Study on Wave Transformation and Tranquillity Studies for the Development of Fish Landing Facility at Ajanur, Kasargod, Kerala

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1 Introduction

Coastal engineering is the study of the processes ongoing at the shoreline and construction within the coastal zone. The field involves aspects of near shore oceanography, marine geology, and civil engineering, often directed at combating erosion of coasts or providing navigational access.

Coastal engineering can be divided in three groups:

- Understanding coastal processes.
- Coastal structures and their impacts on coastal processes.
- Tools available for solving the problems.

As seaways are the cheapest way of transportation, the development of ports and harbour contributes significantly to the development of country. India being the 3rd biggest exporter of fisheries, the construction of new fishing harbour and the maintenance of older fishing harbour and port also play an important role. In view of above, it is extremely needed to test the tranquillity of harbours by studying the wave conditions because waves are the most pre dominant phenomenon that affects the operation of berths and jetties. If the harbour is not tranquil then it will affect the loading and unloading of cargos (CWPRS Technical Report No 4645, 2009).

For this study, Ajanur village has been selected. Ajanur village is situated about 15 km south of Kasargod district at Latitude 12.330 and longitude 75.180 on the west coast of India in Kerala state Fig. 1.Wave tranquillity studies to assess wave disturbance in the harbour and the study of littoral movement and shoreline changes were done.

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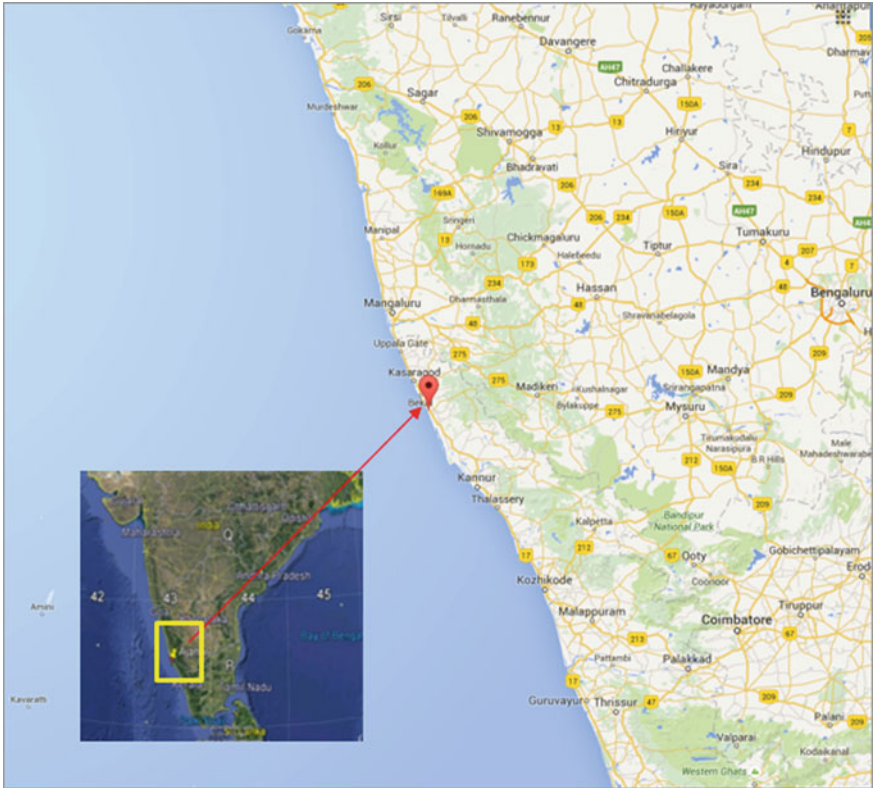e-mail: amritajha.cuj@gmail.com

Fig. 1 Index map of Ajanur, Kasargod, Kerala

2 About MIKE Software

MIKE 21 is a computer program that simulates flows, waves, sediments and ecology in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions. It was developed by DHI.

