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Study of Wave Energy Converter as Protective Structure to Arrest Erosion at Endangered West Coast Of Karnataka, India

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ABSTRACT:
The intense usage of energy propels development all across the planet. However, energy availability is restricted, while country energy demands continue to rise. Renewable energy has the capacity to supply the hasty demand without depleting existing resources. The wave energy is one kind of sustainable energy that can be useful to produces energy; moreover this attempt will alleviates the erosion of coastal area. Hence, the present work is devoted to check the feasibility of Wave Energy Converter (WEC) to protect the coastal area. For present work, the study area has been selected as Ullal, Karnataka. The methodology used in this work was, the MIKE-21 spectral wave model (SW) was calibrated and validated using the wind and wave data in the offshore location and near the Ullal, for year 2015 and data was obtained from ESSO – INCOIS. The wave assessment was carried by the numerical model MIKE 21 spectral wave model (SW). Moreover, calibrated SW model's result of wave energy potential is used to know transmission of waves through WEC and is studied using MIKE 21 Boussinesque wave (BW) model. The observed and simulated data shows good agreement, indicating the acceptance of model. The results showed that, there was a significant reduction in the wave height in the lee side of the WEC. The wave climate in the lee side of the WEC, is used for the sediment drift studies. Sediment drift with and without the effect of WEC was calculated using LITPACK. It was seen that as a result of the protection of WEC, drift along the shore has reduced considerably. Overall, the study concludes that using a wave energy converter as a protective construction to alleviate erosion is practical and sustainable, and that such efforts benefit the nation's economy.

Keywords: Coastal Erosion, Wave Energy Converter, WEC, Spectral Wave Model, Litpack, Littoral drift, ESSO-INCOIS.

I. INTRODUCTION

India came in fourth place on the list of carbon emitters. India plays a crucial role in the fight against global warming, and it is one of the fastest developing countries in the world, constantly attempting to shift away from polluting coal energy and toward cleaner, but less well-established renewable energy sources. India is one of the countries that has ratified the Paris Agreement on Climate Change (2016). India has altered gears in recent years to move away from coal and toward renewable energy, powered by ambitious goals and supportive government policies.In order to meet the Paris Climate Change Agreement's green targets, India is making rapid and significant progress toward generating 40% of its electricity from renewable energy sources (RES) by 2030. In March 2019, the Government of India (GOI) approved major hydropower projects exceeding 25 MW through the Cabinet Committee on Economic Affairs, and enabled energy produced utilising various forms of ocean energy, such as tidal wave and ocean thermal energy conversion, to be considered as renewable energy.

To mitigate the negative effects of climate change, the world is pursuing non-fossil fuel-based energy sources such as solar, wind, hydropower, and ocean energy. Wave energy is a significant source of ocean power. India's wave energy potential is estimated to be between 40 and 60 gigawatts (GW)[14] due to its vast coastline of 7515 kilometres. Ocean energy technology, on the other hand, is still in its early phases of development in India when compared to other renewable energy sources. In the Indian setting, the study of assessing wave energy potential and estimating wave energy conversion will be groundbreaking.

The waves are caused by wind passing over the surface of sea. As circulated wind is slower than wind above the wave, energy transfer takes place between wind and waves. Due to this air pressure varies between the upwind and lee side of wave peak. During this, friction also varies on water surface by wind. This all is responsible for making the water to go for shear stress and causes growth of waves.

The haphazard nature of sea surface wave makes it more complicated phenomena in ocean engineering, features of ocean wave is determined by field measurement, Numerical simulation, Physical modelling and analytical solution. Among these in resent numerical modelling is widely used as it is more powerful tool to study wave energy. As it is difficult to measure wave parameters due to density of sea water and spatial extent of measurement required. Numerical model is very beneficial for studies regarding coastal and off shore phenomenon. AmitDhawade[2] has assessed the wave energy potential along the west coast of India (Ullal, Karnataka) with the help of a third-generation spectral wave model MIKE 21 SW for the year 2005. Author concluded average wave energy during south-west monsoon was around 16.83 to 17.85 kW/m and annual average wave energy was found to be varying from 7 to 8.40 kW/m. Average wave energy during southwest monsoon is almost 2.5 to 3 times of the annual average wave energy.

