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Study and Analysis of Soil Erosion due to Coastal Waves and Control Measures

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ABSTRACT: The land ward displacement of the shoreline caused by the forces of waves and currents is termed Coastal Erosion. The Coastal areas have become more prone and vulnerable to natural, and human made hazards which lead to Coastal Erosion. The Shoreline retreat is recognized as a burgeoning threat because of global climate change and other anthropogenic activities that alter the natural processes of sustaining beaches and coasts. Coastal Erosion mainly occurs when wind, waves and longshore currents move sand from shore and deposit it somewhere else. The sand can be moved to another beach, to the deeper ocean bottom, into an ocean trench or onto the landside of a dune. The removal of the sand from the sand sharing system results in permanent changes in beach shape and structure. The impact of the event is not seen immediately as in the case of Tsunami or Storm Surge, but it is equally important when we consider loss of property. It generally takes months or years to note the impact of erosion; therefore, this is generally classified as a “Long Term Coastal Hazard”. The present paper attempts to describe a Review on Coastal Erosion Process, Parameters’ effecting, and methodologies are adopted to identify the erosion and recommend a solution.

KEYWORDS: -Wind,Rainfall, Wave Pressure, HEC-RAS Software, RS-GIS Data.

I. INTRODUCTION

1.1 General

Shoreline or coastline, the boundary between land and sea, keeps changing its shape and position continuously due to dynamic environmental conditions. Various developmental projects are made in shoreline areas, placing great pressure on it, leading to diverse coastal hazards like soil erosion, sea water intrusion, coral bleaching, shoreline change; etc. Considering Coastal erosion, it is a global problem affecting almost every country around the world having a coastline. It’s a hazard affecting the shoreline or coastline pertaining to several changes in the climate, atmospheric disturbances and constant changes in the water bodies.

However, globally it is estimated that about 60% of the population is dwelling in coastal environments. Although the coastal environment can retain some degree of natural character, increased human modification reduces the “naturalness” (Dahm, 2000). The accelerated release into the atmosphere of Carbon dioxide and other greenhouse gasses has resulted in a projected global warming of about 3°C by the year 2030. This increase would be enough to raise the global sea level by as much as 5 m in a few centuries, which is a short time in terms of human occupation of the coast. This phenomenon has the tendency to expose a significant proportion of vulnerable coastal areas to flooding and destruction of habitats for migratory birds and other endangered species. Occurring in synchrony with these continual changes is the recession of shorelines, estimated to occur on coastal population and infrastructure of major economic and cultural importance in almost all coastal regions globally. The location of the shoreline and changing position of this boundary through time are of elemental importance to coastal scientists, engineers and managers. Relief and development agencies also depend on such information to facilitate development of effective measures to prevent, mitigate or manage disasters. Both sustainable coastal management and engineering design require information about where the shoreline is, where it has been in the past, and where it is predicted to be in the future. Such information is required in the design of coastal protection, to calibrate and verify numerical models, to assess sea-level rise and to develop hazard zones. Remote Sensing helps to replace the conservative survey data by its rhythmic and less cost-effectiveness. Several studies using satellite data have proven its efficiency in understanding various coastal processes.

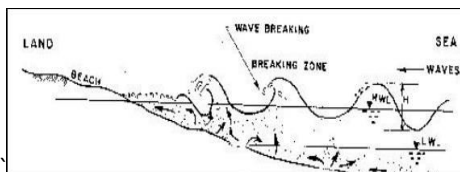


Figure 1 Breaking of waves

1.2 Approaches to reduce Soil Erosion

To build protective structure in order to avoid coastal erosion: - (such as)

1.2.1 Sea walls:

A seawall is a structure made of concrete, masonry, or sheet piles, built parallel to the shore at the transition between the beach and the mainland or dune, to protect the inland area against wave action and prevent coastal erosion. Seawalls are usually massive structures designed to resist storm surges.

1.2.2 Artificial reef:

Coastal defense artificial reefs are therefore often constructed as multipurpose structures, i.e., besides the main function to defend the coast from erosion they also maximise secondary objectives such as to improve spot surfability, to stabilize nourishment material and to create marine parks of increased biodiversity.

1.3 Aim and Objective:

To study socio-economic effects of erosion: -

Soil erosion and socio-economic interactions with each other. Soil and water loss destroys land resources, causes non-point source pollution, affects the recycling and utilization of water resources.

