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Coastal Erosion and Its Prevention along the Coast of Goa: A Field Survey of Ten Beaches

Chaitanyaraj, Abhishek, Shritej Savant & Prof. Priyanka Shinde
Department of Civil Engineering, Jain College of Engineering, Belagavi, Karnataka, India
chaitanyaraj.jce@gmail.com, abhishek.jce@gmail.com, shritejsavant@gmail.com, priyanka22jce@gmail.com

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Abstract—
Until the 1970s the Goan coast was largely unspoilt, but tourism, population growth and construction have since crowded the shore. This paper reports a field survey of ten beaches in North Goa, Miramar, Candolim, Calangute, Anjuna, Morjim, Mandrem, Arambol, Querim, Ashwem and Vainguinim, which recorded the state of each beach, the protection measures in place and how they performed, from site visits and conversations with local residents. Erosion was reported at seven of the ten beaches. Hard structures failed or performed poorly at several sites: the seawall at Miramar was damaged by wave pressure, and the geotubes at Candolim burst. The beaches that were stable had vegetation and dunes that were left in place. The study is observational and has no measured shoreline-change data, so its findings are qualitative.

Index Terms—coastal erosion, Goa, seawall, geotube, beach nourishment, sand dunes, coastal protection.

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I. Introduction

The coast is one of the most fragile ecosystems because land, sea and air meet there. Geological, hydrodynamic, biological, climatic and human factors all change it. India has a coastline of over 7,500 km, of which about 3,000 km lies on the west coast facing the Arabian Sea, and Goa, the smallest Indian state, draws large numbers of tourists to its beaches.

Coastal erosion is the removal of material from the coast because the supply and export of sediment are out of balance under waves, tidal currents or human activity, which usually makes the shoreline retreat. Waves, tides, ocean currents, sediment shortage and wind are the natural causes. Wave breaking stirs up bed material and sets it moving along the shore as littoral drift. Where removal and deposition are about equal the beach is stable, and when external causes upset the balance it erodes or builds up. Human causes include unplanned construction in the coastal zone, reclamation of inlets and removal of beach sand for construction.

Erosion removes the sediment that protects the coastal ecosystem, weakens the soil and rock along the shore, can cause loss or submergence of land, and puts flora, fauna and coastal infrastructure at risk. This paper surveys ten beaches in Goa to see how erosion appears at each, which protection measures have been used, and how they have worked.

II. Literature Review

Łabuz [1] describes the growing threat of wind, waves, storm surges, ice and flooding on the Baltic coast under climate change. Van Rijn [2] uses the coastal cell concept to analyse sediment volumes, separates chronic from episodic erosion, and assesses soft and hard remedial measures for sandy beaches. Hari Prasad [3] reviews the erosion process, the parameters that affect it and the methods used to identify it, and Nehra [4] reviews its causes and impacts, noting that piers and harbours can add to erosion. Williams [5] lists the standard responses, which are hold or advance the line, accommodation, managed retreat and sacrifice, and stresses setback lines and shoreline management plans. Thampanya *et al.* [6] found that eroded areas increased with shrimp farms, with longer fetch to the monsoon, and where dams cut river inputs, and that mangroves on the east coast had fallen to about half over three decades.

Many Indian studies measure shoreline change with remote sensing and GIS [7]–[9], and similar methods have been used abroad [10], [11]. Vulnerability mapping [12] and numerical models of waves and sand transport [13], [14] are other approaches. The present work does not measure shoreline change and instead records conditions and measures on the ground.

III. Study Area

Goa lies on the south-western coast of India, between latitudes 14°53′54″ N and 15°40′00″ N and longitudes 73°40′33″ E and 74°20′13″ E, with a coastline of about 100 km. Its open coast is a mixture of beaches, rocky shores and headlands. Linear sandy beaches lie between the headlands and are 50–180 m wide. More than 70 km of the coast is sandy and is backed by dunes 1–10 m high that extend about half a kilometre or more inland. Seven major estuarine rivers and four minor river systems cross the coastal zone, and mangroves line most of them. Tides raise and lower the water in the rivers and backwaters by 2–3 m daily.

IV. Methodology

Two kinds of data were collected. In the personal survey the team visited each beach, recorded the protection measures and the state of the shore, and spoke to residents and to the people who run the beach shacks. The second source was published papers, news articles and government sources. Sand-dune areas and dimensions at Candolim, Calangute and Morjim were taken

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from the study by the NCSCM [15]. No instruments were used, so the distances from shoreline to land given below are the values noted in the survey.