MIKE 21 can be used for design data assessment for coastal and offshore structures, optimization of port layout and coastal protection measures, cooling water, desalination and recirculation analysis, environmental impact assessment of marine infrastructures, water forecast for safe marine operations and navigation, coastal flooding and storm surge warnings, inland flooding and overland flow modeling.

2.1 MIKE 21 SW (Phase Averaged Model)

It is a new generation spectral wind wave model based on unstructured mesh. The model stimulates growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. It is used in the design of offshore, coastal and port structure where accurate assessment of wave load is of utmost importance to the safe and economic design of these structures.

MIKE 21 SW can be used for the assessment of wave climates in offshore and coastal areas. A major application area is the design of offshore, coastal and port structures where accurate assessment of wave loads is of utmost important to the safe and economic design of these structures. Measured data is often not available during periods long enough to allow for the establishments of sufficiently accurate estimates of extreme sea states. In this case, the measured data can then be supplemented with hind-cast data through the simulation of wave conditions during historical storms using MIKE 21 SW. It is used to calculate wave conditions and associated radiation stresses (MIKE 21 SW Manual).

2.2 Mathematical Model MIKE 21 BW

The Boussinesq Wave model, MIKE 21 BW, is the state-of-the-art numerical model for calculation and analysis of short- and long-period waves in ports, harbors and coastal areas. MIKE 21 BW can also be used for detailed modeling of wave-induced current fields, surf zone dynamics and swash zone oscillations. The model is based on the numerical solution of the enhanced Boussinesq equations formulated by Madsen et al. (1991).

MIKE 21 BW is capable of reproducing the combined effects of all important wave phenomena of interest in port, harbor and coastal engineering (MIKE 21 BW Manual).

2.2.1 Basic Equations

The governing equation is the wave action balance equation. In horizontal Cartesian co-ordinates the conservation equation for wave action is

$$\frac{\partial N}{\partial t} + \nabla.(\vec{v}N) = \frac{S}{\sigma}$$

where $N(\vec{x}, \sigma, \theta, t)$ is the action density, t is the time, $\vec{x} = (x, y)$ is the Cartesian co-ordinates, $\vec{v} = (Cx, Cy, C\sigma, C\theta)$ is the propagation velocity of a wave group in the four dimensional phase space $\vec{x}$, σ and θ. S is the source term for the energy balance

equation. ∇ is the four dimensional differential operator in the $\vec{x}$, σ and θ space. The equation is solved using cell–centered finite volume method (Berkhoff 1972).

3 Model Set-Up

3.1 Wave Data in Deep Sea

The offshore wave data reported by India Meteorological Department (IMD) as observed from ships plying in deep waters off AJANUR (Latitude 10° N to 15° N, Longitude 70° E to 75° E) were analyzed. The frequency distribution of wave heights from different directions during different seasons and entire year for the above offshore data is given in Tables 1, 2, 3 and 4. Corresponding wave rose diagrams are presented in Figs. 2 and 3. It may be noted that the wave height based on ship observed data closely corresponds to significant wave height, which represents average energy of the random wave train.

Table 1 Percentage occurrence of wave height and direction off Ajanur for South-West Monsoon (June–September)

Wave height (m)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	Total
Direction								Calm %		0.56
22.50	0.09	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.27
45.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.12
67.50	0.00	0.00	0.12	0.00	0.13	0.00	0.00	0.00	0.00	0.25
90.00	0.00	0.09	0.07	0.00	0.08	0.07	0.00	0.00	0.00	0.31
112.50	0.00	0.00	0.17	0.15	0.00	0.12	0.00	0.00	0.00	0.44
135.00	0.14	0.11	0.18	0.37	0.29	0.34	0.00	0.23	0.00	1.67
157.50	0.22	0.25	0.42	0.05	0.19	0.21	0.00	0.23	0.03	1.60
180.00	0.06	0.27	0.40	0.66	0.13	0.15	0.06	0.41	0.18	2.32
202.50	0.30	0.15	0.51	0.34	0.24	0.20	0.21	0.23	0.00	2.17
225.00	0.51	1.08	1.49	1.59	1.11	0.93	0.71	0.33	0.21	7.97
247.50	0.58	2.02	2.09	3.72	1.63	1.72	0.82	1.17	0.71	14.46
270.00	1.43	5.03	4.48	5.58	4.80	6.08	3.15	4.19	2.91	37.66
292.50	0.84	2.47	3.89	4.11	3.01	2.94	1.15	1.27	1.65	21.33
315.00	0.14	0.88	1.16	2.09	1.07	0.72	0.04	0.21	0.48	6.77
337.50	0.18	0.60	0.33	0.36	0.08	0.08	0.00	0.00	0.00	1.63
360.00	0.30	0.07	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.46
	4.79	**13.02**	**15.62**	**19.11**	**12.77**	**13.58**	**6.14**	**8.25**	**6.16**	**100.00**

