ISSN No:-2456-2165

Setting up of a Mathematical Model using MIKE Software for a Coastal Project

Vivek Chandrakant Jadhav
Dr. A. R. Deshmukh (Guide)
Dr. M. Phani Kumar (scientist-D, CWPRS)(Co-Guide)
Department of Civil Engineering
JSPM's Rajarshi Shahu College of Engineering, Tathawade, Pune

Abstract:- This project work involves setting up a mathematical model using MIKE 21 BW software. MIKE 21 BW is based on the numerical solution of time domain formulations of Boussinesq type equations. For the simulation, a two-Dimensional Boussinesq wave module has been used. Mathematical model studies were carried out for assessment of wave tranquility inside the port basin at Kamarajar port, Tamil Nadu. The Port has developed terminals through private sector participation to handle liquids, coal and iron ore. To meet the growing demand in the hinterland and trade, Kamarajar Port has plan for expansion of port facilities. The model simulation is carried out to ascertain the wave disturbance and surface elevation inside the harbour basin for a predominant wave direction. The model set up is successful in obtaining the model results pertaining to wave tranquility. Wave heights at all the berthing locations are within the permissible tranquility limit for the incident wave direction.

Keywords*:- Wave Transformation, Wave Tranquility, Permissible Tranquility Limit*

I. INTRODUCTION

Kamarajar Port, located on the East coast of India, about 24 km North of Chennai Port. It is located on the east coast at Latitude 13° 15' 30" N and Longitude 80° 21' 00" E. It is one of the major Ports of India and first corporate port in the country with autonomous management. Kamarajar Port was commissioned by the then Prime Minister of India on 1st February 2001. This port has adequate road and rail links. Kamarajar Port was originally conceived as a satellite port to the Chennai Port, primarily to handle thermal coal to meet the requirement of Tamil Nadu Electricity Board (TNEB), to decongest the busy Chennai Port, Kamarajar Port is evolving itself into a full-fledged port with the capacity to handle a wide range of products and it handled 30.45 MMT cargo in 2017-18. Terminal facilities at the port comprises of Two coal wharves (16MTPA), Common marine liquid terminal (3MTPA), Common user coal terminal (10MTPA), Automobile export terminal (3MTPA) as working & container terminal and multi cargo terminal is under development. KPL has proposed to invest towards capacity enhancement projects, Capital dredging, Road connectivity, Rail connectivity, Contribution to SPV projects, ECPP liabilities in the coming years. After completion of master plan the harbor basin would be able to handle about 158.6 MTPA cargo of different commodities by 2035.

Problem solving process in Coastal Engineering :

- Identify Problem
- Identify Problem Solving Technique
- Select Appropriate Tool
- Apply Problem Solving Tools & Collect Results
- Interprete Results
- Solution

Physical Models involve the reproduction of real life processes at a reduced scale. The model is designed so that the dominant forces affecting the system are reproduced in correct proportion, by
satisfying one of several scaling criteria. Unlike numerical models which are required to be calibrated prior to being used as an accurate prediction tool, if a physical model is scaled appropriately, the results are expected to be representative. However, model- prototype conformity based on the available data helps improving the efficacy of model results.

Numerical modeling is a process of creating mathematical models and using computational algorithms to simulate and analyze complex systems or phenomena. It involves representing real-world systems or processes using mathematical equations and then solving those equations using computers.
Here are some key steps involved in the numerical modeling process:

- Problem Formulation: Clearly defining the system or phenomenon to be modeled and identifying the relevant variables, parameters, and governing equations.
- Discretization: Breaking down the continuous system or phenomenon into discrete elements or grid points.
- Mathematical Representation: Expressing the governing equations as a set of discrete algebraic equations or differential equations, depending on the nature of the problem.
- Numerical Solution: Employing numerical algorithms and methods to solve the discrete equations iteratively. These methods may include finite difference, finite element, finite volume, or other numerical techniques.
- Validation and Verification: Comparing the numerical results with experimental data or analytical solutions, if available, to ensure the accuracy and reliability of the model. This step helps validate the model's predictive capabilities.
- Sensitivity Analysis: Investigating the influence of different input parameters and boundary conditions on the model output. Sensitivity analysis helps identify key

factors and understand the system's response to variations in these factors.

- *Aim*

Aim of the project is to set up a Mathematical Model for a typical port project on east coast of India viz. Kamarajar Port by acquiring sufficient knowledge of MIKE software and coastal engineering aspects.

- *Objective*

- Setting up of mathematical models using MIKE 21 Boussinesq wave (BW) Module software to ascertain wave hydrodynamic conditions using a mathematical model for a Kamarajar Port.
- To impose suitable boundary conditions to represent site-specific, critical and vulnerable wave flux.
- Useful to optimize the development scheme to achieve desirable tranquility inside the harbour basin.
- Simulation of wave propagation in the Kamarajar Port, to compute wave heights in the Port area for the proposed port layout using mathematical model MIKE21-BW.

