# WAVE TRANSFORMATION ALONG AN APPROACH CHANNEL

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| **Abstract**: When a wave propagates from deep to shallow water regions, the change in wave characteristics is called wave transformation. The processes which affect wave transformations are refraction, diffraction, non-linear interactions etc. the study of the determination of wave transmission in ports is important in designing coastal structures and efficient port operations because wave agitation has influences on the manoeuvring and mooring of vessels. Also, it helps in efficient loading and unloading of ships. Approach channel plays a role in controlling the amount of wave energy entering the harbour. This paper depicts the study of the transformation of waves which encounter an approach channel when propagated towards port from offshore. The wave energy penetrating the harbour is influenced by the sudden depth change which the waves undergo. Long approach channel has a considerable effect on the propagation of waves in and around the port. This paper aims in studying the effect of a long channel direction on wave propagation using Numerical modelling software called MIKE21. The area considered for the study is New Mangalore Port (NMPT), one of the major ports located on the West Coast of India, at longitude and latitude 740 48’E and 120 55’ N respectively situated at Panambur, Mangalore, Karnataka State. It is an artificially developed lagoon type all-weather port with 5200 m long navigation channel dredged to –15.4 m depth contour. Numerical models act as an aid for assessing wave climates in ports with benefit that multiple conditions can be investigated relatively cheap compared to physical models. Transformation from nearshore to the area under consideration is done using MIKE 21 Boussinesq Wave Module (BW). The wave disturbance from different directions with respect true North, derived from MIKE 21 SW model is modelled. Also the difference in wave propagation while varying the time period is also considered. The change in reduction of significant wave height, spreading of wave energy, wave concentration, influence of incident wave field on the wave attenuation and amplification are all the factors which is evaluated and the results obtained showed that there is a considerable effect of approach channel in reducing the wave disturbances. The analysis showed that about 80 perent of the wave energy has been reduced while reaching the ports due to long approach channel . |

### 1. Introduction

Waves in the oceans travel thousands of miles before reaching land .These waves when approaching the shoreline are affected by the seabed and transformations such as refraction, shoaling, bottom friction and wave-breaking occurs. Depth-refraction is the change in the direction of wave propagation when the wave fronts travel from deep to shallow regions. Due to the reduction in wave velocity, the wave fronts make some angle with the depth contours when reaching shallow water depths and therefore, the wave fronts tend to become aligned parallel with the depth contours while reaching the shore. Shoaling is defined as the deformation of the waves, when the water depth becomes less than about half of the wavelength. The shoaling causes a reduction in the wave propagation velocity as well as shortening and steeping of the waves. If the waves meet major port structures or abrupt changes in the coastline, they will be transformed by diffraction also. Diffraction is the process by which the waves propagate into the lee zone behind the structures by energy transmittance laterally along the wave crests. If the structure is steep, reflection occurs and if permeable partial transmission takes place. Wave approaches at an angle to the shore, causing the wave energy to get reflected at an angle equal to the angle which the wave approached which is termed as reflection.

The presence of a navigation channel modifies the wave conditions, both outside and inside a harbour. This shows that the often long navigation channel is to be taken into account in the determination of the relevant wave conditions in the harbour and the surrounding nearshore area. In case of waves encountering a navigation channel in intermediate and shallow water depths, there may be conditions under which part of the waves do not cross the channel, but are reflected by refraction.

Numerical wave models may be used to assess the impact of the navigation channel on the wave conditions. DHI offers the most advanced and proven professional modelling tool MIKE 21 for this purpose. It includes MIKE 21 Boussinesq Wave module, a state-of-the-art tool for analysing wave disturbances in ports, harbours and coastal areas.

MIKE 21 BW is used for detailed modelling of wave induced current fields, surf zone dynamics and swash zone applications in a structured mesh. The model is based on numerical solution of enhanced Boussinesq equation by Madsen and Sorenson (1992).This make it capable for model simulation of propagation of non-linear directional waves from deep to shallow water. The module solves the enhanced Boussinesq equation by an implicit finite difference method with variable defined on a space staggered rectangular grid.

This can reproduce combined effect of all-important wave phenomenon of interest in ports and harbours, which include shoaling, refraction, diffraction, wave breaking, bottom friction, moving shoreline, partial reflection and transmission, non-linear wave-wave interaction, frequency spreading and directional spreading.

### 2. Objectives of the Project

The following objectives were formed to achieve the purpose of the study.