Table 2 Percentage occurrence of wave height and direction off Ajanur for North-East Monsoon Period (OCT-JAN)

Wave height (m)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	Total
Direction								Calm %		0.86
22.50	1.95	2.41	0.95	1.06	0.28	0.16	0.00	0.10	0.00	6.91
45.00	2.22	2.60	1.90	1.81	0.04	0.24	0.00	0.10	0.11	9.03
67.50	1.88	2.71	1.94	0.75	0.33	0.22	0.14	0.00	0.00	7.96
90.00	2.69	3.23	1.71	0.84	0.19	0.43	0.07	0.00	0.00	9.17
112.50	1.55	2.00	0.98	0.80	0.08	0.35	0.10	0.00	0.00	5.87
135.00	0.56	1.45	0.61	0.48	0.03	0.44	0.10	0.00	0.00	3.67
157.50	0.52	0.78	0.99	0.51	0.09	0.22	0.10	0.03	0.00	3.26
180.00	1.19	1.70	1.17	0.97	0.38	0.07	0.00	0.17	0.00	5.65
202.50	0.97	0.50	1.03	0.92	0.25	0.21	0.08	0.00	0.00	3.97
225.00	0.50	1.17	0.77	0.65	0.46	0.04	0.13	0.00	0.10	3.82
247.50	0.90	1.82	1.57	0.83	0.69	0.75	0.10	0.00	0.00	6.67
270.00	0.65	1.82	1.31	1.50	0.17	0.41	0.00	0.00	0.00	5.87
292.50	1.21	1.48	1.63	0.67	0.13	0.19	0.00	0.10	0.00	5.41
315.00	1.15	2.04	0.99	0.47	0.34	0.00	0.00	0.00	0.00	4.98
337.50	1.96	2.77	1.61	0.80	0.11	0.10	0.00	0.00	0.00	7.35
360.00	2.51	3.58	1.73	1.37	0.12	0.22	0.00	0.00	0.00	9.53
	22.43	32.05	20.91	14.44	3.70	4.05	0.83	0.51	0.21	100.00

3.2 Wave Propagation and Surface Elevation Studies

While propagating the waves from 10 m to harbour area, the studies has been done for different layouts.

3.2.1 Studies with Layout 1

Layout 1 consists of north and south breakwaters. The north breakwater is of length 335 m. The southern breakwater consists of shore normal breakwater of length 270 m, which is extended along shore breakwater of length 340 m. The breakwaters extend up to 4–4.4 m depth (Fig. 4). Bathymetry, surface elevation plot of the wave propagation and contours of the wave height in the port for incident wave directions from SW, WSW and West are discussed in the result.

Table 3 Percentage occurrence of wave height and direction off Ajanur for non-monsoon period (Feb-May)