II. METHODOLOGY

This chapter describes the basic methodology adopted for the study. The mathematical model was setup using MIKE 21 Boussinesq Wave (BW) Module. MIKE Software was used to digitize the study area. The wave pattern has been studied in a modeled area. The basic input data needed for model includes Bathymetry, wave data to impose Boundary condition, layout and structural details of berthing structures. Wave and other input data files are prepared using MIKE 21 tool box. The model runs include a Baseline model to model the present site conditions and the model was evaluated, and then followed by harbour basin area. The model simulations were successfully completed, and the results were analyzed. The detailed model setup is discussed in the following sections.

III. SITE CONDITIONS

- *Wave Data In Deep Sea*

The offshore wave data of 33 years of Kamarajar port, reported by India Meteorological Department as observed from ships plying in deep waters were analyzed. The frequency distribution of wave heights from different directions during south-west monsoon (June-September), north-east monsoon (October-January), non-monsoon period (February-May) and entire year for the above offshore wave data is given in Tables.

Table 1A: Percentage Occurrence of Wave Height & Direction off Kamarajar Port South-West Monsoon Period (June-September)

WAVE HT(m)	<0.5	<1	<1.5	<2	<2.5	<3	<3.5	<4	<4.5	TOTAL
DIRECTION(°N)									CALM% 1.19	
22.5	0.07	0.09	0	0.05	0	0	0	0	0.05	0.26
45	0.15	0.03	0	0.02	0.01	0.01	0	0	0.01	0.23
67.5	0.32	0.21	0.05	0.05	0.43	0.22	0	0	0	1.27
90	0.22	0.27	0	0	0.19	0.29	0	0	0.04	1
112.5	0.29	0.25	0.07	0	0.12	0.04	0.12	0	0.02	0.91
135	0.78	0.6	0.04	0.08	0.01	0.01	0.02	0.04	0	1.58
157.5	0.72	1.76	1.09	0.7	0.14	0.13	0.17	0	0	4.71
180	1.51	4.2	2.47	2.54	0.99	0.66	0.15	0.19	0.12	12.83
202.5	1.8	4.97	3.75	3.57	2.83	1.47	0.48	0.29	0.29	19.45
225	0.98	4.46	4.76	5.57	3.66	2.3	1.03	0.28	0.3	23.34
247.5	0.97	4.91	3.9	4.39	3.39	2.1	0.67	0.49	0.63	21.45
270	0.5	2.26	2.44	1.53	1.06	0.46	0.17	0.1	0.03	8.54
292.5	0.33	0.44	0.54	0	0.24	0.12	0	0	0	1.67
315	0.11	0.23	0.33	0.11	0	0.01	0	0.06	0.01	0.85
337.5	0.1	0.03	0.19	0	0.02	0.02	0	0	0.05	0.42
360	0.1	0.08	0.04	0	0.04	0.04	0	0	0	0.31
TOTAL	8.95	24.79	19.67	18.61	13.13	7.88	2.81	1.45	1.55	100

Table 1B: Percentage Occurrence of Wave Height & Direction off Kamarajar Port North -East Monsoon Period (October-January)

WAVE HT(m)	<0.5	<1	<1.5	<2	<2.5	<3	<3.5	<4	<4.5	TOTAL
DIRECTION(°N)									CALM% 2.17	
22.5	0.8	3.63	2.86	2.18	0.78	1.07	0.27	0.37	0.09	12.06
45	2.51	4.42	4.19	3.56	1.55	0.99	0.21	0.27	0.02	17.72
67.5	1.75	3.52	4.13	3	2.65	1.2	0.27	0.12	0.06	16.7
90	1.66	1.74	2.4	1.69	0.65	0.56	0.14	0.27	0.17	9.28
112.5	0.8	0.97	0.86	0.12	0.1	0.13	0.07	0	0.04	3.09
135	0.54	0.41	0.38	0.43	0.03	0.08	0.02	0	0.01	1.92
157.5	0.25	0.94	0.34	0.38	0.1	0.12	0.1	0	0	2.23
180	1.24	2.38	0.98	0.51	0.23	0.18	0	0	0	5.52
202.5	0.26	0.84	0.71	0.67	0.46	0.2	0.17	0.1	0.04	3.46
225	0.54	1.26	0.97	0.84	0.28	0.04	0.06	0.09	0.08	4.16
247.5	0.6	1.67	1.22	1.19	0.63	0.09	0.17	0.16	0.1	5.83
270	0.39	0.73	0.78	0.62	0.42	0.42	0	0.06	0.15	3.56
292.5	0.62	0.58	0.48	0.07	0.16	0.06	0.15	0.13	0.02	2.27
315	0.6	0.58	0.41	0.11	0.24	0	0.04	0.08	0	2.06
337.5	0.33	0.51	0.69	0.27	0.07	0.06	0.16	0	0	2.1
360	0.91	1.33	1.19	1.1	0.4	0.3	0.31	0.23	0.11	5.88
TOTAL	13.8	25.51	22.59	16.74	8.75	5.5	2.14	1.88	0.89	100

Table 1C: Percentage Occurrence of Wave Height & Direction off Kamarajar Port Non Monsoon Period (February-May)