Amitkumarjha, KiranBarve (2017) [1] they compared the results between numerical wave flume using MIKE 21 BW and physical wave flume. The optimal length and orientation of the structure was determined using MIKE 21 BW considering the structure as permeable breakwater. Pravin D Kunte& B G Wagle [3] presents an overview of investigations that were carried out to determine the dynamics of littoral transport along the west coast of India they also indicates that though littoral drift is variable, bi-directional and season dependent, long-term net littoral drift along west coast of India is southwards. Efforts have also been made to highlight the neglected aspects, merits and demerits of various methods used. V sanilkumar, P. R. Shanas [4] concluded Understanding longshore sediment transport (LST) is a prerequisite for designing an effective coastal zone management strategy. The present study estimates the LST along the central west coast of India based on four bulk LST formulae: (1) the Coastal Engineering Research Center (CERC) formula, (2) the Walton and Bruno formula, (3) the Kamphuis formula and (4) the Komar formula. In the study done by Sannasiraj S A, V. Sundar [5] they suggested an improvement over wave energy potential estimate, which has been made on the basis of various parameters such as physical site characteristics, environmental conditions and socio-economic regional state. Elisa Angelelli, Barbara Zanuttigh [6] says in there study that floating farm of wave energy converters for coastal protection purposes through physical and numerical modelling. In this paper, the numerical simulations were carried out by the software MIKE 21 BW, and were calibrated based on the experimental results. Benjamin Drew, Andrew R. [7] Plummer presents review which introduces the general status of wave energy and evaluates the device types that represent current wave energy converter (WEC) technology, particularly focusing on work being undertaken within the United Kingdom.

II. DESCRIPTION OF STUDY AREA

There are areas on India's west coast that are prone to erosion. These are the places where there is a lot of wave energy has been wasted in erosion of coastal areas. So, in present work, authors have selected Ullal, Karnataka as a study area (Fig.1)because it has been identified as a place affected by wave erosion in prior studies of prospective wave energy extraction. Authors have learned from previous reports[2] that Ullal beach is a popular tourist destination in Karnataka that has been severely eroded by powerful monsoon waves.

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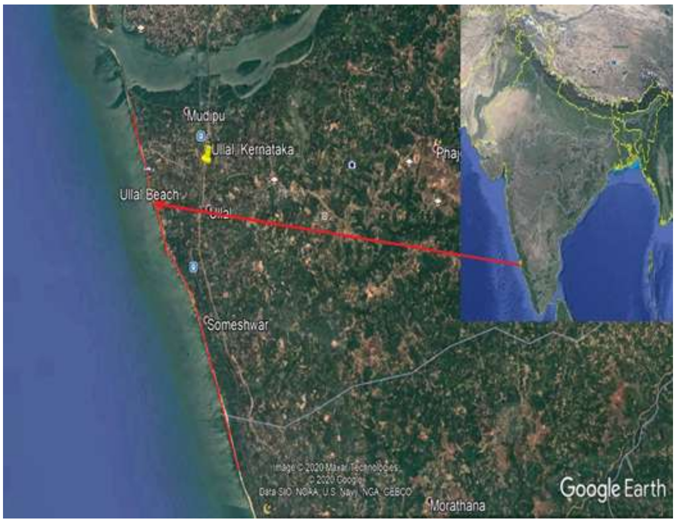

Fig. 1: Study Area

III. MATERIALS AND METHODS

3.1 Data used

The bathymetry data was extracted using MIKE C-Map from Jeppesen charts. This software uses Jeppesen Norway's CM-93 edition 3.0 global electronic chart database.Bathy stretched from 12.799768°N to 12.805066°N in latitude and 74.849269°E to 74.868881°E in longitude. C-Map was used to get land demarcation co-ordinates and co-ordinate bathymetry data.

