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DEVELOPING MULTI NON LINER REGRESSION EQUATION FOR OCCURRENCE OF BREAKING WAVES

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Abstract

The purpose of this study is to explore all characteristics that influence the occurrence of breaking waves, with these parameters chosen based on physical phenomenon behavior and the Buckingham theory process for providing an equation that can be utilized to forecast breaking wave performance. When compared to other parameters of fluid properties and wave characteristics, the results of mathematical dimension analysis with non-dimensional groups show that the parameters that have a major effect on the free surface phase at the braking moment can be summarized as: the depth of water (d), the incident height of wave (Hi) and the length of wave (L). The MNLR shows an ability to predict the breaking wave occurrence with R^2 equal to 83%.

Key words: Breaking waves, MNLR, Buckingham theory, Dimensional analysis.

Introduction

The fundamental concepts of this study centered on breaking wave behavior, the most significant characteristics of waves travelling from the sea to the beach. where H is the wave height measured from the lowest point in the trough to the highest point in the crest, L is the length of the distance between two successive crests for an individual wave, an is the wave amplitude measured from the sea water level to the maximum height of the crest, and d is the water depth measured from the sea water level to the sea bed. (Al Shaikhli and Khassaf, 2021).

According to small amplitude wave theory, wave length L is a function of wave period T and water depth d, as indicated in equation (1), where wave period T is defined as the time it takes the wave crest to move from one point to another. When the depth of water is equal to or more than one-half the length of the wave, like in deep water, the wave length L is solely a function of the wave period T, as indicated in equation (2). (Douglass and Krolak, 2008).

$$L = \frac{g\,T^2}{2\pi} tanh\left(\frac{2\pi\, d}{L}\right) \qquad \text{Eq. 1}$$

$$L = \frac{g\,T^2}{2\pi} \qquad \text{Eq. 2}$$

Where: g represents the gravity acceleration; m/sec^2.

Many studies attempted to realize the occurrence of wave breaking for various types of slopes, such as Stokes in 1847, these studies conducted for the slopes between (1:100 to 1:50) for irregular waves, as a result, the occurrence of wave breaking determined based on wave velocity and progression speed, according to these studies, two indices have been used to express the occurrence of wave breaking, In deep water, the Lo index is commonly employed, while the other is (Hi/d), which is the ratio of the incidence wave height; Hi and the water depth; d. used in shallow water (McCowan, 1894).

McCowan, 1894, investigated and determined the shallow water wave breaking requirement for horizontal bottom to occur when the ratio of wave height to water depth reaches 0.78, as shown in equation (3):

$$\frac{H_b}{d_b} = 0.78 \qquad \text{Eq. 3}$$

Where the subscribe symbol (b) refer to the inception of wave breaking state.

Miche, 1944, developed a theoretical condition equation for wave breaking that depends on the hyperbolic tangent of the wave angle; when used in deep water, the equation yielded a breaker index of 0.88, increasing the limit given by McCowan, 1894, as expressed in equation (4):

$$\frac{H_b}{L_b} = 0.142 \tanh\left(\frac{2\pi\, d_b}{L_b}\right) \qquad \text{Eq.4}$$

Le Méhauté and Koh, 1967, tried to understand the breaking wave behavior that reach to shoreline with an angle and to obtain breaking wave characteristics by proposing equation (5). This equation should satisfy the limits of bed slope; $\frac{1}{50} < m < \frac{1}{5}$ and the wave steepness ratio $\frac{H_o}{L_o}$.

$$\frac{H_b}{H_o} = 0.76\, m^{\frac{1}{7}} \left(\frac{H_o}{L_o}\right)^{-0.25} \qquad \text{Eq.5}$$

Where: m represent the bed slope of shoreline.

Weggel (1972) investigated the breaking incidence of regular waves in shallow water while taking the bed slope into consideration. As a result, the researcher devised an equation (6) that is widely utilised in the construction of sloping shorelines. It is worth noting that this equation may be used for level shorelines with a zero slope to produce a breaking waves index of 0.78, which is identical to the McCowan, 1894, index.

$$\frac{H_b}{d_b} = \frac{\frac{1.5}{(1+e^{-19.5m})}}{\left(1+43.75\,(1-e^{19m})\left(\frac{d_b}{g\,T^2}\right)\right)} \qquad \text{Eq.6}$$

Ostendorf and Madsen (1979) proposed modifying the parameters of Miche's (1944) equation to produce equation (7) with best fit equal to 0.8. Following that, the researchers presented two different equations (8 and 9) derived from Miche's (1944) equation, which take into account the effect of bed slope with two different ranges.

