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ATTENUATION IN ARTIFICIALLY DREDGED CHANNELS FOR PORTS WAVE

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Abstract *: Natural depths in port area and approach region are seldom adequate for catering to present day shipping. Therefore dredging of approach channel is inevitable. Also, the wave tranquility in port region in operational area namely in turning circle and near the berths is required to be obtained by artificial means like provision of breakwaters. Detailed wave tranquility studies are carried out for optimizing the length of the breakwaters since breakwaters are very costly structures with cost per unit length (per meter) of about Rs. 40 lakhs. The several kilometers long approach channel with suitable depths and width for navigation can cause wave attenuation . Studies were carried out at CWPRS for major ports at Mormugao (Goa) , New Mangalore port, which have reaped such benefits.*

However basic studies are required to be carried out for generalised applications. Therefore two dimensional mathematical model studies were carried out for test basin of 4000 m length and 2000 m width. These studies were carried out for two different wave periods of 6 sec and 10 sec and for two different water depths. Also different conditions of side slopes were considered namely vertical edge, side slope of 1:10, 1:20 and 1:40. These studies reveled that difference in the water depth between the surroundings and approach channel had maximum wave attenuating effect of the order of 50 to 60 percent. The side slopes also had some wave attenuation effect of about additional 10 percent. The water levels had also some effect with the lower water levels having more attenuation. The present paper describes generalised result and findings which can be helpful for planning the port developments.
Keywords : *approach channel, wave attenuation, side slopes, wave energy, wave heights.*

INTRODUCTION

In the design of Port layout, the desired degree of wave tranquillity insi de the harbour is an important factor. In case of open coast the pred ominant wave action m ust be considered from all the prevailing directions and care m ust be taken in orient ation of harbour entrance to a direction, w hich has norm ally less wave energy flux entering the habour. Generally the breakwaters are provided for achieving wave tra nquillity in various region of interest like

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Turning Circle, berth, near jetties etc. In order to provide access for large vessels to harbour, long approach channel has to be dredged outside the sheltered area. The alignment of the approach channel and layout of port basin are designed for the minimum wave flux entering the port area as simplistic choice. The West coast of India is well-known to be having flatter sea bed slope of 1:300 to 1:500. Thus result in very long approach channels of about 5 km to 10 km. Wave penetration over such long approach channel is vital important for determining the wave conditions outside and inside the harbour. In order to get more realistic effectiveness of the approach channels causing wave attenuation detailed basic studies were carried out at CWPRS, Pune and described in the present paper.

TEST BASIN AND TESTING CONDITIONS

A test basin having length of 4000 m and width of 2000 m consisting of 200 m wide approach channel was considered for the studies. The approach channel has been dredged to -10 m whereas depth of water outside the approach channel were kept to 5 m hence the water level difference between basin and approach channel was 5 m. The details of basin area with grid size of 10m by 10m are shown in Fig 1. The basin with plain horizontal bed and vertical edge was considered with grid interval of 10 m.

