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# Review on Numerical Modelling Studies to Optimize the layout of Fishery Harbour on the West Coast of India

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**Abstract -** *For any harbour, one of the main criteria is to ensure safe ship berthing and achieve an acceptable level of wave disturbance within the harbour basin for better optimization of the harbour layout. The breakwaters sheltering, wave reflection, wave transmission studies are considered to achieve the above. In the paper, a site along the West coast of India is selected to carry out such studies. The study was carried out in 2 parts include; using MIKE 21-SW model (wave height transformation from deep water to 10m depth) and MIKE 21-BW model (for determination of near shore wave climate). A modified layout of the site was prepared to check the possibility of reduction in the breakwater lengths. The suggested layout as well as the modified layout was analyzed for tranquility condition. The mathematical model studies were carried out for the two layouts; and the layout which was within the permissible limits of the studies was determined.*

***Key Words***: Harbour, MIKE 21, Wave tranquility.

## 1. INTRODUCTION

Approximately 95% of India trade (by volume) is through water transport and it plays an important role in national and international trading.

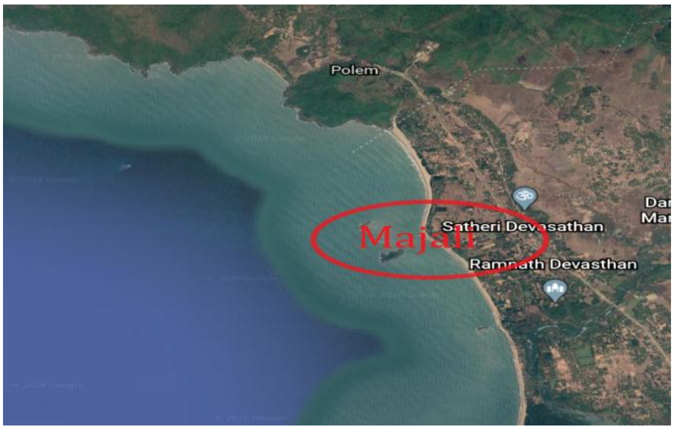


**Fig -1**: Location map of Majali, Karnataka

The ease with which the cargo is transferred between the connecting land and the ship is also important. The tranquility criteria checked in the studies is not only important for safe anchorage but also for efficient port operations and to reduce the excitation of the moored ships. Determining and transforming the wave climate conditions outside the harbour to inner harbour berth locations is also important.

Mathematical model studies of the layout to develop the fishing harbour was conducted from wave tranquility viewpoint at CWPRS (Central Water and Power Research Station), Pune at Majali, located on the West coast of India at about 13km North of Karwar in Uttar Kannada District, Karnataka (Fig. [1]).

## 2. SITE CONDITIONS

The Majali Fishery harbour is located on West coast of India 14° 53' 34" N latitude and 74° 5' 46" E longitude.
The tidal levels at Majali are:-
Mean Highest High Water (MHHW) : 1.83m.
Mean Lowest Low Water (MLLW) : 1.55m.
Mean Sea Level (MSL) : 1.13m.
The bathymetry at the site location is not very complex in nature having depth contours running almost parallel to each other.

## 3. METHODOLOGY

Due to the absence of near shore wave data, offshore wave data was collected by IMD (Indian Meterological Department) as their ships ply in the deep waters off Majali. The data was then transformed by MIKE 21-SW (Spectral Wave) model to get near-shore wave climate conditions. This near shore wave data was used for simulation of MIKE 21-BW (Boussinesq Wave) model to get the wave pentration and propagation in the harbour.

The MIKE 21 (SW & BW) models are developed by DHI (Danish Hydraulic Institute), Denmark.

## 4. NUMERICAL MODEL USED IN THE STUDY

Mike 21 SW model is based on the wave action balance equation. In Cartesian co- ordinate system; the wave action balance equation is given by,

$$\frac{\partial N}{\partial t} + \nabla \cdot (\vec{v}\,N) = \frac{S}{\sigma} \qquad (1)$$

where,
N ($\vec{x}$,σ, θ, t) = action density.
t = time.
$\vec{x}(x, y)$ = Cartesian co-ordinates.
$\vec{v} = (c_x, c_y, c_\sigma, c_\theta)$ = propagation velocity of the group in the four dimensional phase space $\vec{x}$, σ and θ.
S = source term for energy balance equation.
∇ = four dimensional differential operator in $\vec{x}$, σ and θ space.
MIKE 21-BW model applied for harbour tranquility simulations takes into consideration the impacts of various hydrodynamic features such as partial reflection and transmission, wave refraction, shoaling, bottom friction, wave diffraction, frequency spreading and directional spreading. Time dependent depth averaged Boussinesq equations are solved in this module. The governing equations (1), (2) and (3) are given as follows:

Continuity equation:

$$n\frac{\partial s}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0 \qquad (2)$$