Design and development of remedial measures to control coastal erosion: -

Hard structural/engineering options use structures constructed on the beach (seawalls, groynes, breakwaters/artificial headlands) or further offshore (offshore breakwaters). These options influence coastal processes to stop or reduce the rate of coastal erosion.

II. LITERATURE REVIEW

2.1 Research Papers: -

2.1.1 Sathish Sathasivam, K. Rasheed, R.S. Kankara , Manikandan Muthusamy, Arockiaraj Samykannu Rajan Boopati.SSC Analysis of South Maharashtra Coast: A Case Study from Vengurla Coastal Region.

To understand the suspended sediment transport pattern along South Maharashtra coastal region, a case study was conducted at Vengurla coastal waters. To do that, the sea water samples at 6 transects (18 stations) were collected for analysis of suspended sediment concentration (SSC) during pre-monsoon and post-monsoon periods. The results showed that during post monsoon, the SSC pattern at surface, mid and bottom layers having 10-20mg/l, 10-19mg/l and 50-60 mg/l respectively. But during the pre-

monsoon, the respective layers show 5-20mg/l, 4-15mg/l and 70mg/l of SSC concentration. In addition, Ocean Colour Monitor (OCM) satellite images were analyzed in the same study area to know the SSC distribution pattern. In Vengurla, post-monsoon, the SSC values of surface coastal waters ranging from 5-15mg/l from OCM satellite images and SSC is compared with OBS 5+ profiles. In this paper, the SSC distribution pattern of both seasons is narrated and validations of SSC using OCM satellite data are also discussed

2.1.2 Lalit M. Thakare and Tushar A. Shitole Vulnerability Assessment of the Ratnagiri Coast (Maharashtra, West Coast of India)

Vulnerability assessment of the Ratnagiri coast (Maharashtra, west coast of India). Journal of Coastal Research, 00(0), 000-000. Coconut Creek (Florida), ISSN 0749-0208. The Ratnagiri coast, situated in Maharashtra state, West Coast of India, is potentially vulnerable to the erosional hazards, frequent rehabilitation of land, and accelerated sea-level rise. In recent years, the evidence shows erosional threats and gradual submergence along the creeks and lowlands of Ratnagiri. To deliberate the vulnerability of these hazards, vulnerability ranking was assigned using a coastal vulnerability index (CVI) using six geophysical parameters. The datasets were obtained from the satellite data of Landsat series from the

years 1973, 2015, and 2019 to derive geomorphology of the coast and coastal landforms. Shoreline changes along Kelshi, Kachave-Undi-Waravde region, and Mirya Bay and beach have been evaluated using the Digital Shoreline Analysis System by demarcating the baseline and shorelines from the series of Landsat data. Data obtained is re-improvised with Google data for updating the recent change in the study area. Elevation data is extracted from Advanced Spaceborne Thermal Emission and Reflection Radiometer data of 30 m spatial resolution, the susceptibility of coastal inundation was derived using General Bathymetric Chart of the Oceans data, and this has indicated northerly submergence of the coast, prone to become vulnerable.

2.1.3 Basu B. 2017 Wave height estimates from pressure and velocity data at an intermediate depth in the presence of uniform currents. *Phil. Trans. R. Soc. A* 376: 2017

Bounds on estimates of wave heights (valid for large amplitudes) from pressure and flow measurements at an arbitrary intermediate depth have been provided. Two-dimensional irrotational steady water waves over a flat bed with a finite depth in the presence of underlying uniform currents have been considered in the analysis. Five different upper bounds based on a combination of pressure and velocity field measurements have been derived, though there is only one available lower bound on the wave height in the case of the speed of current greater than or less than the wave speed. This article is part of the theme issue 'Nonlinear water waves.'

2.1.4 M. D. KUDALE Overview Of Coastal Protection In India & Innovative Methods Of Protection

India has a coastline measuring over 7500 km of which about 3000 km stretch is on the west coast; about 2700 km on the east coast and the rest includes the coastline of Lakshadweep and Andaman Group of Islands. The west coast of India has flatter slopes (1:500 to 1:1000) as compared to the east coast (1:100 to 1:150). The continental shelf extends to about 150 km on the west coast as compared to 50 km on the east coast. Several storms occur on the east and west coasts of India every year, particularly during the periods from April to June and October to January, due to typical meteorological conditions in the oceans. The frequency of cyclones is low on the west coast (about 2 per year); whereas on the east coast, cyclones are more frequent (about 5 per year).

