Assessment of Wave Diffraction behind the Breakwater Using Mild Slope and Boussinesq Theories

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***Abstract*— Today Boussinesq theory as a method that was known and accepted is common in order to assess the Calmness of Port Basin. But considering the advantages and disadvantages of each of the intermediate and shallow water equations, review other equations and methods in order to choose the best method for layout design and the port seems to be necessary. Accordingly, in this study the method results (Boussinesq Waves Theory) and the results of the numerical solution of a mild slope equation (Mild Slope Waves Equation) for the ratio of opening width to the input wavelength is obtained. And then a comparison between the results and applied graphs will be done.**

***Keywords*— Coastal Engineering, Wave Diffraction, Boussinesq Theory, Mild Slope Equation, Mike21 Software**

I. Introduction

One of the most important parameters in determining the percentage of troubled days is an effective port, Vessels affected by the height of a wave pool that the client cannot receive the necessary services in the basin.[1] The height of the wave function of vessels tonnage and the user has access to the pool. For example, wave height permitted for vessels with a tonnage of vessels with a tonnage less than the above, is less. The sensitivity of the system loading and unloading vessels are flexible (such as oil vessels), is less than the longer waves. And the wave height permitted for these vessels will be relatively higher. [2]

This study is diffraction pattern in the back of opening the breakwater. The mild slope equations and the governing equation on Boussinesq theory are able to consider this theory. So in this study will be tried using these two methods for obtaining diffraction pattern with the application graph is presented comparing. [3]

Since the elliptic mild slope equation (Elliptic) can considers every four phenomena of refraction, diffraction, shoaling and reflection waves, but the mild slope of the parabolic equation (Parabolic) is unable to consider the phenomenon of wave reflection, at the beginning of this study a comparison is done between these two equations. Then the best equation is selected and used for comparison with Boussinesq theory.

II. Methodology

A. *Boussinesq Theory*

The linear theory is assumed that the sine wave, if it is not in reality and in vitro and sharper wave crest and the bottom is wider. Since the linear theory can take in some of the non-linear phenomena, and also because of the theory of nonlinear wave wares used. The proposed nonlinear theories, the theory of long wave theory is also known boussinesq. Boussinesq equations by Madsen and Sorensen 1992 for wave propagation from deep water to shallow water, which is solved by numerical solution of these equations Mike is a software module BW. boussinesq one variable equation which in 1872 provided the following: [4]

$$\eta_{tt} - h\eta_{xx} - \left(\frac{3}{2}\frac{\delta}{h}\eta^2 + \frac{\mu^2}{3}h^2\eta_{xx}\right)_{xx} = 0 \quad (1)$$

B. *Mild Slope Theory*

Mild slope of the linear theory of wave equation is derived by Berkhoff 1972. [5] This equation can calculate the wave propagation in the sea bed with a gentle slope. In order to solve these equations, parabolic method (Parabolic) and elliptical (Elliptic) provided that parabolic solution can not consider the phenomenon of wave diffraction. But solving the elliptic equation with a gentle slope to the phenomenon of diffraction phenomena of refraction (Refraction) and creep (Shoaling) considers. [6]

C. *Comparison of Elliptic and Parabolic Mild Slope Equations*

Considering that the numerical solution of two equations, Elliptic and Parabolic mild slope (EMS, PMS) are available in the Mike 21 software [7], this software is used for this study. Thus the answers of these equations are compared with each other in Different sections of behind the breakwater. In order to compare the answers the two equations PMS and EMS, wave height profiles toward the distance from the line of beach coastline is drawn back to the breakwaters. Specification of input data is given in Table 1.

TABLE 1: ASSUMPTIONS OF INPUT DATA (EMS & PMS)

Water Depth (m)	Breakwater Length (m)	Wave Height (m)	Wave Period (s)
5	300	1.5	8

1) Analysis of models

In order to evaluate and compare the results of the numerical solution of elliptic and parabolic mild slope of the equation, wave height in the model after reaching steady state, are evaluated. As a result, the required output, the graphics file is dfs2 total wave height in bathymetry shows. Graphical output wave height (H_{rms}) of both models is presented in Figures 1 & 2.