Momentum equation in X direction:

$$n\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) - \frac{\partial Rxx}{\partial x} + \frac{\partial Rxy}{\partial x} + F_x = 0$$

$$n^2 gh\frac{\partial s}{\partial x} + n^2 p\left(\alpha + \beta\sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}}\right) + \frac{gp\sqrt{p^2+q^2}}{h^2C^2} + n\Psi_1 = 0 \qquad (3)$$

Momentum equation in Y direction:

$$n\frac{\partial p}{\partial t} + \frac{\partial}{\partial y}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) - \frac{\partial Ryy}{\partial y} + \frac{\partial Rxy}{\partial y} + F_x = 0$$

$$n^2 gh\frac{\partial s}{\partial y} + n^2 p\left(\alpha + \beta\sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}}\right) + \frac{gp\sqrt{p^2+q^2}}{h^2C^2} + n\Psi_2 = 0 \qquad (4)$$

The parameters used in this relationship include:
s: Water surface level above the base level (m).
p: Flux density in the X-direction ($m^3/s/m$).
q: Flux density in the Y-direction ($m^3/s/m$).
h: Total water depth (m).
H: Average water depth (m).
n: Porosity number.
α: Resistance coefficient for laminar flow in porous media .
β: Resistance coefficient in turbulent fow in porous media.

## 5. CALMNESS CRITERIA IN BERTHING POSITIONS

The threshold wave heights for the berthing criteria is estimated on the type, size and cargo handling characterstics of the ship. Permissible wave height is 0.3m for fishing harbour which is used as a limiting value in the study. The following are the threshold wave height for various ships:-

1. Small ships (<500 tonnes) = 0.3m.
2. Large / Average ships (between 500 to 50000 tonnes) = 0.5m.
3. Very large ships (>50000 tonnes) = 0.7-1.0m.

## 6. WAVE TRANSFORMATION

The bathymetry used in the study covered an area of 240 km*150 km and 100m in depth (see Fig.[2]). From the IMD data analysis it was indicated that predominant wave directions in deep water were from SW to N with maximum wave heights of 5.5m (see Fig.[3a]). The near-shore wave climate of the fishing harbour was obtained from these input conditions which was run on MIKE 21-SW model.

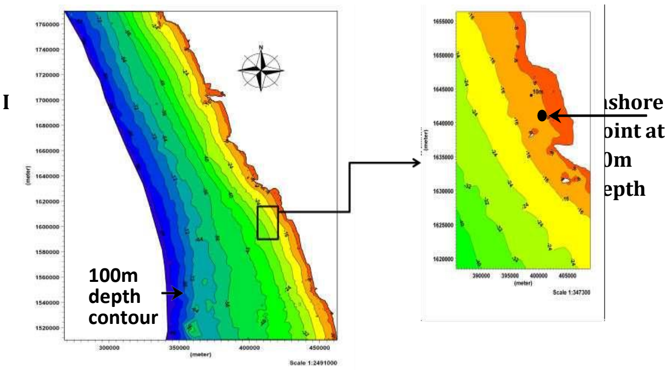


**Fig -2:** Bathymetry for Wave transformation from Offshore to Near-shore

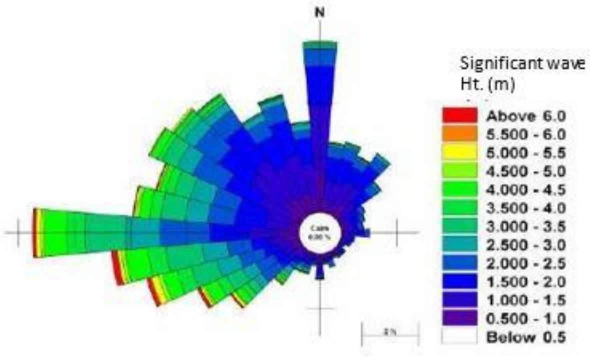


**Fig -3(a)**: Offshore wave rose at Majali

The frequency distrubution of near-shore waves at the Inshore point in 10m depth for SW monsoon, NE monsoon, non-monsoon and entire year is shown in Fig.[3b]. The waves predominantly approached from the sector between 220ºN to 290ºN. As the breakwater in the sector 260ºN to 290ºN gave full protection against the wave attack; the MIKE 21-BW model was stimulated only for the sector 220ºN to 250ºN, where the incident wave height was 2.5m and peak wave period was 10sec.

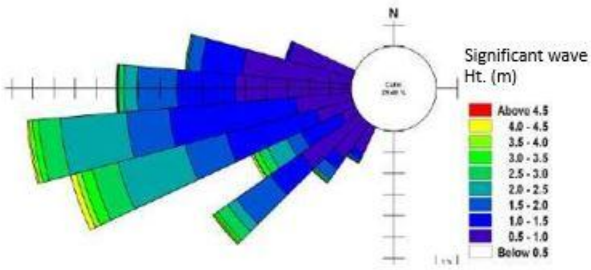


**Fig -3(b)**: Nearshore wave rose at Majali

## 7. BOUSSINESQ WAVE MODEL

The model was set such that there should be maximum grid spacing in horizontal directions of X & Y so that the minimum wave length were also solved. The minimum distance between internal boundaries of wave generation and harbour entrance was maintained equal to four wave lengths.