V. Coastal Protection Methods

Methods are classed as soft or hard. Soft solutions add or protect natural material. They include artificial beach nourishment, in which sand is added to the existing beach, and planting of vegetation, which stabilises dunes and reduces wind loss of sediment. Hard solutions are structures. Seawalls are massive structures parallel to the shore and are prone to damage by scour at the toe. Revetments are sloped to match the shore profile and face smaller wave attack. Bulkheads retain land and dikes prevent flooding.

Other structures trap sediment. Groynes are built in series perpendicular to the shore and interrupt longshore drift, but they may cause erosion down-drift. Offshore breakwaters are built parallel to the shore and break the waves before they arrive. Artificial reefs and sills are submerged and trap sand. Combining nourishment with such structures keeps the sand in place and avoids repeated refilling, and its cost depends largely on the availability of suitable sand. Other options are mild-slope seawalls with dissipating armour blocks, which reflect less wave energy and reduce toe scour, and beach dewatering, which lowers the beach water table but needs continuous pumping during storms.

VI. Observations at the Beaches

A. Miramar

Miramar is on the left bank of the Mandovi estuary, about 3 km from Panaji. The beach is 30–90 m wide and about 3.5 km long. The survey found very high erosion with the shoreline close to the land. The seawall built to control it failed under wave pressure (Fig. 1a). The sand dunes had been disturbed by human activity, upstream mining was reported to have triggered erosion, and wind speeds near 20 km/h carry sand onto the road. Trees planted along the beach give some protection against wind. The measures proposed are 1 m high wooden sand fences to trap wind-blown sand and a dune-protection project by the Government of India and the World Bank, and the team suggests gabions or a revetment, or a seawall with a breakwater.



Fig. 1. (a) Rubble seawall along the Panaji coast, (b) geotubes at Candolim, (c) burst geotubes.

B. Candolim

Candolim has seven dune patches with a total area of 87,949 m² [15], but the survey found very high erosion, disturbed dunes and a shoreline 103 m from the land. The 2018 cyclone had a strong effect. Shack owners laid sand-filled bags in front of the shacks. Two parallel rows of geotubes, one larger than the other, were filled with sand by pumps, but waves burst them and the sand escaped (Fig. 1b, c). The tidal range of 2.53 m was not allowed for in the design, and the tubes were not protected from ultraviolet light and wave action. The team suggests a seawall with a breakwater.

C. Calangute and Anjuna

Calangute has a haphazardly built-up coast with roads laid across the dunes. Many dunes have been levelled, and four patches remain with a total area of 49,682 m², the largest being 345 m by 217 m and 3–5 m high [15]. No protection measure was found, and the team suggests planting trees to break the wind. At Anjuna the dunes are 1–2 m high and the beach is partly protected by trees. Tetrapods have been laid along the shore by the Goa Coastal Zone Management Authority (GCZMA). The report suggests that no new structure is needed because erosion is less.

D. Morjim

Morjim has six dune patches with a total area of 180,098 m² and a maximum width of 258 m, and most of them are eroding. A line of Casuarina trees covers the southern coast, which is also a nesting site of the Olive Ridley turtle (Fig. 3b). The shoreline is 130 m from the land, and the wave current is low. Sand bags and large concrete blocks (Fig. 2a) have been placed to check erosion, and erosion effects are also seen on the Chapora River.



Fig. 2. (a) Concrete blocks at Morjim, (b) tetrapods at Querim, (c) concrete wall under construction at Vainguinim.

E. Mandrem and Arambol

Mandrem is well protected, with a shoreline 100 m from the land, low wave current and protected vegetation, and Casuarina has been planted along the shore. Sand extraction was observed to have triggered some erosion. No structure is needed. Arambol has a rocky northern coast, a sandy beach in the south and three dune patches. No measure has been taken, but a fresh-water lake near the beach is gradually being affected, and the team recommends a hard structure or nourishment.

F. Querim

Querim has a sandy beach backed by a seawall with tetrapods (Fig. 2b), and one stable dune lies 110 m inland. The shoreline is also 110 m from the land. The beach has high wave current, has lost shoreline over time and is one of the most affected areas, and sand extraction has contributed. Gabions, tetrapods and a Casuarina belt (Fig. 3a) have been used, and debris of the seawall can be seen on the beach. The team recommends control of sand extraction.

G. Ashwem and Vainguinim

Ashwem is quiet and undeveloped, its flora and fauna are in very good condition, and Casuarina has been planted, so no measure is needed. Vainguinim is a commercial belt with many hotels and strong human activity, and land is being eroded at a high rate. A concrete seawall was being built at the time of the

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visit (Fig. 2c), and the team recommends control of human interference.



Fig. 3. (a) Casuarina plantation along the coast, (b) Olive Ridley turtles nesting at Morjim.