1. To understand and analyse the behaviour of waves at the area of interest.
2. Simulating wave transformation from nearshore region to area under consideration using *MIKE* 21Boussinesq Wave Module classical equation and enhanced equation.
3. To determine the percentage of wave attenuation along the approach channel, in three different wave directions.
4. To determine the percentage of wave attenuation for different time periods when the waves travel along the approach channel
5. To study the various wave transformations occurring during wave propagation (refraction, diffraction, shoaling, combined effects of them etc.)

### 3. Overview of the Project

Wave transformation along a long navigational channel (New Mangalore Port Region) is the subject for the study.

* 1. Using *MIKE 21* BW Setup, the wave transformation from nearshore (-15m depth) to area under study (along the approach channel) is to be analysed.
  2. The analysis is to be done in both classical method and enhanced method for different wave directions and also by varying the wave periods.
  3. Analyse the results and find the suitable direction of approach channel.

### 4. Data collection & methodology

The bathymetry data required for Mike 21 is in .xyz format. The water data was collected from Mike C Map while the land data was obtained from Google Earth which was then converted to required format through the software ArcGIS.

Literature Survey

Data Collection

Preparing the bathymetry for 3 different wave directions

* West
* Along the channel
* West-southwest

Setting up the model in Mike21 BW module

* Classical method
* Enhanced method

Steps:

* Bathymetry
* Sponge layer
* Porosity layer
* Internal wave generation

Simulation

Output

Analysing the result, finding the suitable direction of channel

## 5. Wave Transformation along Approach Channel

### 3.3.1 Study Area (New Mangalore Port)

New Mangalore Port (NMP) is one of the major ports located on the West Coast of India. It is an artificially developed lagoon type all-weather port situated at Panambur, Mangalore, Karnataka State.

### 3.3.2 Location & Site Details

The name "New Mangalore Port" distinguishes it from an old harbour or port in Mangalore city which is called "Mangalore bunder" or "Old bunder". The old harbour is south of New Mangalore port and is now used for fishing and for ferrying small goods. The coordinates of port are Latitude 12° 55’ North and Longitude 74°48’ east. The port is in Panambur, Mangalore on the west coast of India. It is to north of confluence of Gurupura (Phalguni) river to Arabian Sea. It is 170 nautical miles (310 km) south of Mormugao Port and 191 nautical miles (354 km) north of Kochi Port. New Mangalore Port is a lagoon type harbour with a long approach channel artificially created by dredging. The Port is a modern all-weather port situated at Panambur, Mangalore (Karnataka state in south India), on the West Coast of India, The port comprises three dock systems viz. Eastern Dock arm, Oil Dock arm and the western dock arm; it has in all 15 berths. The maximum draft available is 14.0 m at some of these berths. The port is approached through a 7.5 km long channel with water depths in the outer channel being 15.4 m and that of the inner channel being 15.1 m. The Port has a total land area of approximately 822 ha and water spread area of 120 ha.

**3.3.2.1 Meteorology**

The climate at Mangalore is governed by the monsoons. During the months June-September, the south-west monsoon occurs. The later period is often indicated as the post-monsoon period.

***i.Winds***

Wind in Mangalore during monsoon months of June, July and August are predominantly from southwest and west with a maximum intensity of 5 on the Beaufort scale.

***ii.Rainfall***

The average annual rainfall is approximately 3,467 mmm. The rainfall is concentrated in the SW monsoon (June, July, August and September). During this period, the average rainfall is as much as 84% of the total annual rainfall. The maximum rainfall is observed to be in July (1,102.7 mm), and it decreases gradually to 1.9 mm in February.

***iii. Temperature***

Mangalore experiences moderate temperature throughout the year. The temperature varies from 22° C to 36° C. The low temperature occurs during south west monsoon in December and January. The hottest months are from March to May. The mean temperature in the hottest month, before the onset of SW monsoon, is from 33° C to 37° C and lowest temperature recorded is 16.7° C.

***iv. Visibility***

Generally visibility is excellent except for a few days during monsoon. During SW monsoon, thick haze develops in Mangalore with a maximum of 3 no. of foggy days.

***v. Cyclones***

While the average frequency of cyclonic storms in the Arabian Sea is about one per year, there have been years when two or three such storms have occurred. There have also been years without any storms. The maximum wind speed so far recorded has not exceeded 62 kmph (16.9 m/s), except once during 1965 when the maximum speed recorded was 97 kmph (26.9 m/s).

