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Design of Coastal Structures for the Protection of Ponnani Coast

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***Abstract*—As an effect of sea water rise and storm surges caused by the global climate change, the coasts are subjected to rapid erosion along with anthropogenic activities. Severe erosion leads to land loss flooding and building loss. In this paper we are designing a seawall as well as an offshore breakwater at the Ponnani coast situated in Malappuram district of Kerala to prevent further coastal erosion which happened due to various factors involving coastal hydrodynamics, storm surge as well as due to the effect of the cyclone Ockhi. The effect of rising sea levels, frequent storm surge, frequently occurring cyclones have eroded the coast drastically up to 15m according to the data collected for the past few years. As a measure of beach management, these coastal structures of appropriate length were designed after collecting adequate wave data and tidal data from various sources. The sea wall is designed according to the Engineering Manual 1110-2-1614 for the length of 2100m.The cross section of the sea wall is designed using AUTOCAD. The sea wall is generally designed to consist of three layers that are core, secondary layer and an armour layer. For beach restoration adequate breakwaters were also designed.**

Keywords—Coastal Erosion; Seawall; Breakwater

I. INTRODUCTION

India has lost about one third of its coastline to erosion between 1990 and 2016, putting at risk more than 560 million people living in the coastal areas. Threats to India’s coastline are set to exacerbate with the long term removal of sediments and rocks along the coastline or the displacement of the land resulting from the action of waves as well as climate change, causing higher sea levels, unpredictable precipitation and frequent storms. Various methods such as construction of groins, detached seawalls, anti-sea erosion bunds, offshore breakwaters can be formed using sand-filled Geo synthetic tubes/bags etc. are generally taken to prevent erosion. The coast of Ponnani situated in the Malappuram district lost 15mof its beach due to coastal erosion. Dozens of houses along the coast of Ponnani and adjacent areas were damaged as the turbid Arabian sea carved into the coast at the places where the sea wall was missing as the coast suffers from the strong action of waves, high tides and storm surge. The cyclone Ockhi also gave a drastic push in the process of erosion. As this is a severe coastal erosion a sea wall can be chosen as the first and the most suitable coastal structure that can be designed. Sea walls are vertical, general or massive concrete structures emplaced along a considerable stretch of shoreline at urban beaches.From the datas we realize that reducing the effect of the waves with which it hits the shore as well as controlling storm surge flooding can greatly reduce erosion. Thus designing a new seawall as well as an offshore breakwater can be the best form of coastal structure and the best measure chosen for proper beach management. A Seawall is a wall or embankment erected to prevent the sea encroaching on or eroding an area of land.There are mainly three types of seawalls –vertical , curved and mound .Design of a seawall consists of four layers-an armour layer, a core layer,a toe mound and a bedding layer. A Breakwater is mainly a barrier built out into the sea to protect a coast or harbor from the force of wave.Rebuilding the beach that we lost all these years is also possible through the construction of these two coastal structures due to sediment deposit brought forward towards the shore by the force of waves on the structures.

II. OBJECTIVES

- To conduct desk studies
- To design a seawall
- To design a breakwater

III. METHODOLOGY

3.1.Study Area Identification

The study area selected was the coastline near Ponnani in Malappuram district, along the centre coastline of Kerala. Ponnani is a seashore town situated at the mouth of Bharathapuzha,bounded by Arabian sea on the west and estuaries and backwaters on the northern side. The coastal town is located around 10^{0}46’3” N Latitude and 75^{0}55’30” E Longitude.The Major fishing harbour of Ponnani is situated in the mouth of the Bharathapuzha river.The average elevation is five metres above MSL.A 30 m light house is situated near the shore which was commissioned on 17 april 1983.

Fig 1 : Satellite imagery of the Ponnani Coast (source:Google Earth)

3.2 Desk studies

The satellite imageries of a coastal stretch provide useful information concerning the shoreline changes and if available over a number of years may be superposed to understand the effect of natural /man made interventions on the shoreline changes. The shoreline behaviour adjacent to protruding land masses will serve as an indicator for the direction of net alongshore sediment transport. For the present analyses, satellite imageries adjacent to the shore connected structures were collected, analyzed and the direction of sediment movement was assessed.

A location near to lighthouse is fenced and marked for analysing the changes undergone by the shore. It is near to the Ponnani harbour which is at a distance of approximately 1051 m, having mouth of length 236 m and jetties of length 386m .

Fig 2 : Google earth satellite imagery of December 08,2009

Fig.2 clearly shows the longshore current which is a powerful transportation agent transporting longshore drift, or littoral drift in action on the fenced region having a beach of length 10.57m and a seawall was constructed for preventing erosion.