$$\frac{H_b}{L_b} = 0.142 \tanh\left(0.91\ \frac{2\pi\, d_b}{L_b}\right) \qquad \text{Eq.7}$$

$$\frac{H_b}{L_b} = 0.14 \tanh\left((0.8+5m)\frac{2\pi\, d_b}{L_b}\right) \qquad \text{for } m \le 0.1 \qquad \text{Eq.8}$$

$$\frac{H_b}{L_b} = 0.14 \tanh\left(0.13\ \frac{2\pi\, d_b}{L_b}\right) \qquad \text{for } m > 0.1 \qquad \text{Eq.9}$$

Kamphuis, 1991, sought to examine regular and irregular wave circumstances and produced two new equations, which have an exponential shape with a bed slope parameter and are used to determine the breaking wave index. For regular and irregular wave circumstances, equations (10 and 11) are provided.

$$\frac{H_b}{L_b} = 0.127\, e^{4m} \tanh\left(\frac{2\pi\, d_b}{L_b}\right) \qquad \text{Eq.10}$$

$$\frac{H_b}{L_b} = 0.095\, e^{4m} \tanh\left(\frac{2\pi\, d_b}{L_b}\right) \qquad \text{Eq.11}$$

Kawasaki and Iwata (1998) show statistically that crest width is an important component in determining breaking wave index. They conducted a study of impermeable rectangular submerged breakwaters and found that breaking wave index decreased as crest width increased and relative depth decreased. Following that, Kawasaki and Iwata, 2001, assumed that breaking wave index is affected by submergence and incident wave heights. However, a study of impermeable trapezoidal submerged type of breakwater revealed that the bed slope and side slope of the breakwater have no effect on breaking wave index.

Rattanapitikon and Shibayama, 2000, investigated the height of breaking waves using 24 existing equations and experimental data from 574 cases. The results showed that equations with bed slopes between 0m0.07 can be predicted with reasonable acceptance and equations with bed slopes between 0.1m0.44 can be predicted with lower confidence level. As a result, based on linear wave theory and regular wave conditions, the researchers suggested two new equations (12 and 13) for wave breaking index. This accessible equation for bed slope varied between 0m0.44 to 0.001H/L0.1, as indicated:

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$$\frac{H_b}{d_b} = 0.17\frac{L_o}{d_b}\left(1 - e^{\left(\frac{\pi\, d_b}{L_o}(16.21\, m^2 - 7.07m - 1.55)\right)}\right) \quad \text{Eq.12}$$

$$\frac{H_b}{L_b} = 0.14\tanh\left[\frac{2\pi\, d_b}{L_b}(-11.21\, m^2 - 5.01m - 0.91)\right] \quad \text{Eq.13}$$

Yao et al., 2013, conducted a series of laboratory tests in a wave flume to explain the behavior of submerged reef breakwater, as a result, the ratio of the submergence to the wave height considered an important factor to describe wave breaking index as present in equation (14), top to that, the results showed that the influence of bed slope seems not important according to the studied experimental conditions.

$$\frac{H_b}{d_b} = \frac{Y_1 - Y_2}{2}\left\{tanh\left[\frac{\alpha}{1.4}\left(1.4 - \frac{R_c}{H_o}\right)\right] + \frac{Y_1 + Y_2}{Y_1 - Y_2}\right\} \quad \text{Eq.14}$$

This equation can be applied when $0 \leq \frac{R_c}{H_o} \leq 2.8$ therefore, Y equal to Y_1 at $\frac{R_c}{H_o} = 0$, while Y equal to Y_2 at $\frac{R_c}{H_o} = 2.8$. The best fitting curves demonstrated that: $Y_1 = 1.07$, $Y_2 = 0.61$ and $\alpha = 3.24$.

Chiang et al., 2017 investigated sediment transport processes in coastal engineering under nonlinear wave impacts. For the theoretical background, the researchers combined (Le Méhauté and Koh, 1967) equation and (Goda, 1974) equation to develop equation (15) as shown:

$$\frac{d_b}{L_o} = -\frac{\ln\left[1 - 4.47(m)^{\frac{1}{7}}\left(\frac{H_o}{L_o}\right)^{0.75}\right]}{1.5\pi\left(1 + 15\, m^{\frac{4}{3}}\right)} \quad \text{Eq.15}$$

Multiple Nonlinear Regression Approach (MNLR)

The multiple non-linear statistical regression technique is also employed for predictive models to determine the hydraulic characteristics of wave breaking state according to experimental results. The dependability of the proposed relationships is measured by the regression coefficient (R^2). In order to compute the parameters of the proposed relationships, IBM SPSS Statistics 23 is a tool. The coefficient of regression may be computed as :

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_o - y_p)^2}{\sum_{i=1}^{n}(y_o - \bar{y})^2} \quad \text{Eq.16}$$

Where R^2 is the regression coefficient, yo is the observed value, yp is the predicted value, $\bar{y}$ is the mean value of yo and n is the number of data.