WAVE HT(m)	<0.5	<1	<1.5	<2	<2.5	<3	<3.5	<4	<4.5	TOTAL
DIRECTION(°N)									CALM% 3.15	
22.5	0.84	1.52	0.5	0.35	0.28	0	0	0	0	3.49
45	1.89	1.76	1.93	0.71	0.62	0.11	0	0.09	0	7.11
67.5	2.67	3.04	2.06	1.24	0.3	0	0.08	0.16	0	9.54
90	3.51	3.74	2.27	1.09	0.17	0.04	0	0.05	0	10.87
112.5	1.87	2.11	1.27	0.44	0.15	0.1	0.15	0.03	0	6.13
135	1.25	2.15	1.07	0.55	0.06	0.05	0.03	0.02	0	5.18
157.5	2.58	3.96	1.89	0.88	0.17	0.27	0.07	0.15	0	9.98
180	2.93	4.83	2.73	1.81	0.65	0.24	0.04	0	0	13.24
202.5	2.02	2.67	2.01	1.68	1.33	0.51	0.4	0	0.1	10.72
225	0.88	1.5	1.83	1.18	0.86	0.69	0.19	0.1	0	7.23
247.5	1.09	1.5	1.31	0.92	0.53	0.27	0.07	0.23	0	5.91
270	0.38	0.43	0.25	0.11	0.24	0.06	0.08	0	0	1.55
292.5	0.41	0.74	0.06	0.09	0	0	0.06	0	0	1.36
315	0.37	0.63	0.28	0.01	0	0	0.01	0	0	1.29
337.5	0.37	0.11	0.35	0	0	0	0	0.03	0	0.86
360	0.87	0.43	0.68	0.17	0	0.11	0.08	0.06	0	2.39
TOTAL	23.93	31.12	20.49	11.23	5.36	2.45	1.26	0.92	0.1	100

ISSN No:-2456-2165

Table 1D: Percentage Occurrence of Wave Height & Direction off Kamarajar Port Entire year (January-December)

WAVE HT(m)	<0.5	<1	<1.5	<2	<2.5	<3	<3.5	<4	<4.5	TOTAL
DIRECTION(°N)									CALM% 4.63	
22.5	0.57	1.77	1.18	0.87	0.34	0.37	0.09	0.13	0.05	5.37
45	1.55	2.18	2.2	1.55	0.78	0.39	0.08	0.14	0.01	8.88
67.5	1.54	2.26	2.04	1.44	1.15	0.47	0.13	0.09	0.02	9.15
90	1.84	1.88	1.56	0.91	0.34	0.3	0.05	0.11	0.07	7.06
112.5	0.97	1.09	0.74	0.17	0.11	0.1	0.11	0.01	0.02	3.32
135	0.79	1.08	0.54	0.37	0.03	0.05	0.02	0.02	0.01	2.90
157.5	1.06	2.23	1.06	0.66	0.12	0.16	0.12	0.04	0	5.46
180	1.62	3.27	2.02	1.63	0.62	0.38	0.06	0.06	0.04	9.70
202.5	1.29	2.79	2.25	2.01	1.53	0.76	0.28	0.1	0.15	11.16
225	0.72	2.15	2.45	2.33	1.45	0.96	0.39	0.15	0.13	10.73
247.5	0.76	2.31	2.12	2.02	1.36	0.86	0.28	0.27	0.27	10.26
270	0.42	1.02	1.08	0.71	0.48	0.32	0.08	0.06	0.05	4.24
292.5	0.43	0.54	0.32	0.05	0.11	0.07	0.06	0.05	0.01	1.63
315	0.35	0.51	0.34	0.08	0.09	0.01	0.02	0.05	0	1.44
337.5	0.3	0.23	0.41	0.11	0.03	0.03	0.06	0.01	0.01	1.17
360	0.62	0.63	0.64	0.44	0.15	0.15	0.12	0.1	0.03	2.90
TOTAL	14.81	25.94	20.94	15.38	8.69	5.39	1.94	1.38	0.88	100

➢ *Tide Levels*

Tidal levels at Chennai were considered for the model studies and are given in table

Table 2 : Tide Levels

Tidal Levels	
Mean High Water Spring (MHWS)	+1.1 m
Mean High Water Neap (MHWN)	+0.8 m
Mean Sea Level (MSL)	+0.65 m
Mean Low Water Neap (MLWN)	+0.4 m
Mean Low Water Spring (MLWS)	+0.1 m

IV. WAVE TRANSFORMATION STUDIES

➢ *Wave Transformation For Assessment Of Near-Shore Wave Climate*

The wave climate near Kamarajar Port was obtained by transforming the ship observed deepwater wave data, using MIKE 21 SW model. Bathymetry in the model region of about 34 km X 78 km and extending up to 150 m depth contour was schematized with an unstructured triangular mesh. The model was run to obtain near-shore wave climate at the inshore point in 20 m depth contour. The wave direction and the transfer function (ratio of wave heights) at the inshore Point for waves with 12 sec wave period with different directions of wave incidence at the offshore boundary are given in the following Table.