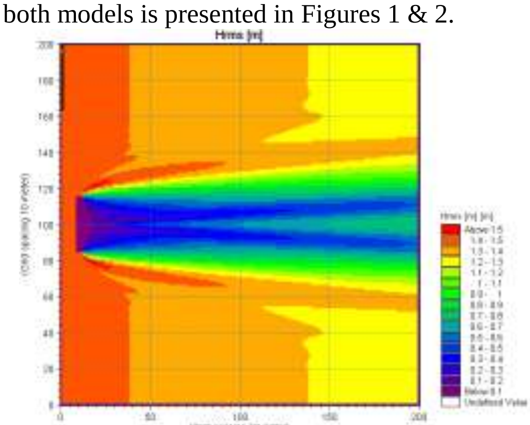

Fig. 1 Wave heights in PMS model

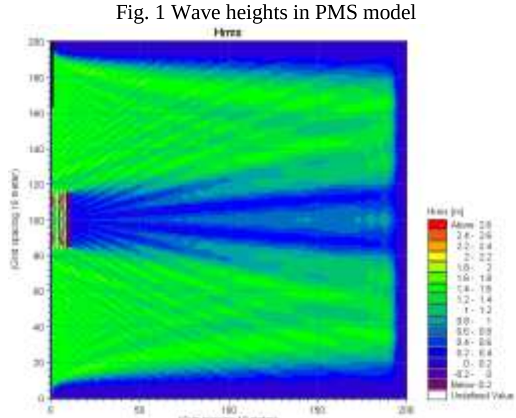

Fig. 2 Wave heights in EMS model

2) Evaluation of results

In this part, to compare these two methods, the profiles of wave height are plotted behind the breakwater to the shoreline, in different sections of the breakwater relative to the center.

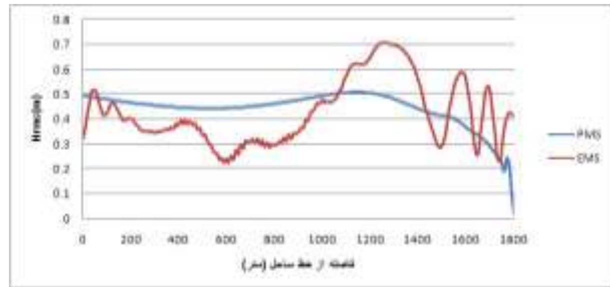

Fig. 3 Wave height profile in the 100 meters of the breakwater

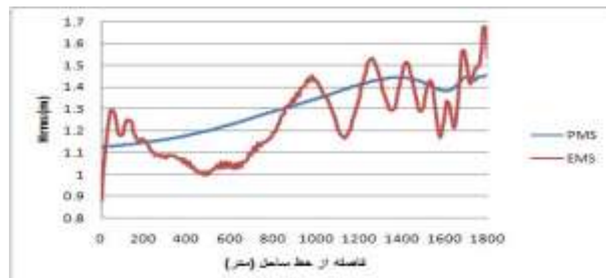

Fig. 4 Wave height profile in the 300 meters of the breakwater

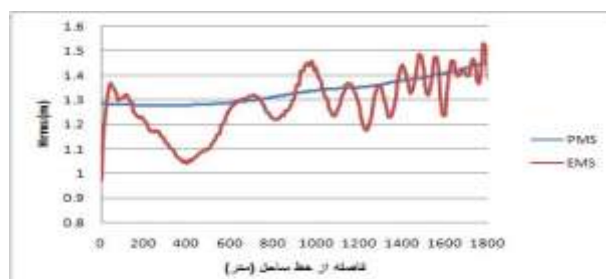

Fig. 5 Wave height profile in the 500 meters of the breakwater

According to the wave height profile, the following results:

- Profile in PMS from beginning to end was almost uniform, but in the EMS process is periodic wave height along the profile.
- The PMS wave height is smaller than the average height of waves in EMS. That it shows the EMS has a higher gain results.
- It was observed, with a move away from the range and scope of the outer breakwater, the results of two models are closer together.
- An important result of this section is that we can solve the elliptic equation mild slope (EMS) is more consistent with what occurs in reality. So in the next section is the main part of this research, the comparison between EMS theory and boussinesq theory will be discussed.