2.1.5 R.S. Kankara, M.V. Ramana Murthy & M. Rajeevan. MINISTRY OF EARTH SCIENCES National Centre for Coastal Research, Chennai National Assessment of Shoreline changes along Indian coast (1990-2016) Beach erosion is a chronic problem along many shores of the Indian coast. As coastal population continues to grow and community infrastructures are threatened by erosion, there is increased demand for accurate information regarding past and present trends and rates of shoreline movement. There is also a need for a comprehensive analysis of shoreline movement that is inconsistent from one coastal region to another. One purpose of this work is to develop standard, repeatable methods for mapping and analyzing shoreline movement so that systematic periodic updates on shoreline changes, coastal erosion hotspots, land gain/ loss etc. can be made for Indian coast.

III. METHODOLOGY

Factors Affecting Coastal Erosion: -

3.1.1 Wind:

Wind-forced choppy waves in enclosed bays, on top of a storm surge, result in erosion. This is the prime mechanism for shore erosion within sheltered harbors and estuarine lagoons.

3.1.2 Rainfall:

Instead of soaking into the soil, rainwater collects and moves down-slope, forming gullies and carrying soil particles which causes soil erosion at coastal as well as hilly regions.

3.1.3 Wave pressure:

Hydraulic action occurs when waves striking a cliff face compress air in cracks on the cliff face. This exerts pressure on the surrounding rock and can progressively splinter and remove pieces. Over time, the cracks can grow, sometimes forming a cave.

3.1.4 Tidal height:

The role of tides in molding coastal landforms is twofold: (1) tidal currents transport large quantities of sediment and may erode bedrock, (2) the rise and fall of the tide distribute wave energy across a shore zone by changing the depth of water and the position of the shoreline.



IV. RESULTS

Case study 1: -Vengurla Coastal Region:SSC Analysis of South Maharashtra Coast: A Case Study fromVengurla Coastal RegionSathish Sathasivam, K. Rasheed, R.S. Kankara, Manikandan Muthusamy, Arockiaraj Samyang, Rajan Boopati .

Abstract:Suspended sediment transport plays a major role in many coastal, estuarine, and offshore engineering applications. The transport of suspended sediment influences the constructions of harbours, constructions of coastal power stations and refineries, safety of offshore platforms and pipelines, erosion and accretion of beaches, quality of the water and many other applications. To understand the suspended sediment transport pattern along South Maharashtra coastal region, a case study was conducted at Vengurla coastal waters. To do that, the sea water samples at 6 transects (18 stations) were collected for analysis of suspended sediment concentration (SSC) during pre-monsoon and post-monsoon periods. The results showed that during post monsoon, the SSC pattern at surface, mid and bottom layers having 10-20mg/l, 10-19mg/l and 50-60 mg/l respectively. But during the pre-monsoon, the respective layers show 5-20mg/l, 4-15mg/l and 70mg/l of SSC concentration. In addition, Ocean Colour Monitor

(OCM) satellite images were analyzed in the same study area to know the SSC distribution pattern. In Vengurla, post-monsoon, the SSC values of surface coastal waters ranging from 5-15mg/l from OCM satellite images and SSC is compared with OBS 5+ profiles. In this paper, the SSC distribution pattern of both seasons is narrated and the validations of SSC using OCM satellite data are also discussed.

Results

SSC in situ From the water sample analysis, average of SSC values (Figure .2) during the post-monsoon period is 20mg/l. At the southern side of the study area of 15m depth of Tr-1 and 10m depth of Tr-2, getting abnormal values such as 90 mg/l and 70 mg/l respectively. The reasons for the unusual hike in SSC values may due to churning action of sediments from the bottom due to currents or any other oceanographic processes. The average SSC is observed to be little low (15mg/l) during pre-monsoon period (Figure.3). At Tr-4 of 15m depth depicting high value of 70 mg/l. At 15m SSC showing an increase in trend from Tr 1 to 4 and thereafter showing a decreasing towards northern side, which is well evident from Figure 3.

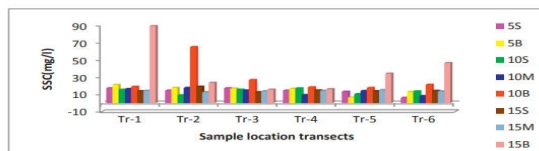


Fig 2. SSC (mg/l) distribution at six transects of Vengurla coast during the February, 2014

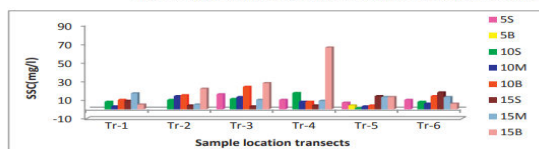


Fig 3. SSC (mg/l) distribution at six transects of Vengurla coast during the May, 2014

It is observed that using OCM analysis, the SSC values (Figure. 3) at surface waters during the post-monsoon season is ~10 mg/l instead of relatively high values observed in the water sample.