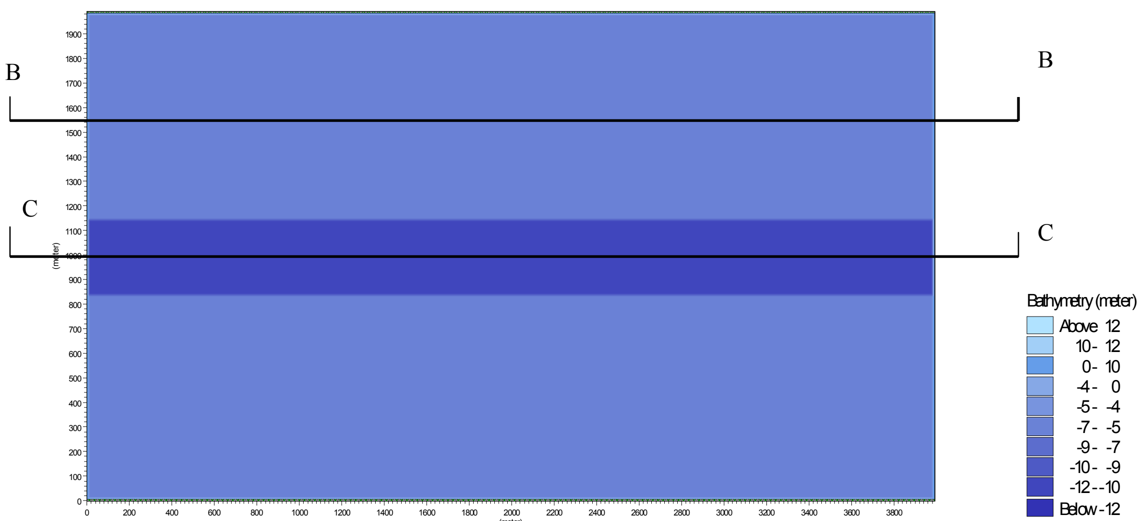

FIG.1 : Bathymetry For Test Basin

The incident regular wave was parallel to the alignment of the channel with 1.0 m wave height. The wave periods of 6 sec and 10 sec were considered for these studies. Three different side slope of 1:10, 1:20, and 1:40 were also considered for the studies (Fig 2). With this test basin the phenomenon of wave attenuation and wave concentration inside and outside approach channel were studied and presented.

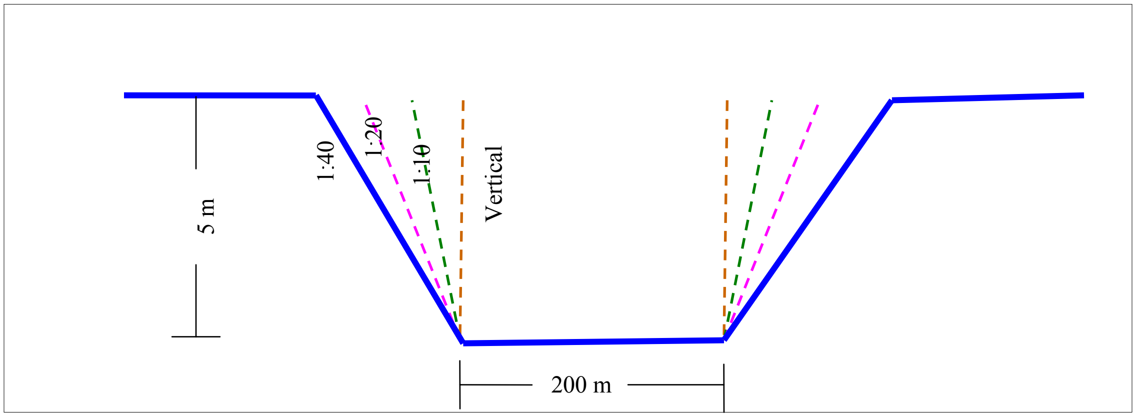

FIG. 2 : Cross Section Of Channel (Not To Scale)

MATHEMATICAL MODEL

To investigate the wave propagation over approach channel a m athematical m odel MIKE21- BW was used. This m odel is based on tim e dependant Bou ssinesq equations of conservation of m ass a nd m omentum obtained by integrating the three-dim ensional flow equations without neg lecting vertical acceleratio n. They ope rate in th e tim e domain, so that irregular waves in addition to regular wave can also be simulated. These equations include nonlinearity as we ll as frequency dispersion. The fre quency dispersion is in cluded in the flow equations by taking in to account the effect of vertical acceleration or the curvature of streamlines on pressure distribution. The model simulates the processes of shoaling, refraction, diffraction of waves. It also takes into account partial reflections from the boundaries, piers and breakwaters. The governing equations are

Continuity Equation:

$$n\frac{\partial\varsigma}{\partial t}+\frac{\partial p}{\partial x}+\frac{\partial q}{\partial y}=0$$