| Wave height (m)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	Total
Direction								Calm %		1.14
22.50	2.30	2.82	1.12	1.01	0.36	0.10	0.16	0.12	0.05	8.04
45.00	2.10	1.40	0.89	0.38	0.13	0.17	0.37	0.37	0.00	5.81
67.50	0.62	1.34	0.22	0.04	0.00	0.22	0.00	0.15	0.00	2.59
90.00	0.87	1.48	0.47	0.60	0.00	0.00	0.00	0.28	0.00	3.69
112.50	0.84	1.33	0.60	0.40	0.00	0.00	0.00	0.05	0.00	3.21
135.00	1.13	1.90	0.86	0.26	0.21	0.00	0.00	0.25	0.00	4.41
157.50	1.58	1.03	1.62	0.62	0.25	0.11	0.04	0.04	0.00	5.32
180.00	1.06	1.98	0.88	0.76	0.07	0.07	0.17	0.10	0.00	5.08
202.50	0.54	0.55	0.96	0.95	0.05	0.16	0.05	0.00	0.00	3.25
225.00	0.98	1.09	0.40	0.61	0.34	0.15	0.26	0.12	0.12	4.07
247.50	0.74	1.02	1.13	1.24	0.23	0.11	0.00	0.10	0.03	4.61
270.00	1.30	2.10	0.81	1.19	0.07	0.48	0.00	0.11	0.08	6.15
292.50	1.68	2.07	1.24	0.40	0.33	0.27	0.00	0.00	0.00	5.99
315.00	3.45	3.18	1.57	0.85	0.45	0.16	0.00	0.00	0.00	9.64
337.50	3.57	4.88	2.78	1.02	0.04	0.15	0.00	0.19	0.11	12.73
360.00	4.78	4.99	2.28	1.10	0.31	0.12	0.30	0.20	0.18	14.25
	27.54	**33.14**	**17.83**	**11.42**	**2.64**	**2.27**	**1.35**	**2.08**	**0.58**	**100.00**

3.2.2 Studies with Layout 2

Layout 2 consists of north and south breakwaters. The northern breakwater consists of shore normal breakwater of length 250 m which is extended along shore breakwater of length 315 m. The southern breakwater is 385 m long and shore normal. The breakwaters extend up to 4 m to 4.4 m depth as shown in Fig. 5

3.2.3 Studies with Layout 3

Layout 2 consists of a long north breakwater and a south breakwater. The northern breakwater consists of shore normal breakwater of length 260 m, which is extended along shore breakwater of length 700 m. The southern breakwater is 295 m long and shore normal. The breakwaters extend till 4 0.5 m depth as shown in Fig. 6.

Table 4 Percentage occurrence of wave height and direction off Ajanur for entire period (Jan–Dec)

Wave height (m)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	Total
Direction								Calm %		6.34
22.50	1.30	1.61	0.71	0.62	0.19	0.08	0.05	0.07	0.01	4.64
45.00	1.29	1.26	0.90	0.67	0.05	0.12	0.11	0.13	0.03	4.57
67.50	0.75	1.26	0.71	0.26	0.14	0.13	0.04	0.04	0.00	3.35
90.00	1.06	1.50	0.75	0.48	0.10	0.15	0.02	0.08	0.00	4.15
112.50	0.72	1.04	0.57	0.43	0.04	0.14	0.03	0.14	0.00	2.98
135.00	0.56	1.07	0.56	0.37	0.12	0.24	0.03	0.14	0.00	3.08
157.50	0.70	0.68	0.96	0.42	0.19	0.18	0.05	0.09	0.01	3.28
180.00	0.69	1.22	0.78	0.76	0.20	0.10	0.07	0.20	0.06	4.08
202.50	0.54	0.40	0.78	0.68	0.18	0.18	0.10	0.07	0.00	2.93
225.00	0.60	1.03	0.86	0.90	0.60	0.36	0.33	0.15	0.13	4.97
247.50	0.66	1.51	1.52	1.86	0.86	0.84	0.31	0.41	0.23	8.21
270.00	1.02	2.73	2.15	2.76	1.73	2.26	1.01	1.37	0.91	15.94
292.50	1.12	1.88	2.14	1.74	1.17	1.12	0.40	0.46	0.50	10.52
315.00	1.42	1.91	1.23	1.13	0.61	0.29	0.02	0.07	0.14	6.83
337.50	1.70	2.58	1.50	0.71	0.09	0.10	0.00	0.05	0.03	6.77
360.00	2.24	2.65	1.26	0.78	0.14	0.10	0.09	0.06	0.05	7.37
	16.38	**24.32**	**17.39**	**14.56**	**6.39**	**6.41**	**2.67**	**3.42**	**2.10**	**100.00**
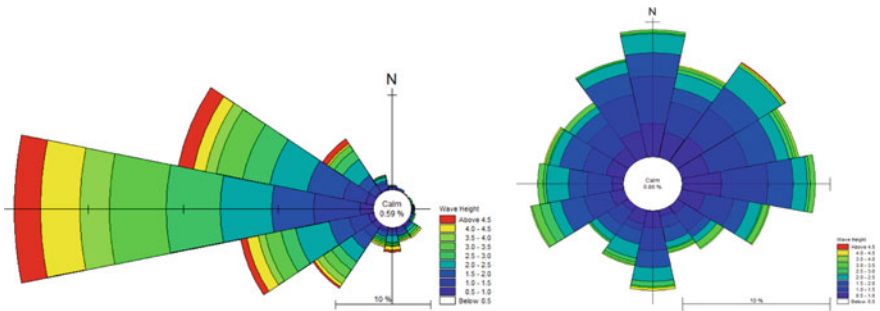
Fig. 2 Wave Rose diagram offshore of Ajanur for SW monsoon (Left) and NE monsoon (Right)