Case study 2 :- Assessment of the Ratnagiri Coast ,Maharashtra Vulnerability Assessment of the Ratnagiri Coast (Maharashtra, West Coast of India) Lalit M. Thakare and Tushar A. Shitole .

Abstract:

Vulnerability assessment of the Ratnagiri coast (Maharashtra, west coast of India). Journal of Coastal Research, 00(0), 000–000. Coconut Creek (Florida), ISSN 0749-0208. The Ratnagiri coast, situated in Maharashtra state, West Coast of India, is potentially vulnerable to the erosional hazards, frequent rehabilitation of land, and accelerated sea-level rise. In recent years, the evidence shows erosional threats and gradual submergence along the creeks and lowlands of Ratnagiri. To deliberate the vulnerability of these hazards, vulnerability ranking was assigned using a coastal vulnerability index (CVI) using six geophysical parameters. The datasets were obtained from the satellite data of Landsat series from the years 1973, 2015, and 2019 to derive geomorphology of the coast and coastal landforms. Shoreline change along Kelshi, Kachave-Undi-Waravde region, and Mirya bay and beach have been evaluated using the Digital Shoreline



Analysis System by demarcating the baseline and shorelines from the series of Landsat data. Data obtained is re-improved with Google data for updating the recent change in the study area.

Elevation data is extracted from Advanced Spaceborne Thermal Emission and Reflection Radiometer data of 30 m spatial resolution, the susceptibility of coastal inundation was derived using General Bathymetric Chart of the Oceans data, and this has indicated northerly submergence of the coast, prone to become vulnerable.

8. Shoreline Changes

Coastal processes are highly responsible for the changes occurring along the coast. Ratnagiri coast is no exception to this; however, rocky coastline and headlands may reduce the rates of erosion and accretion, but significant rise in wave height, frequent storm surges and changing tidal patterns, anthropogenic impact altogether are causing changes along the coast (Markad et al., 2014). The shoreline changes were attained by analyzing Landsat data for the years 1973 multispectral scanner (MSS), 2015 thematic mapper (TM), and 2019 enhanced thematic mapper (ETMp). Multiresolution data such as Landsat MSS, TM, and ETMp acquired from the USGS Earth Explorer website with a spatial resolution of 60 meters and 30 meters, respectively (Table 1) as a similar resolution is not available over the chosen period. The spatio-temporal interval from 1973 to 2019 (46 years) is quite precise but may challenge the accuracy standards of the data. These images were geo-referenced using ERDAS IMAGINE software and processed by image enhancement.

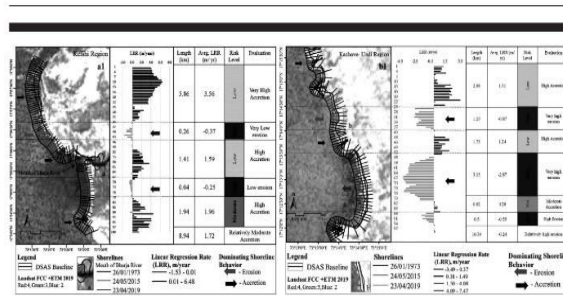


Figure 3. Decision matrix showing shoreline evolution and risk assessment for the most sensitive regions: (a1) Keshi beach and (b1) Kachave-Undi-Waravde (KUV) region. The transects are constructed from annually digitized baselines and shorelines between the years 1973 and 2019 using LRR functionalized in DSAS. These transects represent shoreline variations (erosion/accretion rates).

Figure 2 Decision matrix showing shoreline Evolution

Result

The present study results in the assessment of all CVI parameters that reveals a high risk of vulnerability along with low-lying areas of Ratnagiri coast and low risk along rocky coastlines. The assessment and ranking for each parameter are discussed in the next section.

V. CONCLUSION

5.1 RATE OF SOIL EROSION

Coastal length of Maharashtra, out of the total coastal length of 742.26 km, 449.5 km (60.55 per cent) is under erosion, 244.47 km (32.93 per cent) in under accretion, and just 48.29 km (6.50 per cent) of the coastal length is stable. About 34% of Indian coastline is under varying degrees of the threat, says Earth Sciences Ministry.