The bathymetry is discretized in a rectangular grid with a grid spacing of 2 m in both the x and y directions, i.e. normal to the coast and along the coast, as shown in fig. 2. The bathymetry stretch is 3600 metres long and 3600 metres wide.The breakwater is installed at the depth of -10m in the sea. As the breakwater is permeable it will reduce theenergy and the reduced energy can be converted to generate electricity so it is called as wave energy converter (WEC). The installed WEC has transmission coefficient of 0.45 and width is 24m. The alignment of WEC is fixed by considering the predominant wave direction at an angle of 250°, 260°, 270°, 280° out of which plots for 260° and 280° are shown in this paper.

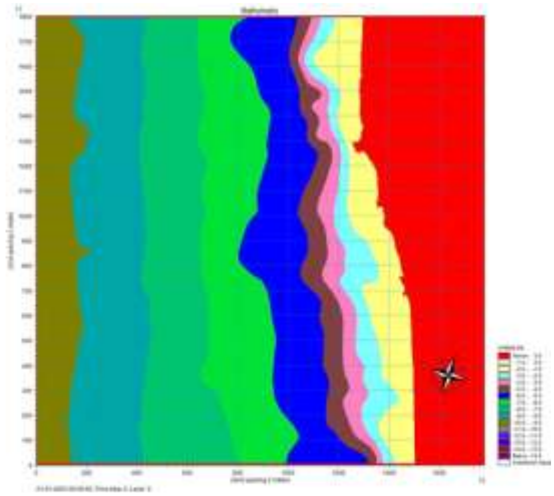

Fig. 2: Classical Bathymetry

3.2 Methodology used

The MIKE BW and MIKE Litpack models are used in this study. The wave energy evaluation is based on a SW model that was developed based on prior investigations conducted in the Ullal area. The SW results are fed into the BW model as input (Fig.3).

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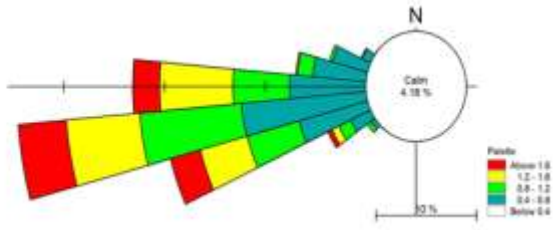

Fig. 3: Wave Rose Diagram obtain from SW model

Fig. 4: Simulated significant wave height obtained from SW model

MIKE 21 BW was used to run simulations with and without the permeable breakwater. The incidence wave directions were taken into account, with 250°, 260°, 270°, and 280° being the most common throughout the Monsoon season [1]. The results are graphed to aid comprehension (Fig.4). The BW model is run on the study region, and wave extraction is performed at seven spots in a straight line that are perpendicular to the suggested brake water site.Random wave with the significant wave height was Hm0 = 1m and the spectral peak periods of Tp = 7.5s is generated. The waves were synthesized based on a mean JONSWAP spectrum. As the minimum wave period was tmin = 6.7s, the problem can be solved using the classical Boussinesq's equations (i.e. the dispersion coefficient is B= 0). The time step of 0.18 sec and total simulation period of 10,000 time steps selected. WECs are represented by porosity layer. The porosity coefficient of 0.95 corresponding to the transmission coefficient of 0.45, is considered in the study. A sponge layer was given at the boundary to reduce the effect of wave reflection.

MIKE Litpack Module calculates non-cohesive sediment transport over quasi-uniform beaches using the BW model result in the points and littoral drift. The reduction in littoral drift or sediment movement occurring along the beach before and after the installation of brake water can be concluded from this module.

IV. RESULT AND DISCUSSION

In present work, a permeable breakwater with a transmission coefficient of 0.45 and a WEC width of 24m is used to investigate the permeability of a WEC. Wave energy is converted by these permeable breakwaters (WECs). For the numerical investigation of wave energy conversion, permeable breakwaters of 260m each at a depth of -10m are examined. MIKE21-BW is used to mimic the area's wave height and direction. A appropriate choice of porosity value, taking into account the width of the WEC and the wave duration, is used to incorporate the wave transmission coefficient of a WEC into the model.