3.3 Spectral Wave Model Setup

From this setup, after simulation we can find the waves in the generation area are of variable heights and frequencies and propagate in all direction.
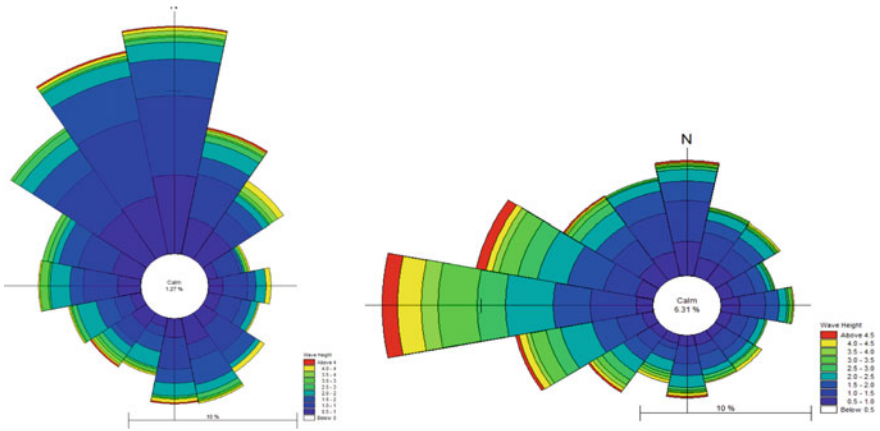
Fig. 3 Wave Rose diagram offshore of Ajanur for non-monsoon (Left) and entire year (Right)
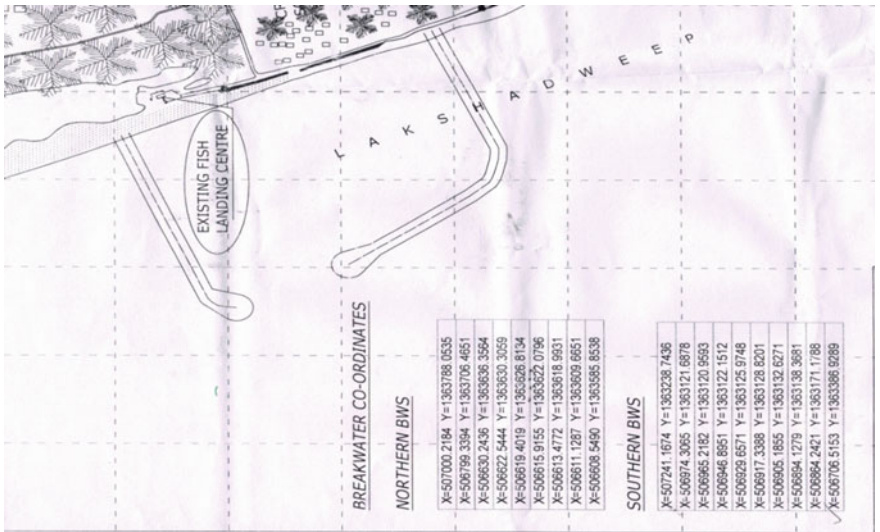

