between ports
- 5m
- ~ 4.5m as required
Take a Balanced Approach

- Understand the Site for a site-specific design
- Make a preliminary Selection of Options that will ‘work’ at the site
- Aim to address the causes of erosion not the effects
- Evaluate all factors to determine the best option(s)
- Use technical tools (mathematical and physical models) because the beach is complex
- Consider the social and environmental impacts
- Protect the beach and the land - not just the land
- Coastal protection is a national issue applied at local level
Save Beaches

collage of images of people on the beach

help people