X Momentum Equation:

$$n\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{pq}{h}\right)+n^2gh\frac{\partial\varsigma}{\partial x}+n^2p\left(\alpha+\beta\sqrt{\frac{p^2+q^2}{h^2}}\right)-\frac{p^2}{nh}\frac{\partial n}{\partial x}-\frac{pq}{nh}\frac{\partial n}{\partial y}$$

$$= n\frac{D^2}{3}\left(\frac{\partial^3 p}{\partial x^2 \partial t}+\frac{\partial^3 q}{\partial x \partial y \partial t}\right)$$

Y Momentum Equation:

$$n\frac{\partial q}{\partial t}+\frac{\partial}{\partial y}\left(\frac{q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{pq}{h}\right)+n^2 gh\frac{\partial \varsigma}{\partial y}+n^2 q\left(\alpha+\beta\sqrt{\frac{p^2+q^2}{h^2}}\right)-\frac{q^2}{nh}\frac{\partial n}{\partial y}-\frac{pq}{nh}\frac{\partial n}{\partial x}$$
$$= n\frac{D^2}{3}\left(\frac{\partial^3 q}{\partial y^2 \partial t}+\frac{\partial^3 p}{\partial x \partial y \partial t}\right)$$

Where,
$\zeta(x,y,t)$ = water surface elevation above datum
$p(x,y,t)$ = flux density in x direction
$q(x,y,t)$ = flux density in y direction
$D(x,y)$ = still water depth $h(x,y,t)$ = water depth
$n(x,y)$ = porosity g = gravity
α = resistance coefficient for laminar flow in porous media
β = resistance coefficient for turbulent flow in porous media
x, y = space coordinates t = time

These differential equations are so lved using a time-centered implicit finite difference scheme with variab les defined on a space-stag gered rectangular grid. For m odeling of wave propagation in approach channel up to the ha rbour entrance, MIKE21-BW is suited since it simulates the com bined effect of refraction, dif fraction and reflections f rom side slope of the channel.

RESULTS OF EXPERIMENTS

For investigation of behavior of wave pr opagation a test basin area of 4000 m long and 2000 m width with 200m wide ap proach channel was considered for m athematical m odel studies. Initially 1 m regular wave with 6 sec wave period was generated at the seaward side of channel. The depth inside the channel was kept to 10 m , while at surrounding area to 5m . For running the model, a grid size of 10m by 10 m was used. One of the important param eter to assess the wave propagation is a wave height. The studies reve led that considerable wave attenuation occurred along the approach chan nel with wave attenua tion up to 0.45 m with vertical edges of the channel, such attenuation was not noticed outside th e channel region. It was also of interest to exam ine the wave pr opagation with sam e basin condition for different side slopes viz 1:10, 1:20, 1:40. The results reveled that attenuation of wave height to 0.42 m, 0.40 m, 0.36 m for side slopes of 1:10, 1:20, 1: 40 respectively. The wave attenuation could be attributed to transfer of wave energy along the edges of the channel due to interaction of waves of higher celerity in the dredged channel compared to low celerity waves outside the channel region. The results for wave heights along approach channel are presented in Fig 3 for 6 sec wave period. The wave height plot of surrounding region of approach channel is shown in Fig. 4