D. Comparison of Elliptic Mild Slope Equation and Boussinesq Theory

This study is diffraction pattern in the back of opening the breakwater. The elliptic mild slope equation and the governing equation on Boussinesq theory are able to consider this phenomenon. So in this study will be tried using these two methods for obtaining diffraction pattern with the application graph is presented comparing. Considering that the numerical solution of two equations, Elliptic mild slope (EMS) and Boussinesq theory (BW) are available in the Mike 21 software [7], this software is used for this study.

Thus answers the above equations in different sections behind the breakwater are compared with each other and with application graphs. In order to this assessment, according to the application graphs, the four openings with lengths B=L, B=1.5L, B=2L and B=2.5L are created (L=Wave Length). Then, using software modules Plot Composer in Mike Zero, aligned lines of wave height is plotted behind the breakwater and the against the openings. Specification of input data is given in Table 2.

TABLE 2

ASSUMPTIONS OF INPUT DATA (EMS & BW)

Water Depth (m)	Wave Length (m)	Wave Height (m)	Wave Period (s)
10	60	1	7

III. RESULTS AND DISCUSSION

After modelling bathymetry two-dimensional grid and define the wave absorbing layers and boundaries, analysis of models is done with the assumptions and with BW & EMS theories until achieve steady-state in Mike21 software. As was stated earlier, to evaluate and compare the results of the numerical solution of the equation, in EMS and BW, wave heights after reaching steady-state model are evaluated. As a result, the required output is the graphics file (dfs2) that shows wave height in the entire of bathymetry. For instance, graphical outputs of wave height (H_{rms}) for B = 2.5L = 120m are shown in Figures 6 & 7.

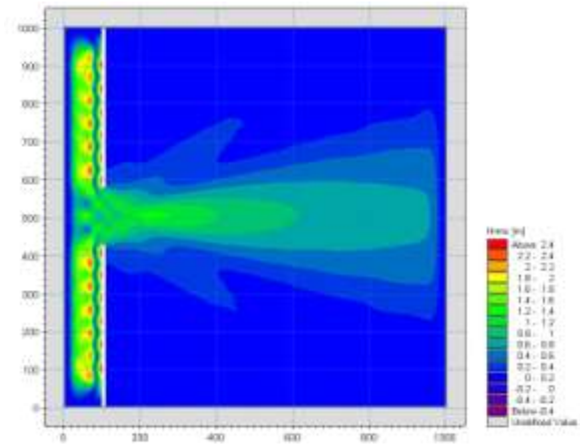

Fig. 6 Wave heights in EMS model

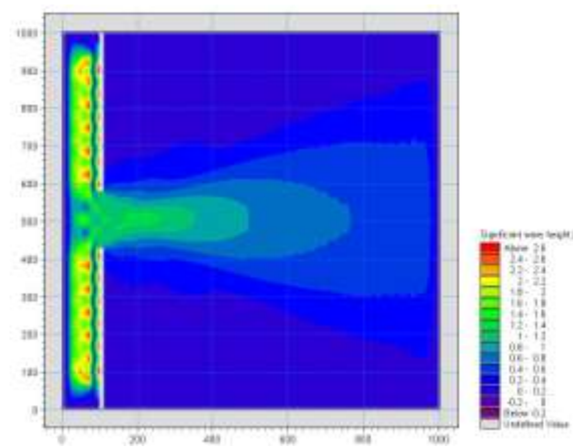

Fig. 7 Wave heights in BW model

In order to further evaluate and compare the results of the numerical solution of the equation, EMS and BW, aligned lines of wave height in front of the four openings breakwater is plotted and evaluated in Plot Composer module. They are created four openings respectively 60, 90,120 and 150 meters.

