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Viscous Flow Model for Breakwater Wave Force in Marine Engineering

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Abstract: The research on the wave force of breakwaters in marine engineering refers to avoiding the damage caused by wave propagation and reducing the damage of waves to structures in marine engineering, so as to ensure the safety of buildings and oceans in marine engineering. In order to solve the deficiencies of the existing viscous flow model-based research on breakwater wave force in marine engineering, this paper discusses the functional equations of the viscous flow model and the concept of breakwater wave force structure types. The model briefly introduces the data simulation and calculation parameters of the wave force application of the breakwater in marine engineering. And the design of the model structure based on the viscous flow model for the wave force of the breakwater in marine engineering is discussed. Finally, the simulation value calculated by the viscous flow model and the MLAC model is compared with the average analytical value of the breakwater wave force in the experimental analysis. The experimental data show that the numerical simulation value of the strength of the breakwater wave force in the viscous flow model is closer to the average analytical value of the breakwater wave force than the MLAC model, and its error is within 4%, while the numerical simulation error of the MLAC model is close to 10%, thus verifying the practical value of the viscous flow model for breakwater wave force in marine engineering.

1. Introduction

The wave force of the breakwater is mainly used to resist the interference of waves to the waters in marine engineering, and also has the effect of preventing flow and mud, maintaining the safety of waters and facilities in marine engineering and ensuring the normal operation of ships. Therefore, the construction based on viscous flow model in marine engineering It is of great significance to model the wave force of breakwaters in order to form a safe marine engineering.

Nowadays, more and more scholars pay attention to the research on the wave force of breakwaters in marine engineering by various technologies and platforms, and through practical research, some research results have also been achieved. Hayashi K first realized the synchronization process of water level and wave through the continuous tidal and wave-making of wave generator and tidal device, so as to realize the dynamic coupling simulation of storm surge and wave in the laboratory. Then, the physical model tests of typical seawall sections are carried out under the dynamic coupling of storm surge and waves and the conventional fixed water level. During the test, the damage process of the top of the embankment and the rear wall of the breakwater was observed and compared [1]. Zimmaro Pre has done some research and there is still no widely applicable formula for the discharge coefficient that needs to be known to estimate the flood discharge caused by the breach of the dyke. Sometimes the discharge coefficient of a pointed side weir is used to estimate flow, however, in the case of a breach of the dam, the resulting geometry and type of flow are similar to those of a wide-roofed weir. Therefore, Zimmaro Pre established two different openings, rectangular and trapezoidal, at a height of 0.6m in the center of the embankment to simulate the breaching scenario of the embankment, and discussed the influence of two different incoming flow types, river type and reservoir type [2]. Keisuke discusses the hydraulic design of a new 13km flood levee proposed in Malawi. Keisuke uses a state-of-the-art quasi-3D fully hydrodynamic alluvial river model for the analysis. The model includes rupture events, railway embankment breaches and their locations, flood water levels observed in the field, and sediment deposition and losses in the main channel of the Ruohe River south of the breach. After model verification, considering factors such as the long-term rise of the water level of the Xia'er River in the lower reaches of Chiluomo and the excavation of the new main channel of the Ruohe River, the hydraulic design of the proposed new embankment along the railway was carried out [3]. Although the existing research on the wave force of the breakwater in marine engineering is very rich, the research on the wave force of the breakwater in marine engineering based on the viscous flow model is still insufficient.

Therefore, in order to solve the existing problems in the study of the wave force of the breakwater in the existing marine engineering, this paper firstly introduces the functional equation steps of the viscous flow model and the concept of the structure type of the wave force of the breakwater. The data simulation and calculation parameter analysis of the wave force application of the breakwater in the project. Finally, the model framework for the application of the wave force of the breakwater in the marine engineering based on the viscous flow model is designed, and the wave force of the breakwater is calculated in the marine engineering through the viscous flow model. The application is carried out experimental test, and the final experiment shows the effectiveness of the viscous flow model proposed in this paper in the application of the wave force of the breakwater in marine engineering.