Table 3 : Transformation From Deep To Shallow Coastal Waters

Sr. No.	Offshore Direction (Deg. N)	Inshore Direction (Deg. N)	Transfer Function (Hi /Ho)
1	22.5 (NNE)	56.64	0.562
2	45.0 (NE)	63.44	0.777
3	67.5 (ENE)	74.90	0.853
4	90.0 (E)	90.65	0.849
5	112.5 (ESE)	107.66	0.824
6	135.0 (SE)	123.80	0.783
7	157.5 (SSE)	137.08	0.714
8	180.0 (S)	143.76	0.555
9	202.0 (SSW)	145.00	0.301
10	225.0 (SW)	143.19	0.098

Hi = Wave height at the inshore Point
Ho = Offshore wave height

Above transformation was applied to the deep water wave data [Tables 1A to 1D] to obtain the frequency distribution of waves at the Inshore Point in 20 m depth for SW monsoon, NE monsoon, non-monsoon and entire year [Tables 4A to 4D]. The corresponding wave rose diagrams are shown in fig 7 below.

Table 4A: Percentage Occurrence of Wave Height & Direction Near Kamarajar Port in 20 m Depth during South-West Monsoon (June- September)

Wave Ht(m)	0.5	1	1.5	2	2.5	3	3.5	4	TOTAL
Direction								Calm	13.5
67.5°N(ENE)	0.83	0.78	0.55	0.41	0.41	0.16	0.04	0.02	3.2
90°N(East)	0.78	0.6	0.04	0.08	0.01	0.03	0.04	0	1.58
112.5°N(ESE)	0.72	1.76	1.09	0.7	0.27	0.17	0	0	4.71
135°N(SE)	14.07	28.27	20.81	9.69	3.19	0.44	0.48	0.12	77.1
Total	16.4	31.41	22.49	10.88	3.88	0.8	0.56	0.14	100

Table 4B: Percentage Occurrence of Wave Height & Direction Near Kamarajar Port in 20 m Depth during North - East Monsoon (October-January)

Wave Ht(m)	0.5	1	1.5	2	2.5	3	3.5	4	TOTAL
Direction								Calm	47.81
67.5°N(ENE)	4.21	10.36	8.91	3.93	0.78	0.4	0.44	0.04	29.1
90°N(East)	0.54	0.41	0.38	0.43	0.03	0.1	0	0.01	1.9
112.5°N(ESE)	0.25	0.94	0.34	0.38	0.22	0.1	0	0	2.23
135°N(SE)	5.53	7.36	3.91	1.3	0.72	0.1	0.04	0	19
Total	10.53	19.07	13.54	6.04	1.75	0.7	0.48	0.05	100

Table 4C: Percentage Occurrence of Wave Height & Direction Near Kamarajar Port in 20 m Depth during Non Monsoon (February-May)

Wave Ht(m)	0.5	1	1.5	2	2.5	3	3.5	TOTAL
Direction							Calm	21.22
67.5°N(ENE)	8.05	10.95	5.08	1.78	0.35	0.25	0.08	26.54
90°N(East)	1.25	2.15	1.07	0.55	0.06	0.08	0.02	5.18
112.5°N(ESE)	2.58	3.96	1.89	0.88	0.44	0.07	0.15	9.97
135°N(SE)	9.73	12.55	8.76	4.67	1.25	0.04	0.1	37.1
Total	21.61	29.61	16.8	7.88	2.1	0.44	0.35	100

Table 4D: Percentage Occurrence of Wave Height & Direction Near Kamarajar Port in 20 m Depth during Entire Year (January-December)

Wave Ht(m)	0.5	1	1.5	2	2.5	3	3.5	4	TOTAL
Direction								Calm	30.26
67.5°N(ENE)	4.35	7.27	4.89	2.02	0.5	0.28	0.19	0.02	19.52
90°N(East)	0.79	1.08	0.54	0.37	0.03	0.07	0.02	0.01	2.91
112.5°N(ESE)	1.06	2.23	1.06	0.66	0.28	0.12	0.04	0	5.45
135°N(SE)	8.82	14.9	10.88	5.13	1.7	0.16	0.21	0.04	41.84
Total	15.02	25.48	17.37	8.18	2.51	0.63	0.46	0.07	100

It is seen from these studies that the predominant directions at 20 m depth are ENE, East, ESE and SE. The 95%occurenece values of wave heights from Table 4(D) from different directions were considered for assessment of wave tranquility in Kamarajar port basin and are as given below.

ISSN No:-2456-2165

Table 5: Input Wave Conditions for MIKE-21 BW Model

WAVE DIRECTION (Degree N)	WAVE PERIOD (Sec)	WAVE HEIGHT (m)
East	11	2.5

V. SETTING UP THE MODEL

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

- *Bathymetry*

Bathymetric data provides information about the shape, relief, and features of the underwater terrain, including the location of underwater mountains, valleys, canyons, and other geological formations. You have to specify the bathymetry as a type 2 or type 1 data file containing the water depth covering the model area.