Fig 3: Google earth satellite imagery of January 05,2012

Fig.3 shows no significant changes in shore from 2009 to 2012 .There is still considerable beach area .Fig.4 shows an increase in beach area due to accretional process. Due to interventions to stabilize the shoreline such as seawall, reduced erosion rate was observed.

Fig 4: Google earth satellite imagery of January 17,2015

Fig 5: Google earth satellite imagery of April 12,2017

Fig.5 shows significant changes in the shoreline. The sea can be seen invading land and complete loss of beach upto the seawall is observed. A loss of about 15 m width of beach is observed.

Fig 6: Google earth satellite imagery of March 21,2018

Fig.6 shows the image during the year 2018. It can be observed that complete destruction of seawall near the lighthouse occurred during cyclone Ockhi which was the most intensive tropical cyclone in the Arabian sea happened on November 2017.The shoreline reaches the land area and there is a significant loss of land over 5 m as well as destruction of the compound wall of Ponnani lighthouse.

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Fig 7: Google earth satellite imagery of April 01,2020

Fig.7 shows the changes happened to the site. A new seawall was constructed which prevents further erosion. The width of seawall is found to be 9m.

The overall analysis showed that the entire coast is eroding, eventhough there were some places with accretional processes seen due to the effect of sediment from river inlet. Some areas in coastal zone were found to have deposition of sand, but mean rate of accretion were less than that compared to erosion. Cyclone Ockhi has severely affected the shore resulting in land loss and destruction of seawall. The coastal stretch of Ponnani lighthouse is located at about 2km north of river inlet. This river brings lot of sediments in to the sea. Two training walls are constructed at confluence point and it results in direct discharge of sediments during rainy season. As the sediments are not allow to settle along the coast, the it is not getting transferred to adjacent beaches by waves .This is also one of the reason for beach erosion

3.3 Wave data

The wave data of Ponnani coast which belongs to grid no:8 were taken from wave atlas

TABLE 1:OFFSHORE WAVE DATA FOR GRID 8

Month	Wave direction w.r.t north	Average wave height(m)	Wave period(sec)
January	340	1.5	7
February	340	1.5	7
March	330	1.5	7
April	300	1.6	7
May	300	1.8	7
June	270	2.5	7.5
July	270	2.5	7.5
August	270	2.5	7.5
September	280	2.5	7.5
October	300	1.5	7
November	340	2.25	7.5
December	340	1.5	7

3.4 Tidal data

- Mean high tide=1.6 m
- Mean low tide=0.1m
- Average tide =0.9 m

3.5 Design Of Seawall

1. Design Procedure

- water depth = 0.50m
- tidal height =0.90m
- storm surge =0.50m
- Mean sea level=0

∴ Total maximum water depth=0.50+0.90+0.50=1.90m

The maximum possible sustainable wave height in a particular water depth is,

Maximum wave height, Hmax = 0.78 ×water depth

= 0.78 ×1.90

=1.48m (3.5.1)

The design water depth can be calculated from the mean water depth, tidal level and the water level set up during the storm. In the calculation of armour weight, the design wave height, represented by significant wave height is needed to be established.

∴ Significant wave height,

$H_S = H_{max} / 1.8$ (3.5.2)

= 1.48/1.8

= 0.82m

- Slope of seawall
- Sea side=1 in 3
- Landside=1 in 1.15

Crest elevation=MSL+ high tide +storm +H_s (3.5.3)

=0.00+0.90+0.50+0.82

= 2.22m

Add freeboard=2.78+2.22=5m

2. Structure Design

- **Armour Layer**

Hudson formula was used for the estimation of the stable weight of armour rubble stone, W_{50}

$$W_{50} = \frac{\mathrm{Wr} \times Hs^3}{(S_r - 1)^3 \times K_D \times cot\emptyset}$$

The following rubble characteristics were assumed.

The unit weight of sea water, W_s =1025 kg/m3.

The unit weight of armour, W_r =2650 kg/m3.

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The stability coefficient, K_D was adopted to be 2.0

Slope angle of layer=1 in 3

∴

$$W_{50} = \frac{2650 \times 0.82^3}{((\frac{2650}{1025}) - 1)^3 \times 2 \times 3} = 61 \text{ kg}$$

But provide minimum of 1000 kg or 1T.

The nominal median diameter of stones corresponding to the armour rubble stone weight can be calculated using

$$D_{50} = \left[\frac{W_{50}}{W_r}\right]^{1/3} \qquad (3.5.4)$$

$$= \left[\frac{1000}{2650}\right]^{1/3}$$

$$= 0.72m$$

The thickness of armour layer (t) can be calculated using

$T=n \times K_D \times D$

Assume number of stone layers,n=2

Layer coefficient K_D=1.15

We know, D=0.72m

∴ T=2×1.15×0.72

=2.0m

Top width=2.0m

Provide top width =4.0m, so as to move vehicles.