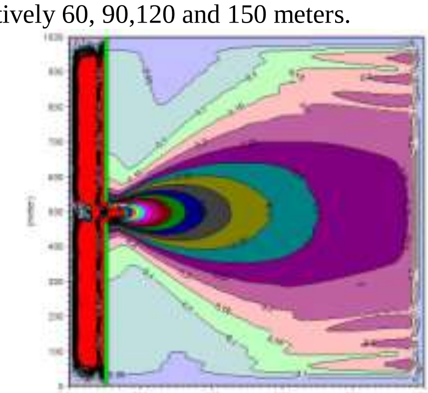

Fig. 8 The contour lines of wave height in EMS model (B=L=60m)

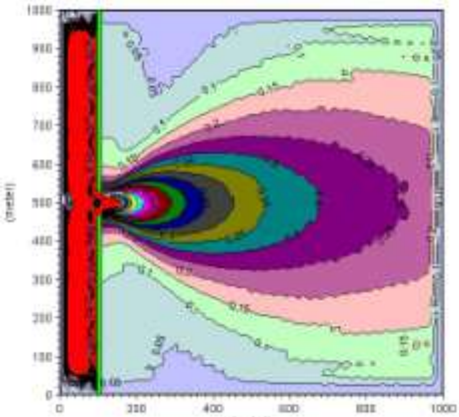

Fig. 9 The contour lines of wave height in BW model (B=L=60m)

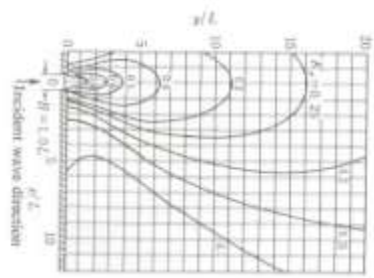

Fig. 10 Wave diffraction graph JSCE (1971) (B=L)

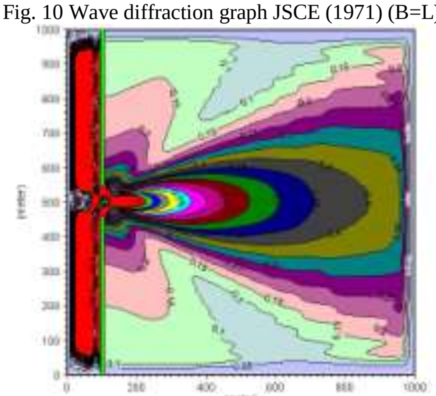

Fig. 11 The contour lines of wave height in EMS model (B=1.5L=90m)

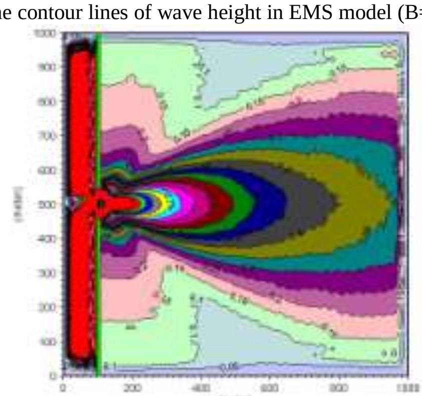

Fig. 12 The contour lines of wave height in BW model (B=1.5L=90m)

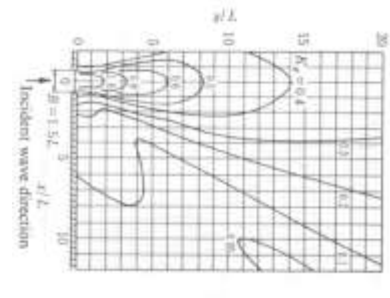

Fig. 13 Wave diffraction graph JSCE (1971) (B=1.5L)

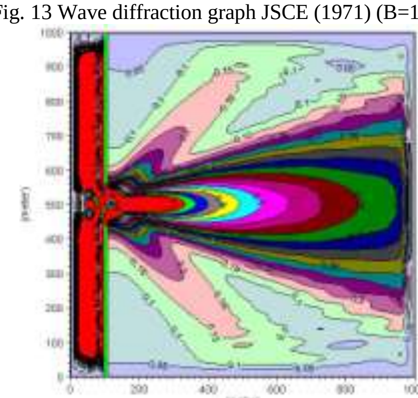

Fig. 14 The contour lines of wave height in EMS model (B=2L=120m)