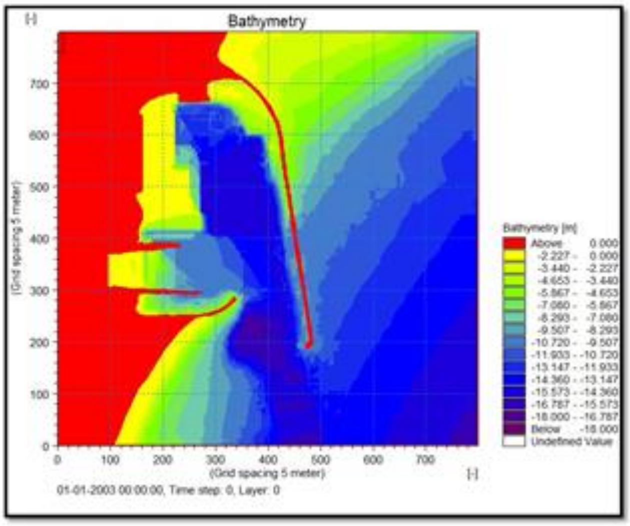

Fig 1:Bathymetry created for tranquility study of Kamarajar Port (.dfs2 file)

- *Sponge Layer*

In mathematical modeling, a "sponge layer" refers to a technique used to absorb or dampen waves near the boundaries of a computational domain. This technique is commonly used in numerical simulations that involve solving partial differential equations (PDEs) in unbounded domains or domains with open boundaries.

In practical for all MIKE 21 BW applications one has to prepare maps (2DH, dfs2- file) or profile series (1DH, dfs1-file) for efficient absorption of short and long period waves and to avoid unrealistic reflections.

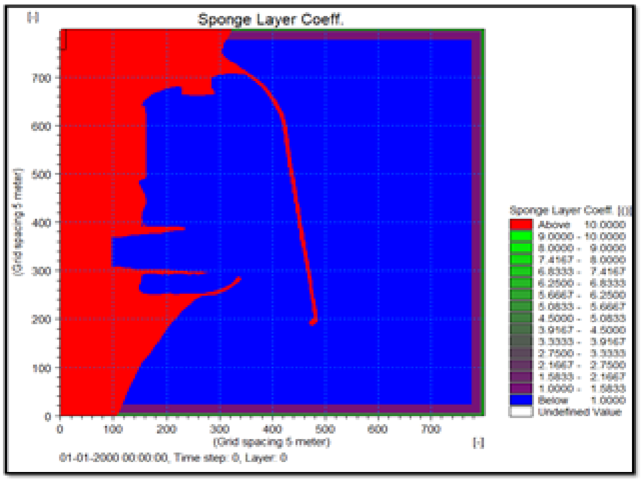

Fig 2: Sponge Layer provided at model Boundaries of Kamarajar Port Model(.dfs2 file)

- *Porosity Layer*

In mathematical modeling, a porosity layer is a concept used to represent a region with varying levels of permeability or porosity within a mathematical model. It is commonly used in the field of fluid dynamics, particularly in the study of flow through porous media.

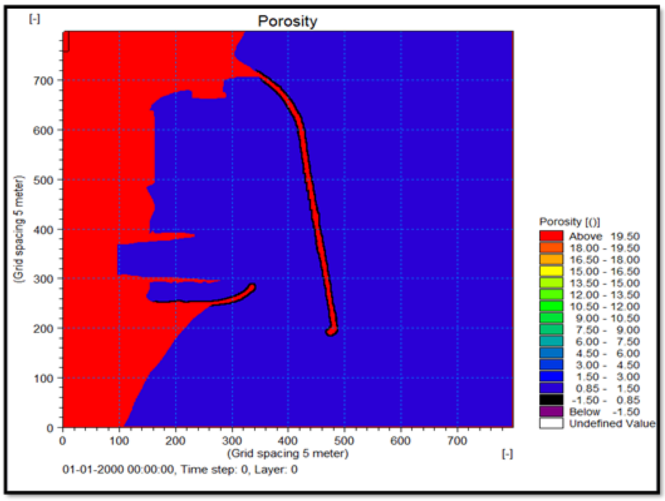

Fig 3; Porosity Layer

Modeling of partial reflection/transmission requires preparation of maps (2DH) or files (1DH). This can be done by preparing porosity layers for inclusion in the specification file of the model.

- *Boundary Data*

In most cases you will force the model by waves generated inside the model domain. The internal wave generation of waves allows you to absorb all waves leaving the model domain (radiation type boundaries). This input file has to be prepared based on the site-specific conditions using Mike-21 tool box

ISSN No:-2456-2165

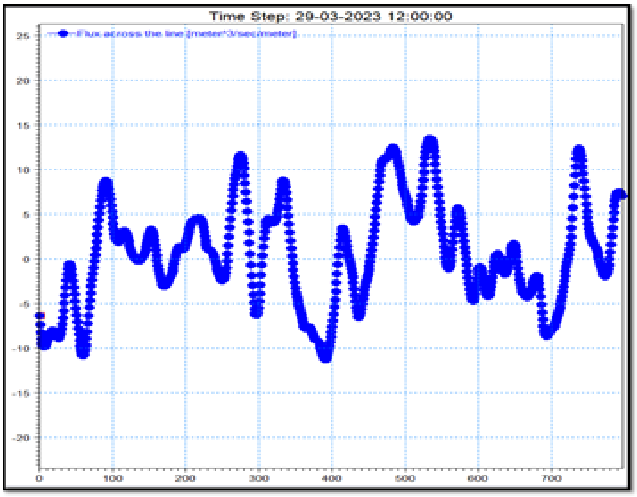

Fig 4: Wave Setup created for the internal wave generation during Simulation of Model (.dfs1 file)