- **Core Layer**

Weight of stone=W/200 to W/4000 (3.5.5)

= 1000/200 to 1000/4000

=5 kg to 0.25 kg

∴ provide 10 kg to 1 kg

- **Toe Mound**

A toe mound is to be placed on side of the seawall preventing the sliding of the stones and protecting the seawall from slope failure and scouring.

Weight of Toe mound = W_{50}/10 (3.5.6)

= 1000/10

= 100 kg

Width of toe mound = $2 \times H_S$ (3.5.7)

=2×0.82

=1.64m

OR

= 0.4 x d (3.5.8)

= 0.4 x 1.90

= 0.76m

Adopt 2.0m

Provide height=width/2

=2/2

=1.0m

- **Bedding Layer**

Minimum thickness=0.50m

Provide 10 kg to 1 kg

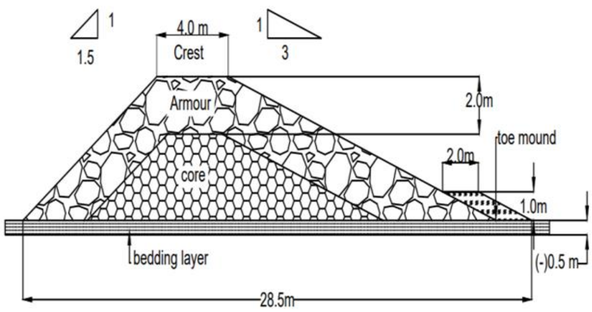

Fig 8 : Crossection Of A Seawall

3.5. Design Of An Offshore Breakwater

Design as per "Japanese Manual for Construction" by Coastal engineering research centre CETN III-23.It is an empirical method based on the survey of 1500 projects from 1983 to 1985.

Depth of breakwater proposed(d_0)=(-)1.50 m located 15 m from coast

Assumed slope of the coast=1/15

Total land loss in the form of beach from lighthouse to river=300 m

Average width of beach lost=15 m

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Hence in the project it is proposed to create 15m of "salient"

Wave period considered=7 sec

Wave height adopted=1.25m

Wave length at(-)1.5 m=$T \times \sqrt{g \times d}$

$$\text{L.S.W}= 7 \times \sqrt{9.81 \times 1.50}$$

$$= 27 \text{ m}$$

Calculation of breaker depth using deep water wave equation

Deep water wave length, $L_0=1.56 \times T^2$

=76 m

$$\frac{H_0}{L_0} = \frac{1.25}{76} = 0.016$$

Estimate breaker depth

$$\frac{d_b}{H} = 1.40$$

$\therefore$ $d_b=1.4 \times 1.25$

=1.75 m

As per reference, based on the slope, beach is in type C

$$\frac{d}{d_b} = \frac{1.5}{1.75} = 0.86$$

Calculate salient aspect ratio (SAR)parameter from reference

Here SAR for 0.86=0.70

Salient development expected =0.70×15=11m

Which is nearly the lost width of 15 m

a) Calculation of ranges of length of offshore breakwater[L_s]

For type C, $1.4 < \frac{L_s}{L_{sw}} < 2.3$

$3.8 < L_s < 62$

b) Length of breakwater based on the distance from shore

Distance from shore=15m[X]

As per reference,for type C,

$$1 < \frac{L_s}{X} < 3.5$$

$$15 < L_s < 53$$

From equation (1) and(2) adopt the range as follows

Maximum of lower value and minimum of higher value

Average=38+53=91/2=46m

Adopt the length as 46m

Length of breakwater is 46m[L_s] and

Length of coast is 300m[L_c] as per reference

$2L_s<L_c$

Adopt the following expression for "gap between breakwater

[L_g] based on length of breakwater L_s and distance from shore[X]

$$0.7 < \frac{L_g}{X} < 1.8$$

$$0.7 < \frac{L_g}{15} < 1.8$$

$$11 < L_g < 27$$

Based on length,

$$0.5 < \frac{L_g}{L_s} < 1.0$$

$$0.5 < \frac{L_g}{46} < 1.0$$

$$23 < L_g < 46$$

Adopt maximum of minimum range and minimum of maximum range

$$23 < L_g < 27$$

$$\text{Average} = \frac{23 + 27}{2} = 25m$$

Design between offshore breakwater=25m

Provide 4 offshore breakwaters with 25m spacing

The cross section can be designed using Hudson's formula

1. Design Procedure

- Water depth=1.50m
- Tidal height=0.90m
- Storm surge=0.50m
- Mean sea level=0m

The design water depth can be calculated from the mean water depth, tidal level and the water level set up during the storm.