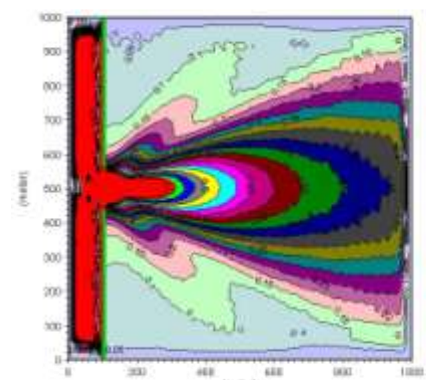

Fig. 15 The contour lines of wave height in BW model (B=2L=120m)

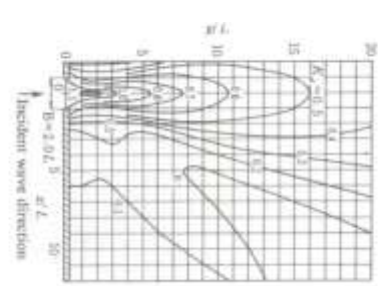

Fig. 16 Wave diffraction graph JSCE (1971) (B=2L)

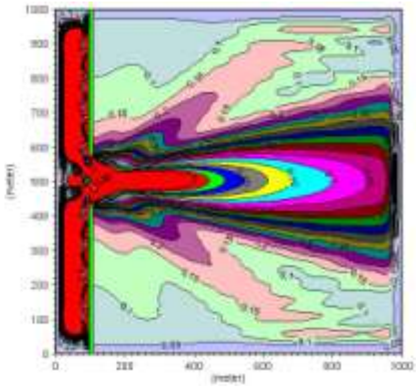

Fig. 17 The contour lines of wave height in EMS model (B=2.5L=150m)

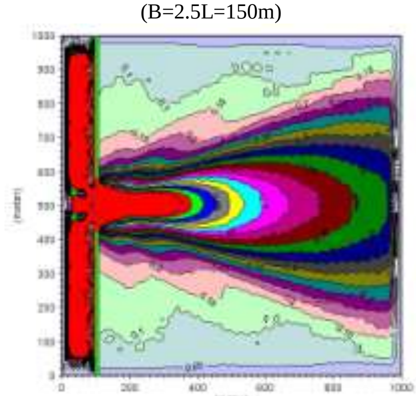

Fig. 18 The contour lines of wave height in BW model (B=2.5L=150m)

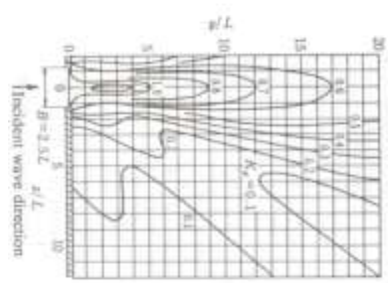

Fig. 19 Wave diffraction graph JSCE (1971) (B=2.5L)

IV. CONCLUSIONS

According to contour lines of wave heights and diffraction pattern against the openings, the following results:

- Generally, in each span length, the diffraction pattern of EMS model is very close and almost equal to the JSCE graphs. This proves that JSCE graphs are obtained using elliptic mild slope equations.
- It can be seen that the EMS diagrams are more stretched than BW diagrams. In other words, the distance between the corresponding lines in the EMS model is greater than BW model. That this process increases with increasing span length.
- The contour lines of wave height in the EMS model are more smoothly but aligned lines in the BW model have small oscillations.
- Also can be concluded to openings the length of a wavelength (B = L) answers of BW model are almost equal to EMS model. Therefore both of two methods can be used to obtain the diffraction pattern in the range of smaller than one wavelength.
- As mentioned earlier in the boussinesq theory used nonlinear wave equations and this diffraction phenomenon is expected to be accessed with higher accuracy. As shown in figures, however mild slope diffraction wave theory is less accuracy than boussinesq nonlinear theory, but has acceptable results.
- According to linear equations in elliptic mild slope method, cost and time of modeling with this method is less than boussinesq nonlinear theory. So the differences between the results are acceptable

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