***vi. Relative Humidity***

The humidity is high throughout the year. From June to September during monsoon the humidity ranges from 90% to 100%. From October to January it comes down to 50% to 70%. During summer months of February to May average humidity is about 60%.

**3.3.2.2 Oceanography**

***i. Waves***

The predominant direction of waves at open sea in the vicinity of Mangalore Port during the monsoonmonths of June, July and August is W and SW whereas the predominant direction during the fairweather months is NW and N. Analysis of the data collected from ships in and around Mangalorerevealed that 0.4% of the waves have a height of 4.9 meters above. The wave heights in the non-monsoonmonths are much less.Inside the harbour, generally clam conditions prevail throughout the year as is well protected fromoutside waves by long breakwater on either side of the outer approach channel.

***ii. Tides***

The tides at Mangalore are semi-diurnal in nature with tidal levels, relative to the Chart Datum (CD) as follows:

Level w.r.t. CD (m)

Highest High Water Spring (HHWS) +1.68

Mean Highest High Water (MHHW) +1.48

Mean Lowest High Water (MLHW) +1.26

Mean Sea Level (MSL) +0.95

Mean Lowest Low Water (MLLW) +0.26

Lowest Low Water Spring (LLWS) +0.03

***iii. Currents***

The currents along the coast during SW monsoon (from February to September) are generally towards S (from 160° to 200°). During the northeast monsoon (from November to January) the currents are found to be towards N (from 0° to 40° and 320° to 360°). In the approach channel region covered by breakwater, the current direction lags 6° to 8° behind the coastal currents. The current in the lagoon area further lags behind the approach channel current by another 6°. The subsurface current on an average leads the surface current by 10° to 15°. The magnitude of the current outside the lagoon area during the monsoon season is about 1 to 1.5 knots has been experienced by pilots.

***vi. Littoral Drift***

Seasonal drift distribution has indicated that during NE monsoon, littoral drift is towards N, whereas during SW monsoon and non-monsoon period the drift is towards S. The northwards drift is comparatively less than the southward drift. The average littoral drift in the region is of the order of 0.58 lakh cum towards south during southwest monsoon and non-monsoon period and 0.08 lakh cum towards N in NE monsoon. The average net littoral drift is 0.5 lakh cum per year towards S. Major portion of siltation in the port occurs during the monsoon months of June to September every year. The quantity of maintenance dredging is of the order of 5 million cum per annum.

**3.3.2.3 Navigational Channel, Turning Circle**

Length of Channel - About 7.5 km

Depth of Outer Channel - -15.4 m CD

Width of Channel - 245 m (Side slopes of the navigational channel measures 1:20 from start of the channel up to the breakwater line and 1:10 in the zone from line connecting the breakwater ends and base line).

Turing Circle diameter - 570 m

Depth of Harbour Basin - -15.1 m CD (Side slopes are maintained to 1:6).

**Breakwaters**

Two number of rubble mound breakwaters, one each on north and south, with length of 770 m each have been constructed in three stages on either side of the approach channel with an in between distance of 1,362 m at the root. The breakwaters terminate at a depth of about -6.0 m CD.

NUMERICAL MODELLING USING MIKE21

## 4.1 Mathematical Model Studies

Mathematical model studies for examining wave conditions in the outer harbour of NMPT were carried out in

* Simulation of wave height in the proposed area of port development (using software MIKE 21BoussinesqWave Module).

*MIKE 21* Boussinesq Wave Module

4.3.1 Setting up the Model

Setting up the model is another way of transforming real world events and data into a format which can be understood by the numerical model *MIKE* 21 BW. Thus generally, all the data collected must be resolved on the spatial grid selected.

1. Bathymetry

Bathymetry must be specified as type2 or type1 data file containing the water depth covering the model area. Describing the water depth in the model is one of the most important tasks in modelling process. Bathymetry is created using Bathymetries in *MIKE* Zero.

1. Sponge Layer

For all *MIKE 21* BW applications maps (2DH, dfs2-file) or profile series (1DH, dfs1-file) is required for efficient absorption of short and long period waves along all code values or the water boundary.

1. Porosity Layers

Modelling of partial reflection/transmission requires maps (2DH) or files (1DH) including porosity. This is provided along the land boundary.

1. Boundary Data (Internal Wave Generation)

Model will be forced by the waves generated inside the model domain. The internal wave generation of waves allows absorption of all waves leaving the model area.