The following relationship forms are suggested to predict the hydraulic properties of wave breaking depend on the dimensional analysis. The dimensional analysis considering one of most

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mathematical approach accustomed explore in details of hydraulic problems or phenomenon that having different affected physical measurements to create a affiliation by recognizing their fundamental dimensions. In this article, dimensional analyses used to analyze the waves field at the certain breaking moment, so the following relationship in equation (17):

$$\frac{H_i}{L} = f(\frac{H_i}{d}) \quad \text{Eq.17}$$

The suggested relationship with regression coefficient (R^2 = 83%) shown in equation (18) and the comparison between observed and predicted results for different incident wave heights shown in figure (1):

$$\frac{H_i}{L} = 0.587 * (\frac{H_i}{d})^{1.073} \quad \text{Eq.18}$$

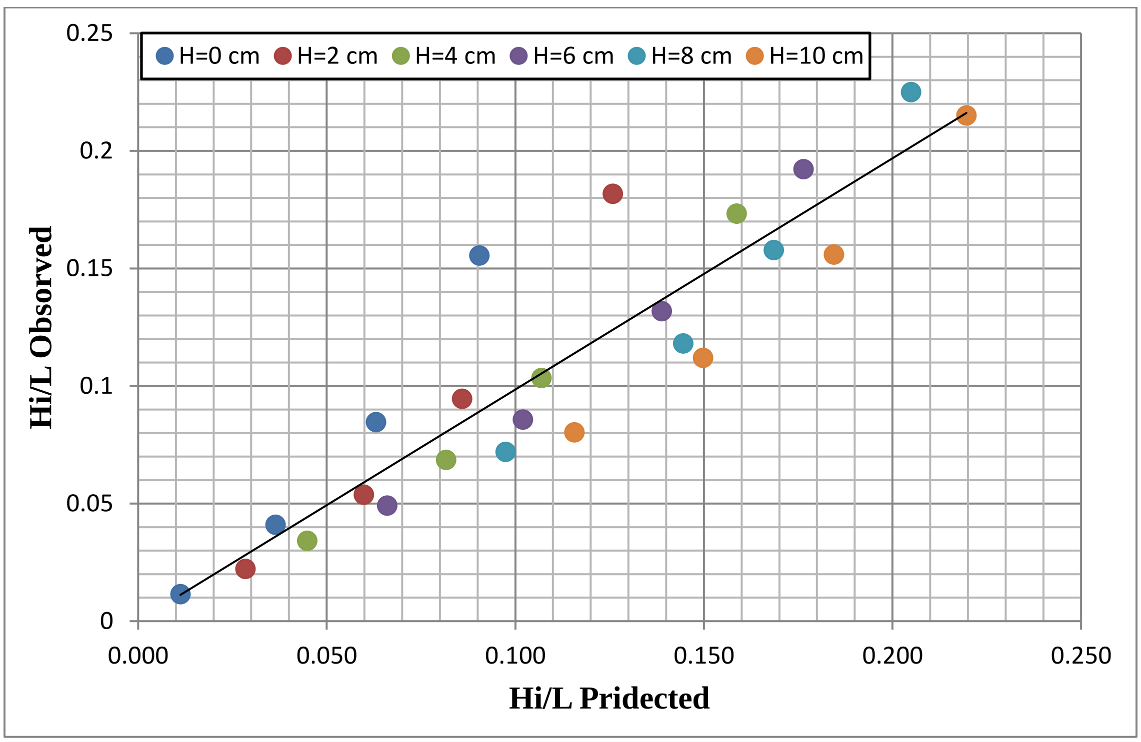

Figure (1): Observed VS predicted curve for different incident wave heights

Conclusions

Using Buckingham theory as a mathematical dimension analysis technique with non-dimensional groups, the wave behavior investigated taken into account the breaking conditions and the effects of all parameters to produce an equation that governs this physical phenomenon shows that the parameters that have a major effect on the free surface phase at the braking moment can be shortened as: the depth of water (d), the incident height of wave (Hi) and the length of wave (L). The MNLR shows an ability to predict the breaking wave occurrence with R2 equal to 83%.

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