Fig. 4 Proposed layout 1

3.4 Boussinesq Wave Model Setup

This model solves the enhanced Boussinesq equations by an implicit finite difference techniques with variable defined on a space-staggered rectangular grid. This module is typically selected for calculation of short and long wave period, wave disturbance in ports and arbor.
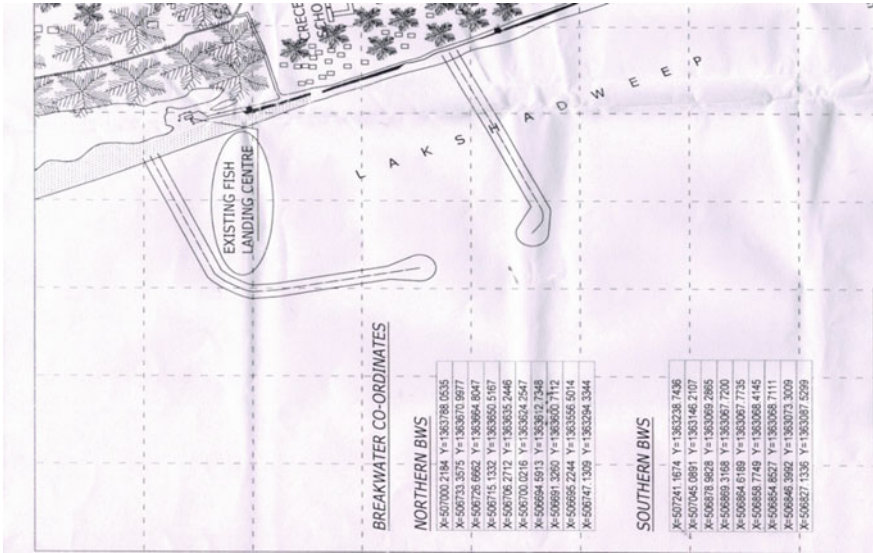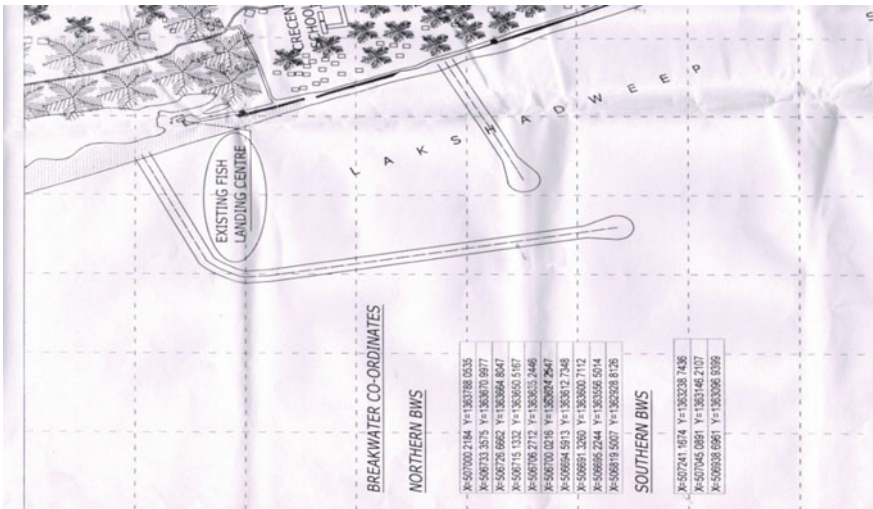
Fig. 5 Proposed layout 2

Fig. 6 Proposed layout 3

For BW model setup, basic focus is on generating 2–3 input parameters i.e. preparation and smoothing of bathymetry, creating wave generation line, porosity and sponge layer.

4   Results and Discussion

4.1   *Result of SW*

The results of the studies of wave transformation from deep water to 10 m depth near Ajanur are shown in rose diagrams (Figs. 7 and 8).