Maximum time step was chosen in order to get the maximum value of Courant number less than 1. Courant number is defined as:

$$C_r = \frac{c\Delta t}{\Delta x}$$

where,
c: Wave velocity.
Δt: Time step for the solution of the equation.
ΔX & ΔY: Distance of calculation grid spacing in the X & Y directions.

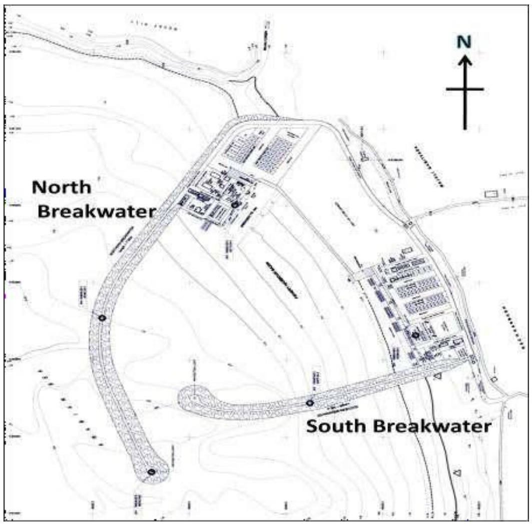


**Fig -4(a)**: Layout suggested by project authorities

A 2m*2m grid spacing and a 0.2sec time step was applied which yielded a maximum Courant number of 0.8m. In order to allow the wave energy to pass out of the model area the outer face of the breakwater was applied with aporosity layer which also resulted in saving computational time. The closing boundaries which backed the sponge layers acted as absorbing boundaries. The following figures shows the suggested layout by the project authorities (Fig.[4a]) and the Modified layout (Fig.[4b]).

**Fig -4(b)**: Modified Layout

## 8. DISCUSSION

| Suggested harbour Layout | Modified harbour layout |
|---|---|
| Nothern breakwater length- 1140m | Nothern breakwater length- 1075m |
| Southern breakwater length- 565m | Southern breakwater length- 415m |
| Distance between northen and southern breakwaters- 130m | Distance between northen and southern breakwaters- 255m |

**Table -1**: Suggested vs Modified harbour layout

Studies for the modified area were also carried out using a model area of 2.2km* 4km which was discretised into a grid size of 2m* 2m. A simulation was also done for MHHS tidal level (1.83m), with critical incident wave direction from 220ºN. The following are the images for the wave height distribution for the suggested and modified layout along with directions.

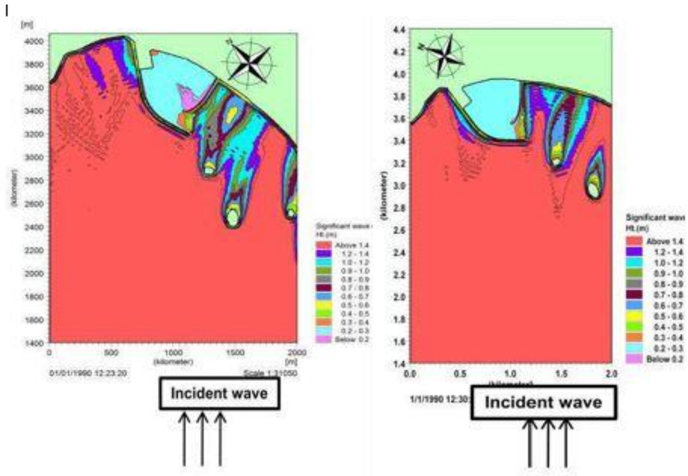


**Fig -5(a):** Wave height distribution from incident waves for Suggested layout from direction 220º & 250º respectively

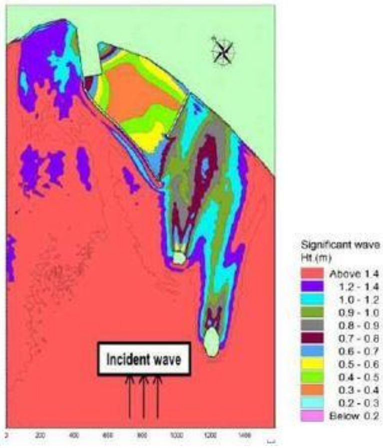


**Fig -5(b):** Wave height distribution from incident waves for Modified layout from direction 220º

## 9. CONCLUSIONS

The studies showed that the sector between 220ºN to 290ºN was predominant for the wave directions; found out using MIKE 21-SW model. It was also seen that the incident waves coming form the sector 220ºN to 250ºN were within the wave tranquility limit of 0.3m which was the port authorities suggested layout, whereas the incident waves coming from 220ºN were of greater height of 2.5m with the modified loyout. Higher wave disturbance was observed with the modified layout with the harbour. Therefore ,the proposed harbour layout was recommended which also protected the harbour from wave attack round the year from all predominant directions.

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