The wave hydrodynamics in the vicinity of the WECs is simulated by the MIKE21-BW model for predominant wave directions i.e., West. The corresponding plots of significant wave height distribution obtained from model results are shown in Fig (5), (6) and Fig (8) for alignment 260°, 260°with breakwater and 280° respectively.

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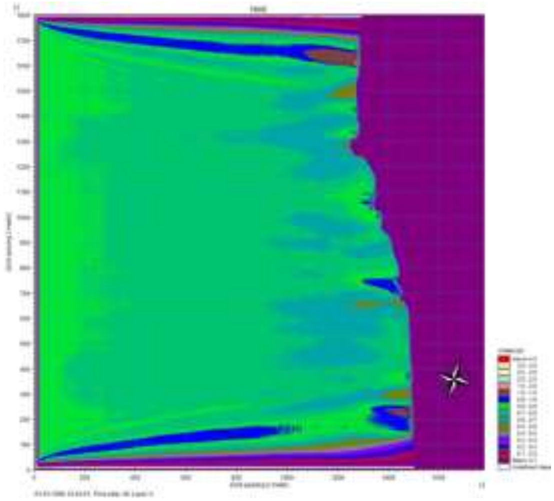

Fig.5: Significant wave height without permeable breakwater (WEC)

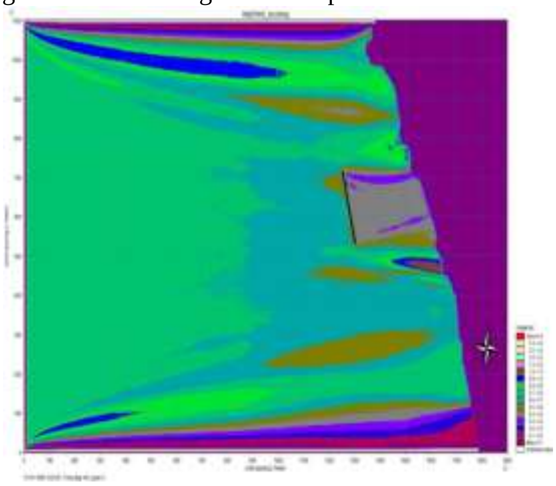

Fig. 6: Significant wave height with permeable breakwater (WEC) with angle of wave incidence 260°

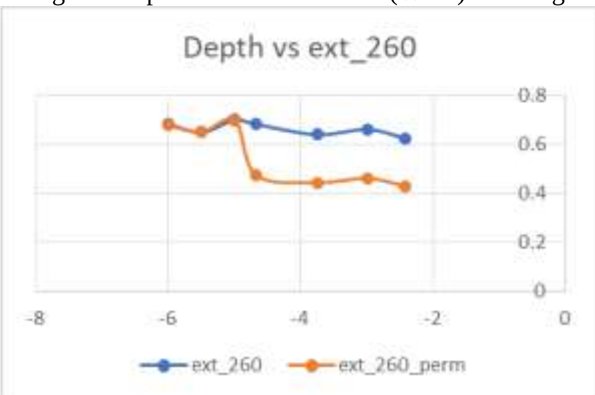

Fig.1: Graph between water depth Vs significant wave height for angle 260°, without the permeable breakwater (WEC) and with the permeable breakwater (WEC).