➢ *Calibrating And Verifying The Model*

The purpose of the calibration is to tune the model in order to reproduce known/measured wave conditions. The calibrated/tuned model is then verified by running one or more simulations for which measurements are available without changing any tuning parameters. Once the model results are validated, the prepared model can be utilised for various simulations / conditions by suitably changing the boundary conditions or geometry. Model simulations for different scenario help evolving the optimum layout and the best possible development strategy.

VI. RESULTS AND DISCUSSIONS

➢ *Surface Elevation*

The surface elevation is a basic model parameter and should always be included in your model specifications. It is calculated on basis of computed water depth and bathymetry.

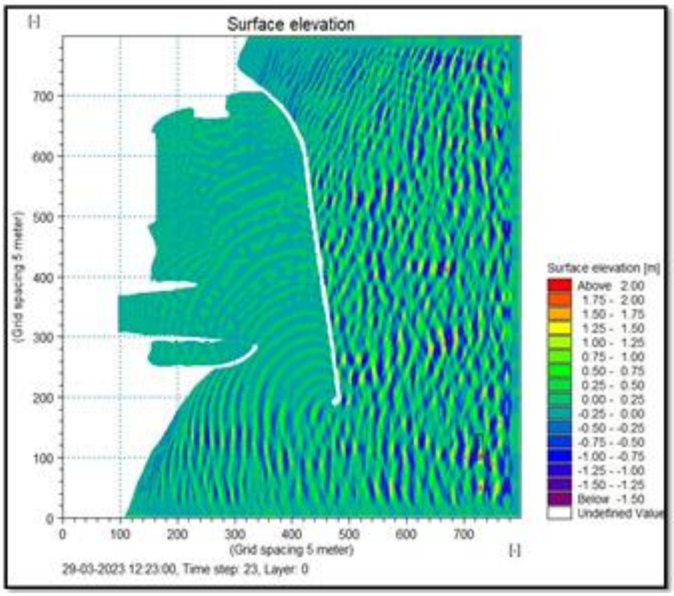

Fig 5: Generated 2D output file of Surface Elevation after complete

Table 6 : Values of Surface Elevation at various location inside port simulation of Model

Location	Surface Elevation		
	Min	Max	Mean
Point A (300,500)	-0.043	0.041	0.005
Point B(228,266)	-0.059	0.052	-0.0008
Point C(357,638)	-0.050	0.040	0.0005
Coal Berth No. 4	-0.076	0.048	-0.003
Coal Berth No. 3	-0.069	0.071	-0.004
Proposed Dock Basin II	-0.075	0.046	-0.004
ProposedMulti cargo Terminal	-0.071	0.054	-0.004
Proposed LNG Berth	-0.061	0.052	-0.002
MLT- I	-0.040	0.037	-0.001
MLT -II	-0.046	0.044	0.0008

Visualisation using MIKE Zero Plot Composer (Time Series Plot). Time series of surface elevation at three different locations is given in fig.

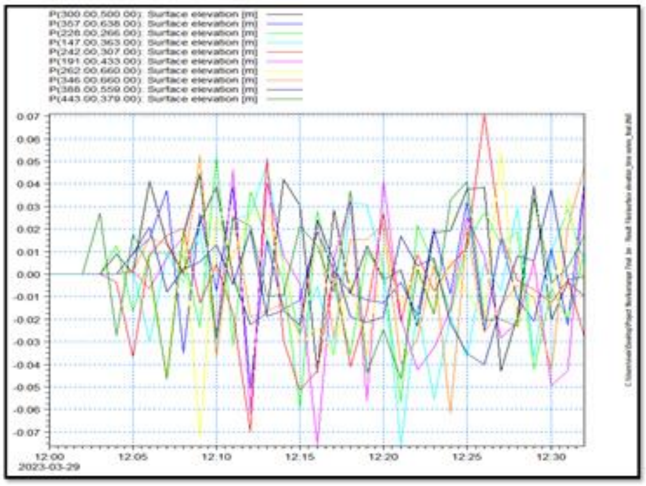

Fig 6: Time Series plot of Surface Elevation at various Locations inside Harbour Basin

➢ *Wave Disturbance Coefficient*

Wave disturbance coefficients are typically derived from experimental or numerical studies and are specific to different types of structures. They are used in the calculation of wave forces and moments acting on the structure, which are essential for structural design and analysis.

By incorporating wave disturbance coefficients into design calculations, engineers can assess the structural integrity, stability, and overall safety of coastal structures under wave loading conditions. These coefficients play a crucial role in ensuring that structures are appropriately designed to withstand the forces exerted by waves and provide effective protection in coastal environments.