- In terms of percentage, West Bengal, located on the eastern coast of the country, with a 534.35 km-long coastline, suffered erosion along about 60.5% of the coast.
- This is followed by Kerala on the west coast, which has 592.96 km of coastline and 46.4% of it (275.33 km) faced erosion.
- Tamil Nadu, with a long coastline of 991.47 km, recorded erosion along 42.7% of it (422.94 km).
- Gujarat, with the longest coastline of 1,945.60 km, recorded erosion along 27.06% (537.5 km).



VI. EXPERIMENTAL PHASE

6.1 Need of lab scale model:

In modern coastal hydraulic study, physical experiment is commonly used in the design of coastal structures and protection systems for morphological evaluation and environmental impact assessment. This study is conducted to determine the stability and efficiency of two proposed coastal protection systems, N-Coastal Block and N-Coastal Wall in 2D Wave Flume and 2D Coastal Basin laboratory. It's important to note that lab-scale models provide valuable insights into coastal processes but may not fully replicate real-world conditions. They are useful for preliminary assessments and evaluating the relative performance of different coastal management strategies.

6.3 Working mechanism:

1. Set up a scaled model of a coastal area in a large water tank or flume, replicating the key features of the coastline, such as the shoreline, beach, and adjacent land.
2. Simulate wave action: Generate waves in the tank using wave generators or paddles, considering wave characteristics such as height, period, and direction. Ensure the waves are consistent and representative of the coastal environment being studied.
3. Establish baseline measurements: Measure the initial shoreline position and beach profile using measuring devices like rulers or laser scanners. Document the initial sediment characteristics, including grain size and composition.
4. Introduce erosion: Allow the waves to impact the coastline repeatedly over a specific period, simulating erosion processes. This can be done by adjusting wave parameters and observing the resulting erosion patterns.
5. Implement the step revetment: Construct a scaled-down version of the step revetment and place it strategically along the simulated coastline. Ensure the revetment is properly aligned and secured.
6. Monitor erosion: Continue wave action and observe the erosion patterns after the revetment has been implemented. Measure the changes in shoreline position and beach profile periodically using the same measuring devices as in the baseline measurements.
7. Comparative analysis: Compare the erosion patterns before and after implementing the step
8. revetment. Assess the effectiveness of the revetment in reducing erosion by analyzing the changes in shoreline position and the stability of the beach profile.
9. Collect sediment data: Take sediment samples from different locations within the tank, both before and after the revetment, and analyze them to understand any changes in sediment transport and deposition.
10. Document observations: Record detailed observations, including visual documentation or photographs, of the erosion patterns, revetment performance, and sediment dynamics.
11. Draw conclusions: Analyze the data collected and draw conclusions about the effectiveness of the step revetment in mitigating erosion in the lab-scale model. Consider factors such as shoreline stability, sediment movement, and changes erosion pattern.

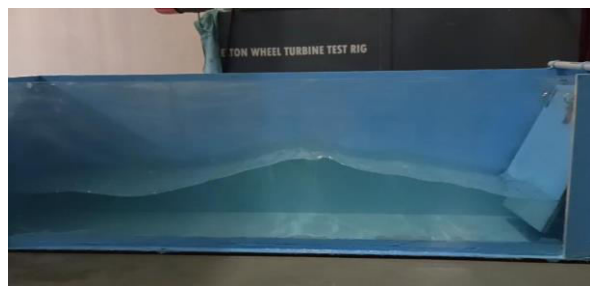


Figure 3 Model Prototype

6.4 Observation:

Table 1: Change in Water Pressure at Depth 0.15 m Before and After Placing Stepped Revetment

The "Water Pressure Before" column represents the initial water pressure measurement at that depth before placing the stepped revetment. The "Water Pressure After" column represents the water pressure measurement at the same depth after placing the revetment. To determine the change in water pressure, we subtract the "Water Pressure After" value from the "Water Pressure Before" value. In this case, the change in water pressure at a depth of 0.15 meters is calculated as -1.3 kPa (a decrease of 1.3 kPa).



Location/Depth (m)	Water Pressure Before (kPa)	Water Pressure After (kPa)	Change in Water Pressure (kPa)
0.15 m	18.5	17.2	-1.3



Figure 5 Observation Table And Armar

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