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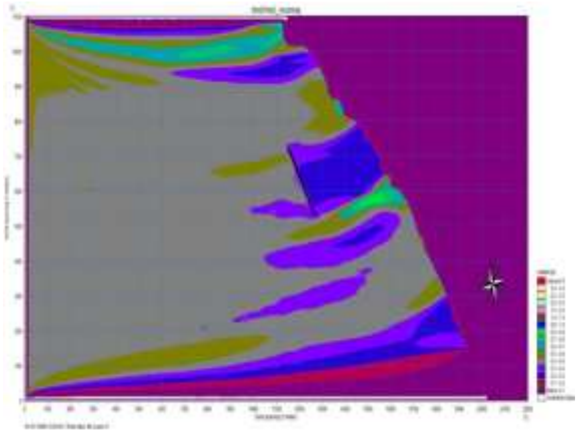

Fig. 8: Significant wave height with permeable breakwater (WEC) with angle of wave incidence 280°

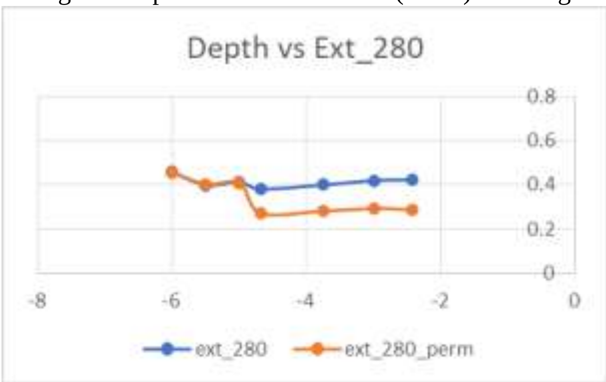

Fig2: Graph between water depth Vs significant wave height for angle 280°, without the permeable breakwater (WEC) and with the permeable breakwater (WEC).

The above Graphs (Fig. 7 and Fig. 9) are plotted using BW model, considering A line is perpendicular to the brake water having seven points on it where wave height reduction is measured. The result of the run is shown using graph, between various water depths (on x-axis) and wave height (on y-axis) for better understanding of reduction of wave heights before and after installing WEC. These graphs plotted for bathymetry for waves coming from an alignment of 260^0 and 280^0 as shown in Fig (6) and Fig (8) respectively. This graph contains extracted wave heights before and after providing permeable breakwater. Moreover, it is observed that, the wave height reduces after providing the permeable breakwater. The difference between the wave heights after providing breakwater is almost 0.2m and 0.12m for alignment 260° and 280° respectively.

4.1 Study of effect of WEC on the longshore drift

For Ullal Beach, annual longshore sediment transport rates were computed. The net long-shore transport rate along ocean beaches is thought to range from near zero to 7.65 x 10^5 m^3/yr, according to a widely held belief (SHORE PROTECTION MANUAL, 1984). The above researchers' predicted net longshore transport rates are within this range. Also, for a particular study area, net and gross transport rates are predicted for two scenarios: when no breakwater is erected and when an offshore breakwater is installed.

The blue line shows positive drift (Fig.10), the green line denotes negative drift, and the black line denotes the study location's shoreline profile. The littoral drift along the shoreline is reduced when a breakwater is erected, as shown in the two graphs below (Fig. 11).