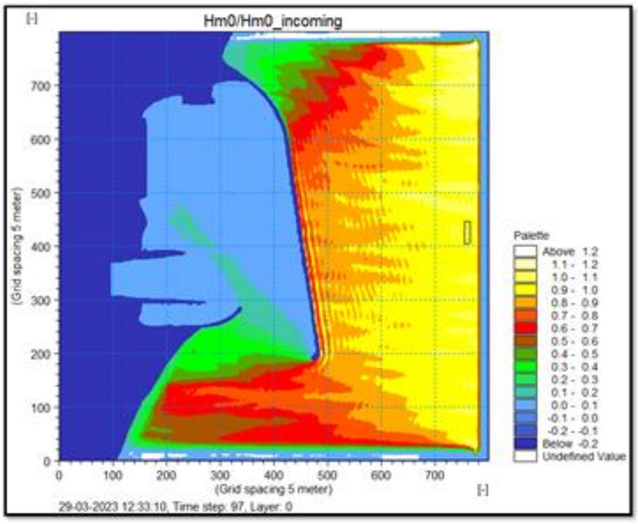

Fig 7: Statistical Results- 2D visualization using MIKE zero Plot Composer Grid Plot. Wave disturbance coefficient at Kamarajar Port.

Table 7 : Values of Wave Disturbance Coefficient at various Location.

Sr .No	Location	Wave disturbance coefficient
1.	Point A(300,500)	0.0404
2.	Point B(357,638)	0.0355
3.	Point C(228,266)	0.0495
4.	Coal Berth No. 4	0.0462
5.	Coal Berth No. 3	0.0453
6.	Proposed Dock Basin II	0.0651
7.	Proposed Multi cargo Terminal	0.0504
8.	Proposed LNG Berth	0.0438
9.	MLT- I	0.0270
10.	MLT -II	0.0393

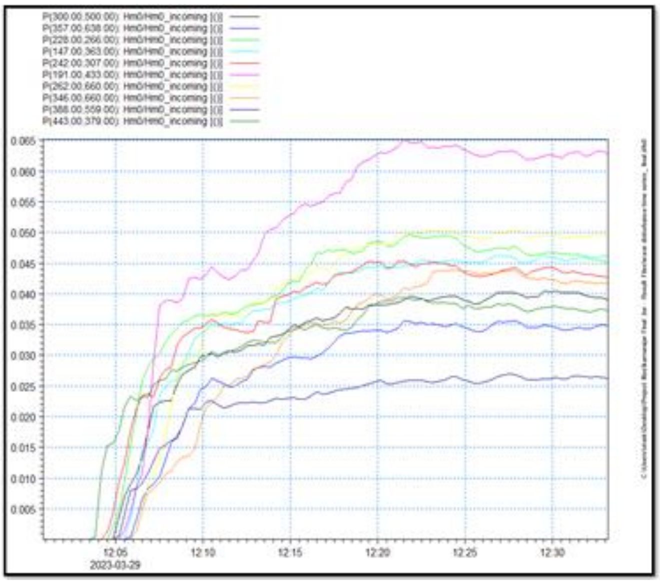

Fig 8: Time Series of Wave Disturbance Coefficient at Various Locations

> *Significant Wave Height*

Significant wave height is a parameter commonly used in oceanography, coastal engineering, and marine forecasting to describe the average height of the highest one-third of waves in a given wave dataset. It provides a measure of the overall wave energy and is a key parameter for understanding and predicting wave conditions.

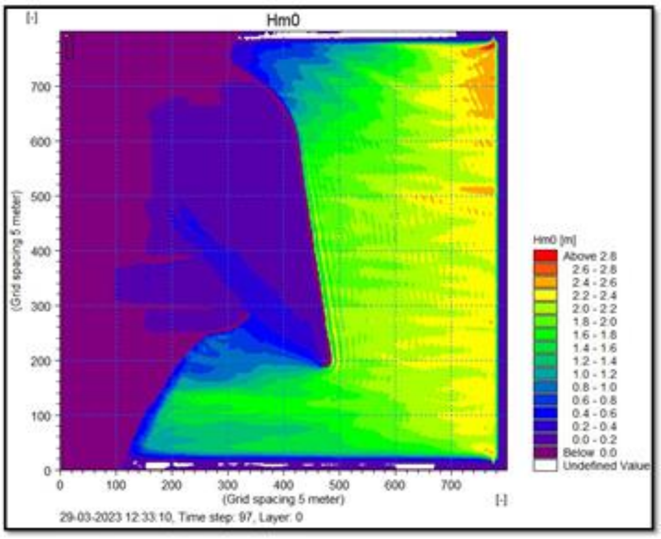

Fig 9: Map of Wave Height simulated by MIKE 21 BW

Table 8 : Values of Significant Wave Height at different location

Sr .No	Location	Wave Height (m)
1.	Point A(300,500)	0.091
2.	Point B(357,638)	0.080
3.	Point C(228,266)	0.106
4.	Coal Berth No. 4	0.106
5.	Coal Berth No. 3	0.099
6.	Proposed Dock Basin II	0.145
7.	Proposed Multi cargo Terminal	0.113
8.	Proposed LNG Berth	0.096
9.	MLT- I	0.060
10.	MLT -II	0.086