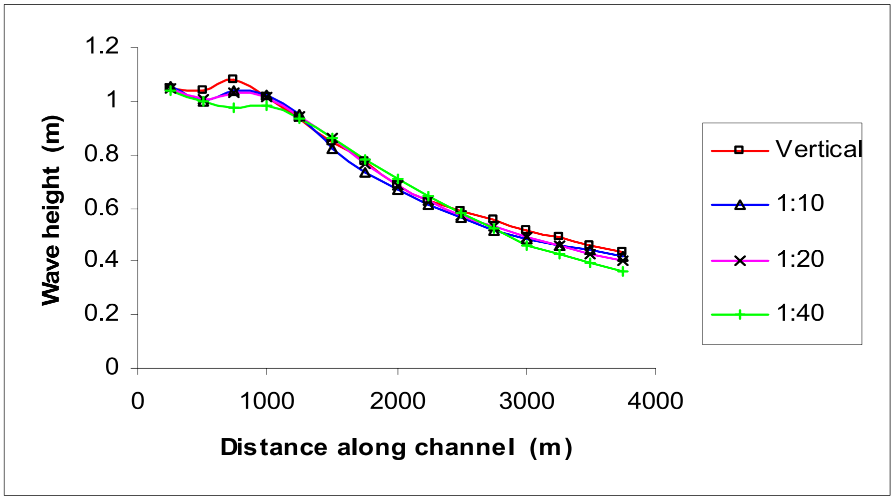

FIG 3 : Wave Heights Along The Channel (Section C-C)

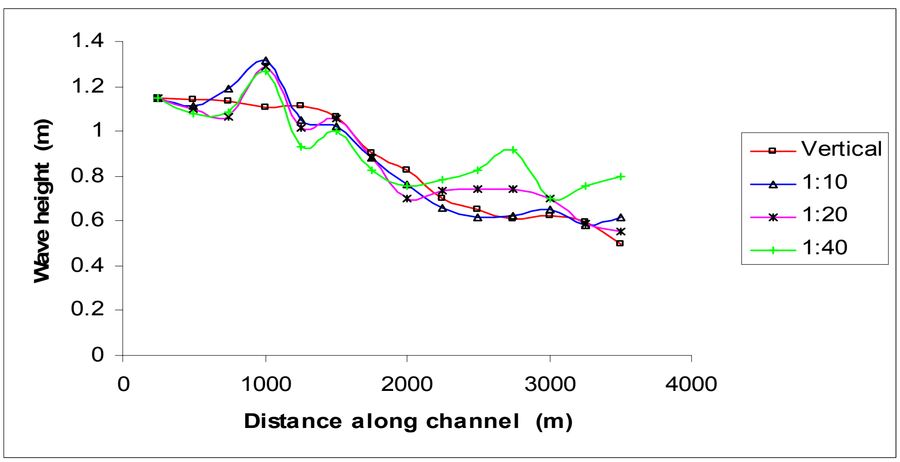

FIG. 4 : Wave Heights At Section B-B

Studies shows that reduction in wave height in the channel, there was increase in wave height in surrounding area interacting the transfer of wave energy from channel to outer region. The effect of wave period on wave attenuation was further studied for 10 sec wave period. The studies indicated that wave attenuation increases with wave period. A typical wave height distribution pattern for 10 sec wave period and 1:20 side slope of approach channel is shown in the Fig 5.