4.1.1   Concluding Remark

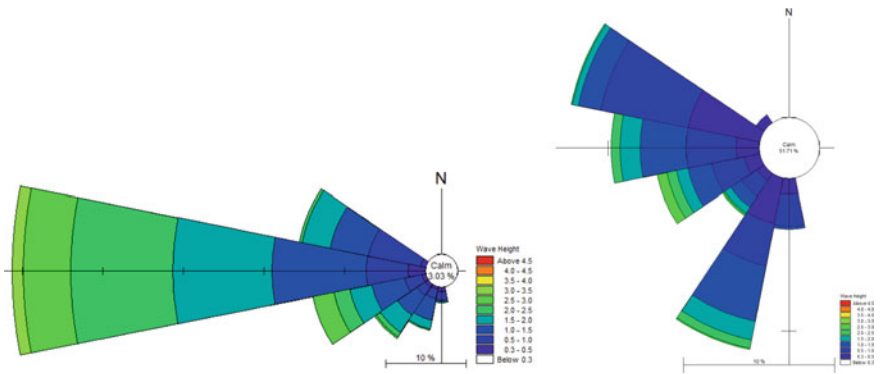The input wave conditions for the wave tranquility studies with MIKE 21 BW model were shortlisted as given in Table 5.

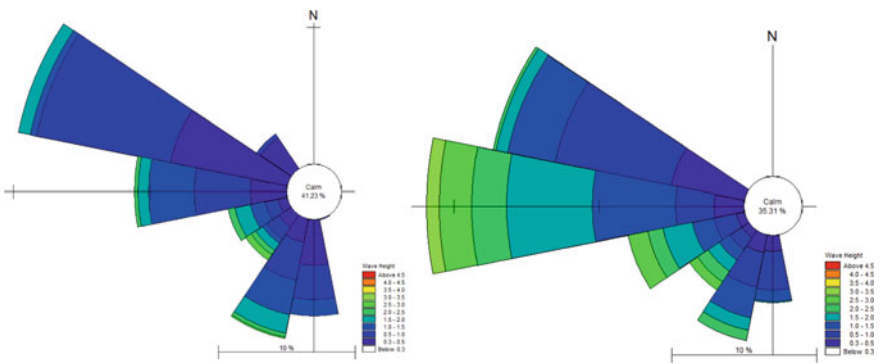**Fig. 7**   Wave Rose diagram near Ajanur for SW monsoon (Left) and NE monsoon (Right)

Fig. 8   Wave Rose diagram near Ajanur for non-monsoon (Left) and entire year (Right)

Table 5 Input wave conditions

Incident wave direction	Incident wave height (m)
SW	2.5
WSW	2.5
Wet	3.0

Table 6 Output from layouts

Wave height	Layout 1		Layout 2		Layout 3		Permissible limit
Incident wave direction	Range (m)	Avg (m)	Range (m)	Avg (m)	Range (m)	Avg (m)	
SW	0.10–0.38	0.22	0.09–0.30	0.19	0.027–0.036	0.03	0.3
WSW	0.13–0.26	0.18	0.23–0.42	0.23	0.028–0.039	0.03	0.3
West	0.16–0.4	0.30	0.19–0.40	0.30	0.018–0.025	0.02	0.3

Since the present development is for fish landing facility, a wave tranquility limit of 0.3 has been assumed for obbtaining the maximum number of operational days of fish landing facility.

4.2 Result of BW

With Layout 3, there is considerable improvement in the wave heights inside the harbour basin. The wave heights are always less than the wave tranquility limit of 0.3 m. With Layout 3, harbour will be operational throughout the year (Table 6).

5 Conclusion

The wave tranquility studies with Layout 1 and Layout 2 indicated that wave heights from west are greater than the wave tranquility criterion of 0.3 m. With the incident wave direction WSW and SW, the wave heights are less than wave tranquility limit of 0.3 m.

With Layout 3, there is considerable improvement in the wave heights inside the harbour basin. The wave heights are always less than the wave tranquility limit of 0.3 m. With Layout 3, the harbour may be operational throughout the year.

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