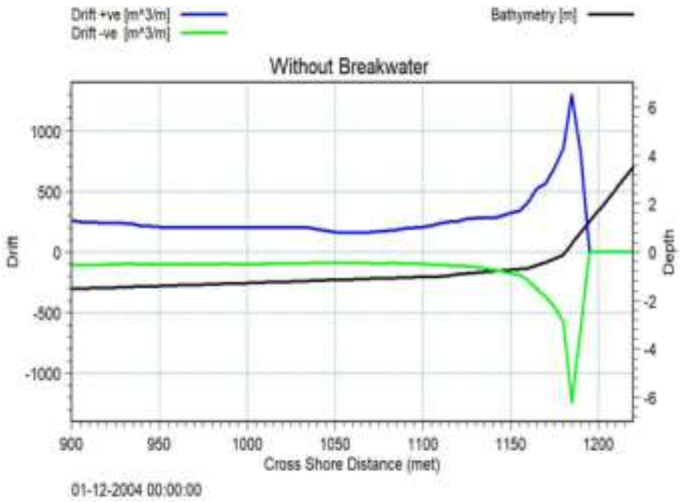

Fig.3: Graph for littoral Drift without breakwater

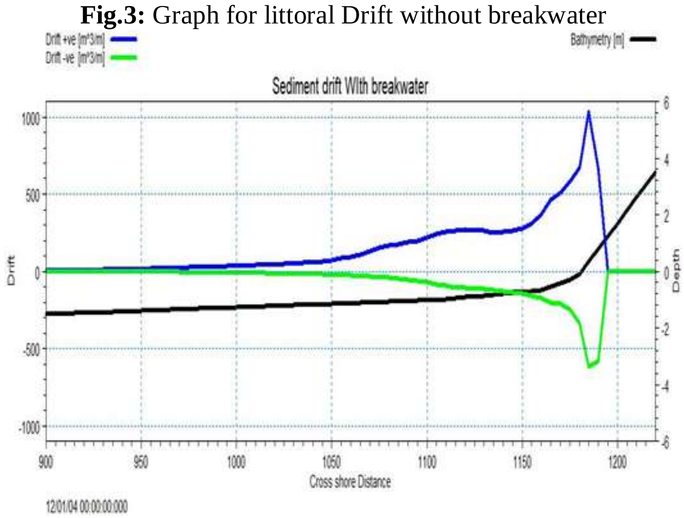

Fig.4: Graph for littoral Drift with Breakwater.

The annual net Longshore Transport Rate (LSTR) and gross Longshore Transport Rate (LSTR) along Ullal coast given in table 1 below,

Table 1. Annual net LSTR and gross LSTR along Ullal

Description	Without WEC (m^3)	With WEC(m^3)
Calculated net transport Rate	0.6752×10^5	0.2571×10^5
Calculated gross transport Rate	1.887×10^5	0.7002×10^5

As we can see from the above table net LSTR decreases by $0.4181\times10^5 m^3$ when WEC is installed and gross LSTR decreases by 1.1868×10^5 $m^3$when WEC is installed.

V. CONCLUSION

The present study engages MIKE 21module to simulate wave characteristics. The authors used the MIKE 21 BW and Litpack modules to determine the wave climate when WEC is deployed in four prominent wave approaches. Furthermore, the authors simulated wave height for these breakwaters with and without BW, taking into account the ratio of wave height with and without BW as well as the change in wave direction. The wave climate was measured at a depth of 3.5 metres. A permeable breakwater with a transmission coefficient of 0.81 and a WEC width of 24m is used to investigate the permeability of a WEC.

The alignment of WECs was fixed by considering the predominant wave directions and plot of wave vector near Ullal. The wave climate analysis indicated the predominant wave directions to be West. The wave hydrodynamics in the vicinity of Ullal was simulated by the numerical model for the four different alignments.

Alignment 1- WEC at 250° N: For this alignment, simulations of wave hydrodynamics using MIKE21-BW were carried out for waves approaching from both West and WSW directions. The difference between the wave heights after providing breakwater is almost 0.2m.

Alignment 2- WEC at 260° N: For this alignment, the model simulations were carried out for waves approaching from both West and WSW directions. The difference between the wave heights after providing breakwater is almost 0.2m

Alignment 3- WEC at 270° N: For this alignment, the model simulations were carried out for waves approaching from both West and WSW directions. The difference between the wave heights after providing breakwater is almost 0.1m.

Alignment 4- WEC at 280° N: For this alignment, the model simulations were carried out for waves approaching from both West and WSW directions. The difference between the wave heights after providing breakwater is almost 0.12m.

The energy ratio was estimated for the distinct alignments of WEC that are alien to the varied angles with respect to north for the West wave direction using the results files generated for those four trials. It is well knowledge that when the transmission coefficient falls, WEC efficiency rises. In addition, as the energy ratio rises, WEC efficiency rises as well. As can be seen, the energy ratio is higher where WEC is implemented.

Wave energy can be absorbed and generated by constructing an offshore permeable breakwater (WEC). WEC can protect shorelines, which decreases erosion, and change wave direction, which minimizes longshore drift, by absorbing wave energy. This will be extremely beneficial in terms of protecting the shoreline and beaches from erosion. The beach maintains its natural aspect because the WEC is located offshore.

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