VII. Discussion

Table I collects the survey answers given in the report for nine beaches (Miramar is described in the text only). Erosion was reported at Querim, Morjim, Anjuna, Calangute, Candolim and Vainguinim, which, with Miramar, makes seven of the ten beaches. Fig. 4 groups the beaches by the type of measure in place. Every beach with a hard structure shows erosion, and the beaches with soft measures only, Mandrem and Ashwem, were not eroded. This does not show that hard structures cause erosion, because they were usually built where erosion was already severe, but it shows that they have not removed the problem.

TABLE I
SURVEY SUMMARY FOR NINE BEACHES (AS RECORDED IN THE REPORT)

Beach	Eroded	Type	Measure	Effective	Sand extraction
Querim	Yes	Rocky	Both	Yes	Yes
Arambol	No	Sandy	None	—	No
Mandrem	No	Sandy	Soft	Yes	No
Ashwem	No	Both	Soft	n/a	No
Morjim	Yes	Sandy	Both	Yes	Yes
Anjuna	Yes	Rocky	Hard	No	No
Calangute	Yes	Sandy	Soft	n/a	No
Candolim	Yes	Both	Hard	No	No
Vainguinim	Yes	Rocky	Hard	Yes	No

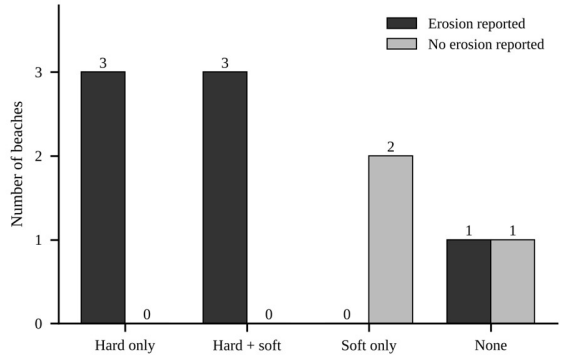


Fig. 4. Beaches grouped by protection measure in place (Miramar counted as hard + soft; Calangute as none).

The measures observed at the ten beaches are summarised in Table II. The hard structures with a recorded failure are the Miramar seawall and the Candolim geotubes, and the Candolim case has clear causes: the tidal range, the ultraviolet exposure and the wave action were not allowed for. Sand bags are temporary. Soft measures, Casuarina planting and the retention of dunes and vegetation, were found at the beaches in the best condition.

TABLE II
PROTECTION MEASURES OBSERVED AND THEIR CONDITION

Measure	Beach	Observed condition
Rubble seawall	Miramar	Failed under wave pressure
Geotubes	Candolim	Burst; sand escaped
Sand bags	Candolim, Morjim	Temporary protection by shack owners / at the shore
Concrete blocks	Morjim	Laid to check erosion
Tetrapods, gabions	Anjuna, Querim	In place; seawall debris seen at Querim
Concrete seawall	Vainguinim	Under construction
Casuarina, dunes	Mandrem, Querim, Ashwem, Morjim	Vegetation intact; Mandrem and Ashwem not eroded

A. Limitations

The study has no measured shoreline positions, erosion rates or wave data, so the ratings of erosion and of effectiveness are the team's own judgements from one visit. The report's tables disagree with its text in some places. Querim and Vainguinim are listed as rocky although the text describes Querim as a sandy beach, and the dune answer for Querim is "no" although the text describes a stable dune. Mandrem is recorded as having no sand extraction although the text says that extraction triggered erosion, and Calangute is recorded with a soft measure although the text says that none was taken. Anjuna is recorded as eroded and its measure as ineffective, while the suggestion says that no structure is needed because erosion is less. Vainguinim's measure is rated effective although the wall was still being built. These entries are shown above as in the report.

VIII. Conclusion

The survey of ten beaches in Goa found erosion at seven of them, with the highest levels at Miramar, Candolim, Querim and Vainguinim. Hard structures were common at the eroding beaches, but the Miramar seawall and the Candolim geotubes failed, the latter because tides, ultraviolet light and waves were not considered in the design. The beaches in the best condition, Mandrem and Ashwem, had intact vegetation and dunes, and unchecked sand extraction, disturbance of dunes and building on the coast were repeatedly linked to erosion. The report recommends proper planning and design that considers wave forces, available materials and site limits, and also favours low-cost flexible measures such as gabions, Chain-O-Block armour and sand-filled coir bags as developed at CWPRS, which can be built with local labour and repaired in parts [16]. These recommendations are drawn from the literature and were not tested in this study. Measured shoreline-change data would be needed to confirm the conclusions here.

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