$\therefore$ Total maximum water depth=1.50+0.90+0.50=2.90m

The maximum possible sustainable wave height in a particular water depth is,

Maximum wave height,

$$H_{max} = 0.78 \times \text{water depth} \quad (3.6.1)$$

$$= 0.78 \times 2.90$$

$$= 2.262\text{m}$$

In the calculation of armour weight, the design wave height, represented by significant wave height is needed to be established.

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∴ Significant wave height, (3.6.2)

$H_S = H_{max} / 1.8$

= 2.262/1.8

= 1.26m

➢ Slope of breakwater:1 in 3

Crest elevation=MSL+ high tide +storm +H_s (3.6.3)

=0.00+0.90+0.50+1.26

=2.66m

Add freeboard=2.78+2.66=5.44m

2. Structure Design

- **Armour Layer**

Hudson formula was used for the estimation of the stable weight of armour

rubble stone, W50 from equation

W_50=(Wr× 〖Hs〗^3)/((〖S_r-1)〗^3×K_D×cotØ)

The following rubble characteristics were assumed.

The unit weight of sea water, W_s=1025 kg/m3.

The unit weight of armour, W_r=2650 kg/m3.

The stability coefficient, KD was adopted to be 2.0

Slope angle of layer=1 in 3

∴W_50=(2650× 〖1.26〗^3)/((〖(2650/1025)-1)〗^3×2×3)=221.7 kg

But provide minimum of 1000 kg or 1T.

The nominal median diameter of stones corresponding to the armour rubble stone weight can be calculated using

D_50=[W_50/W_r]^(1/3)

=[1000/2650]^(1/3)

=0.72m

(7.14)

The thickness of armour layer (t) can be calculated using

T=n×KD×D

Assume number of stone layers,n=2

Layer coefficient KD=1.15

We know, D=0.72m

∴ T=2×1.15×0.72

=2.0m

Top width=2.0m

Provide top width =4.0m, so as to move vehicles.

- **Core Layer**

Weight of stone=W/200 to W/4000

= 1000/200 to 1000/4000

=5 kg to 0.25 kg

∴ provide 10 kg to 1 kg

- **Toe Mound**

A toe mound is to be placed on side of the seawall preventing the sliding of the stones and protecting the seawall from slope failure and scouring.

Weight of Toe mound = W50 /10

=1000/10

= 100 kg

(3.5.4)

Width of toe mound = 2×HS (3.6.4)

= 2×0.82

=1.64m

OR

= 0.4 x d (3.6.5)

= 0.4 x 1.90

= 0.76m

Adopt 2.0m

Provide height=width/2 (3.6.6)

=2/2

=1.0m

- **Bedding Layer**

Minimum thickness=0.50m

Provide 10 kg to 1 kg

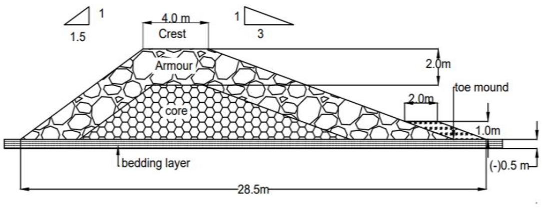

Fig 9 : Crossection Of A Breakwater

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IV. CONCLUSIONS

The coastline is the separation of the land from the sea thus protecting or maintaining that borderline plays a very important role in maintaining the natural Eco balance. Hundreds of millions of people are migrating to the beaches in quest of a better living, and the coastal and marine ecosystems provide very important services. If the coastlines are affected due to natural or manmade reasons immediate measures need to be taken to prevent them, reduce them as well as rebuild those lost coastlines if possible. The coastline of Ponnani was one of the coastlines that was facing the threat of erosion. Design and construction of appropriate coastal structures can not only help to control erosion but would also help to rebuild the lost areas of the beach gradually. Thus for the coast of Ponnani we chose to design two coastal structures. A Seawall to prevent and control erosion and a breakwater to protect port infrastructure from the destructive forces of the waves while also providing calm conditions for the ships berthing.

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REFERENCES

[1] EM1110-2-1614,Design of coastal revetments,seawalls,and bulkheads(June 1995)
[2] Coastal engineering technical note,CETN III-23(Rev 3/95)
[3] R.Sundaravadivelu,S Sakthivel,P.K Suresh,Remedial Measures To Combat Sea Erosion Along West Coast of India,ICOE 2019
[4] Shore protection manual, volume-1, 2, Coastal engineering research centre, Department of the army, Waterway experiment station, Corps of engineers.
[5] Anu Murali,Coastal Protection Measures for Shoreline of Mumbai:Review and Case Study,International Journal of Engineering Research And Technology,2020
[6] Prof V Sundar,Dr.K.Murali,Planning Of Coastal Protection Measures Along Kerala Coast,Department Of Ocean Engineering,Indian Institute Of Technology,Madras