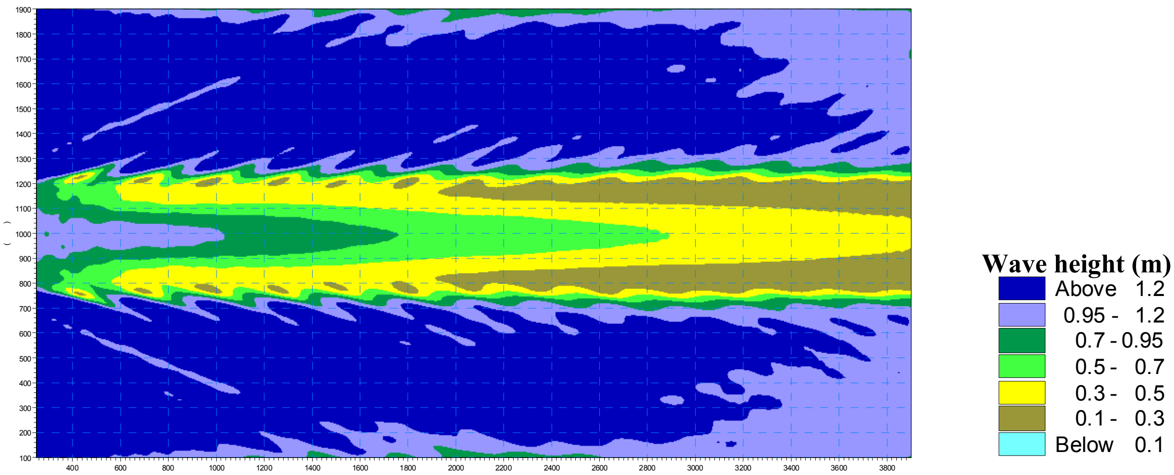

FIG. 5 : Typical Wave Height Distribution

For example with vertical edge of approach channel and 10 sec wave period, attenuation of wave was up to 0.4 m , while for the slopes of 1:10, 1:20, 1:40 the attenuation was up to 0.38 m , 0.35 m , 0.30 m respectively. Studies indicated that wave attenuation is more effective compared to corresponding 6 sec wave period. The Comparison for wave attenuation for 6 sec and 10 sec wave period with vertical edges of the approach channel is represented in Fig 6.

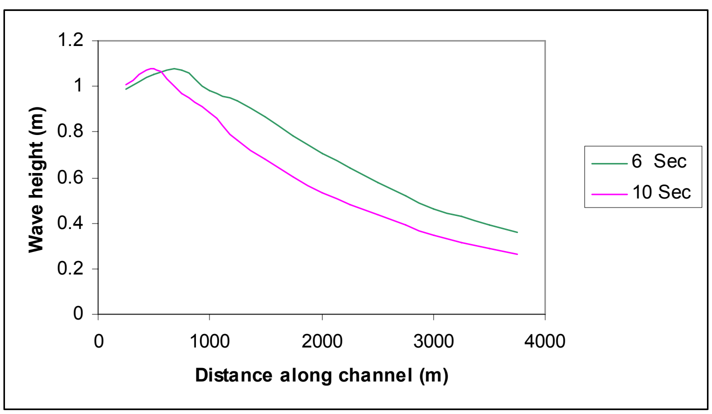

FIG. 6 : Comparison Of Wave Heights

Two different water levels keeping the same basin and wave conditions were also considered for studies. It was found that the wave attenuation were less for higher water level compared to lower water level in the basin.

As the wave energy is proportional to the square of the wave height, the wave energy transmission from the approach channel is a very effective phenomenon. Studies indicated that with the attenuation of 0.5 m wave height in the approach channel, the transmission of wave energy is 75 % from the approach channel to outside basin. With the side slope of 1:20 wave attenuation being up to 0.4 m, the transmission of wave energy is 84 %, it implies that the entrance of the harbour would have small wave energy impact. The studies were also carried out with angular attack of wave with the same test basin condition. It was noticed that wave attenuation with angular attack was less effective compared to parallel incident wave.

Application of this present studies can be considered in the context of any development say on the West coast of India. On the West coast of India, the approach channel lengths are about 4 kms to 10 kms because of flatter sea bed slopes up to 1:500. Studies reported for New Mangalore Port (Ref 3, 4 and 5) revealed that maximum wave energy is incident from the West direction followed by Southwest and Northwest directions.

The waves approaching from West to Southwest directions occurs during Southwest monsoon which have much higher wave height and wave period compared to the waves approaching from Northwest direction which occurs during the pre monsoon seasons. The present studies shows that the orientation of the approach Channel directed towards predominant wave direction would have maximum benefit for the Port development. Such strategy will help in reducing the length of breakwater for ports on the West coast India.

CONCLUDING REMARKS

- Approach channels are very effective wave attenuators causing wave attenuation of more than 80% by natural process of refraction and diffraction.
- On the west coast of India the waves from the West direction are dominant , The orientation of approach channel approximately toward West would be effective in reducing the length of the breakwater.
- With increasing the wave period wave attenuation is more effective which will be benefited because higher wave height are associated with more wave period .
- Side slopes are marginally influential in wave attenuation, so flatter side slopes should be preferred for the port development. It would ultimately help in optimization of breakwater alignment and length.

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