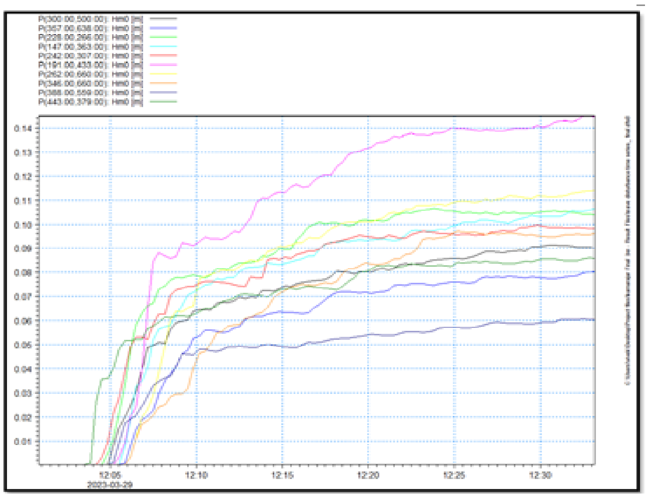

Fig 10: Time Series of Significant Wave Height is plotted at Different Locations

ISSN No:-2456-2165

VII. CONCLUSION

Mathematical model studies carried out for simulation of wave tranquility at Kamarajar port indicated that:

- In the near-shore of Kamarajar port, in 20 m depth, the predominant wave directions are from ENE, East, ESE and SE.
- Wave heights at all the proposed berths were seen to be within the permissible tranquility limit for all the incident waves from East direction i.e. (90°)
- Providing a gentle slope at the container terminals reduces the wave heights in the port basin and the wave height at all the berths are seen to be within the permissible tranquility limit for all the incident waves from East direction.
- Average wave height near the proposed MLT –II and MLT –III berth for both alternative layouts is found to be generally within the permissible wave height of 1.0m for 2,00,000 DWT ships. Therefore the proposal of MLT berths along North Breakwater is feasible from considerations of wave tranquillity at the berth
- Wave height in front of North breakwater shows results on higher side due to reflection effect of North breakwater. However wave height at approach channel shows lower wave height due to the dredged depth of approach channel.
- It was noticed that under normal wave climate, the existing breakwaters would provide adequate tranquility at the entrance where a wave disturbance of 0.90m only would prevail due to diffraction effects from the outer i.e. northern breakwater. From the visual observations and record of wave disturbance, it was noticed that there was considerable wave attenuation as the wave flux pass through outer basin due to diffraction effect due to tip of inner i.e. southern breakwater.
- By creating mathematical model, we can simulate different scenarios and predict the behavior of the port under different conditions, enabling us to make informed decisions about the design and management of the port. These model can also aid in identifying potential safety hazards, improving the efficiency of the port operations, and optimizing the use of resources. Overall, mathematical modelling of a port is an essential tool for engineers and managers to ensure the safety, sustainability, and profitability of the port.

REFERENCES

[1]. Book written by Christopher G. Koutitas on “Mathematical Models in Coastal Engineering”, Pentech Press Limited London,1988

[2]. Singh, A.K., Ranganath, L.R., Karthikeyan, M. (2019). Hydrodynamic Modelling for Development of a Port in an Estuary, CWPRS Pune

[3]. Technical report No.6042 (August,2022) on “wave tranquillity studies on upgraded physical model of Kamarajar Port Chennai, Tamilnadu” by Central water and Power Research Station Khadakwasla, Pune-411024, Ports and Harbour-II Division.

[4]. ROLE OF CWPRS FOR PORT DEVELOPMENT IN INDIA-Edited by: Dr. Prabhat Chandra, Scientist-E & Shri T Nagendra, Scientist-E.

[5]. M. Phani Kumar et al. (2011);’Littoral Drift Management – A Success Story of Visakhapatnam Port’, ISH Journal of Hydraulics Engineering, Vol 17, No.2,2011.

[6]. HYDRAULIC MODELING TECHNIQUES IN COASTAL ENGINEERING

[7]. A.A. Purohit Scientist – “E” CWPRS; Numerical and physical modelling of port andharbour.

[8]. Significants of Bathymetry Survey Coastal Engineering Project; Dr M. PhaniKumar, Scientist-D, CWPRS 2022; Study of water depth of Ocean floor ,river or lake floor.

[9]. MIKE 21 BW, Boussinesq Waves Module ,User Guide Powered by DHI.https://www.mikepoweredbydhi.com/

[10].MIKE Zero, User Guide provided by DHI (2019): https://www.mikepoweredbydhi.com/

[11]. MIKE 21 BW Step By Step Training Guide by DHI (2017):https://www.mikepoweredbydhi.com/

[12]. Hydraulic model studies for development of ports by CWPRS Khadakwasla, Pune https://cwprs.gov.in/Page/Coastal-Engineering.aspx

[13]. Mathematical modeling — A tool for coastal water quality management Author links open overlay panel A.U.Mahajan, C.V.Chalapatirao S.K.Gadkari National Environmental Engineering Research Institute Nagpur, India. https://www.sciencedirect.com/science/article/abs/pii/S0273122399004394