2. Breakwater Wave Force in Marine Engineering Based on Viscous Flow Model

2.1. Viscous Flow Model

The coefficients based on the viscous flow model should be considered in relation to the product of the pulsating flume geometric scale, flume radius, flume amplitude, flume submerged depth [4]. The water wave velocity of the breakwater wave force is expressed by the square root of the coefficient f of the viscous flow model, and the water wave flow rate is proposed:

$$G_r = d_\eta^{'} f^{0.5} z \tag{1}$$

In the above formula, $d_{\eta}^{'}$ is the water wave pressure constant, and z is the coefficient of viscous flow, which is generally calculated by empirical formula [5]. When using this formula to calculate G_r, the key is to determine f in the simulated water tank, and start from the definition of f (1) [6]. A series of operations are performed from the coefficients of the viscous flow model to obtain the f equation:

$$\frac{\partial\ (fR_v)}{\partial i_v} = \frac{\partial}{\partial i_v}\left[\left(x + \frac{x_1}{\varepsilon_f}\right)\frac{\partial f}{\partial i_v}\right] + U_f - a_E \frac{f^{1.5}}{z} \tag{2}$$

In the above formula, A is called the PDT number of the viscous flow model, and its value is around 2.5 [7]. There is no conclusion about the value of the coefficient B, and the E viscous flow model generates terms:

$$U_f = \bar{\theta} r_u r_v \frac{\partial R_u}{\partial x_v} \tag{3}$$

The viscous flow model takes into account the water wave velocity of the breakwater wave force, the water wave flow rate [8].

2.2. Types of Breakwater Wave Force Structures

Breakwaters can be divided into slope type, vertical type and other types according to the structure type [9].

(1) The design section of the slope-type embankment is an inverted trapezoid, and is generally made of natural rubble, artificial concrete blocks, and bagged sand [10]. The embankment core is made of materials, and various artificial blocks and masks with good safety and strong wave dissipation performance are used outside the embankment core [11].

(2) The structural section of the vertical breakwater has vertical or almost vertical walls inside and outside, and is generally divided into two types: gravity type and pile type [12]. The advantage of the vertical embankment is that when the drop is large, the engineering quantity of the embankment core material is significantly lower than that of the inclined embankment [13]. At the same time, the inner side of the dam can also be used as a wharf, and can realize the comprehensive utilization of wave energy power generation [14].

3. Investigation and Research on Breakwater Wave Force in Marine Engineering Based on Viscous Flow Model

3.1. Simulation of Breakwater Wave Force Data in Marine Engineering Based on Viscous Flow Model

In this paper, two identical rectangular structures are used to simulate the floating breakwater [15]. Considering the relationship between the length of the wave absorbing layer and the wavelength of the incident wave and the size of the breakwater spacing, the length of the numerical wave tank, the height of the tank, the water depth, the length and height of the breakwater, the horizontal distance between the anchor point and the edge of the breakwater, the distance between the breakwater, and the distance from the edge of the breakwater were calculated data simulation [16]. The specific parameters are shown in Table 1:

Table 1. Breakwater wave force data

Project	Unit	Parameter
The depth of the water	m	0.7
Long dike	m	0.6
High embankment	m	0.4
Draft	m	0.2
The anchor spacing	m	0.3
The dam spacing	m	0.8

3.2. Calculation Parameters of Breakwater Wave Force in Marine Engineering Based on Viscous Flow Model

In order to facilitate the calculation of the wave force of the breakwater in marine engineering based on the viscous flow model [17]. According to the geometric characteristics of the viscous flow model, the proportions of the water tank for the wave force simulation of the breakwater are set as A/c, U/t, Y/g, and W/q, where A/c is the geometric proportion, U/t and Y/g are respectively is the radius of the water tank, the amplitude of the water tank, and W/q is the submerged depth and water depth of the water tank [18]. In this paper, based on the viscous flow model in the ocean engineering, the calculation parameters corresponding to the numerical value of the breakwater wave force calculation are shown in Table 2:

Table 2. Viscous flow model calculation parameters

Project	A/c	U/t	Y/g	W/q
Project1	0.45	0.87	4.17×10^{2}	2.19×10^{3}
Project2	0.56	2.35	8.56×10^{2}	3.67×10^{3}
Project3	0.67	2.98	2.56×10^{3}	4.78×10^{3}
Project2	0.89	3.78	2.78×10^{3}	5.89×10^{3}

4. Research on the Application of Wave Force on Breakwaters in Marine Engineering Based on Viscous Flow Model

4.1. Calculation Model Structure of Breakwater Wave Force in Marine Engineering Based on Viscous Flow Model

In the numerical simulation of the wave force of the breakwater, certain calculation parameters and the simulation of the experimental data of the wave force of the breakwater in marine engineering are required. The specific calculation structure flow is shown in Figure 1:

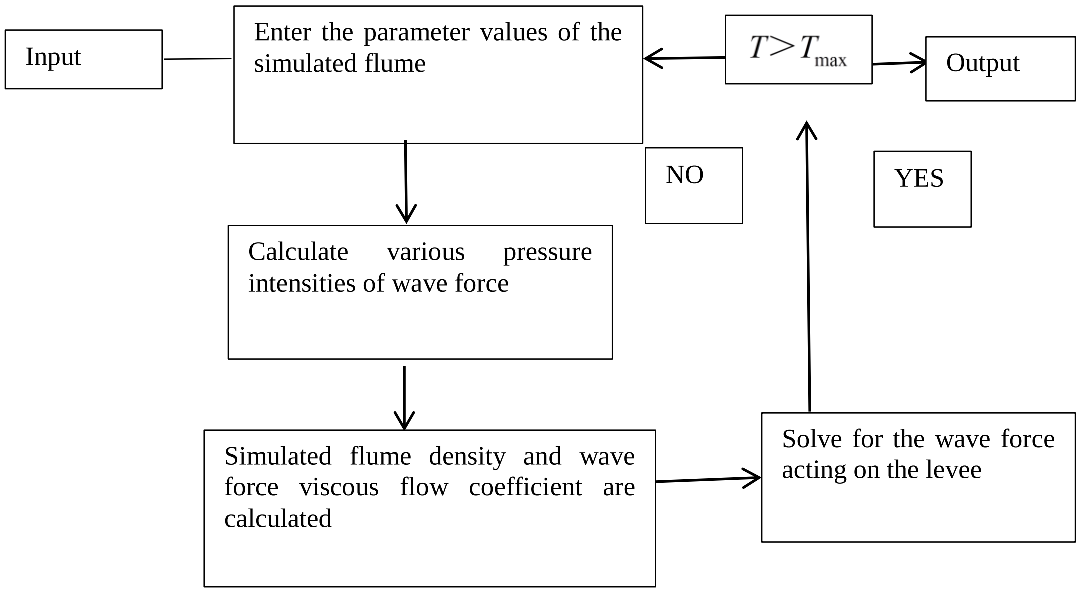

Figure 1. Structure of the viscous flow model breakwater wave force calculation model

On the basis of the above-mentioned simulated water tank calculation parameters and wave force numerical simulation, the viscous flow model is used to numerically solve the water wave pressure, water wave height, total wave force and the strength of the water tank bottom pressure. The specific calculation process is as follows:

(1) The parameters of the geometric scale of the simulated water tank, the radius of the water tank, the amplitude of the water tank, and the submerged depth of the water tank are known.

(2) Solve the viscous flow model equation (1), and calculate the water wave pressure, the water wave height, the total wave force and the strength of the tank bottom pressure in the simulated tank.

(3) Calculate the water wave velocity and water wave flow rate of the breakwater wave force according to the formula (2).

(4) Calculate the density and wave force viscous flow coefficient of the simulated water tank according to formula (3).

(5) Calculate the force of the water wave pressure, water wave height, total wave force and the pressure strength of the bottom of the water tank on the dam according to the formula (1) and (2).

4.2. Calculation and Application of Breakwater Wave force in Marine Engineering Based on Viscous Flow Model

In order to verify the correctness of the viscous flow model proposed in this paper for the calculation of breakwater wave force in marine engineering, this paper is based on the calculation parameters of the viscous flow model for breakwater wave force calculation in marine engineering and the numerical simulation of the breakwater wave force. On the basis of the investigation and research, the results are compared with the average analytical value of the wave force, the water wave height, the total wave force and the intensity of the tank bottom pressure in the simulated tank engineering, the MLAC model simulation value and the simulation value based on the viscous flow model. , the viscous flow coefficients of both water and air are set to A in this experiment. The simulated numerical results of the MLAC model and the viscous flow model are compared with the average analytical numerical results. The specific simulated and average analytical values are shown in Table 3:

Table 3. Analog numerical and average analytical numerical data

Wave force intensity	Simulation numerical	Viscous flow model	MLAC model
Water pressure	24.25	23.69	17.67
Water wave height	21.45	20.89	15.78
The waves total force	19.56	20.14	13.89
Tank bottom pressure	18.25	18.96	11.78

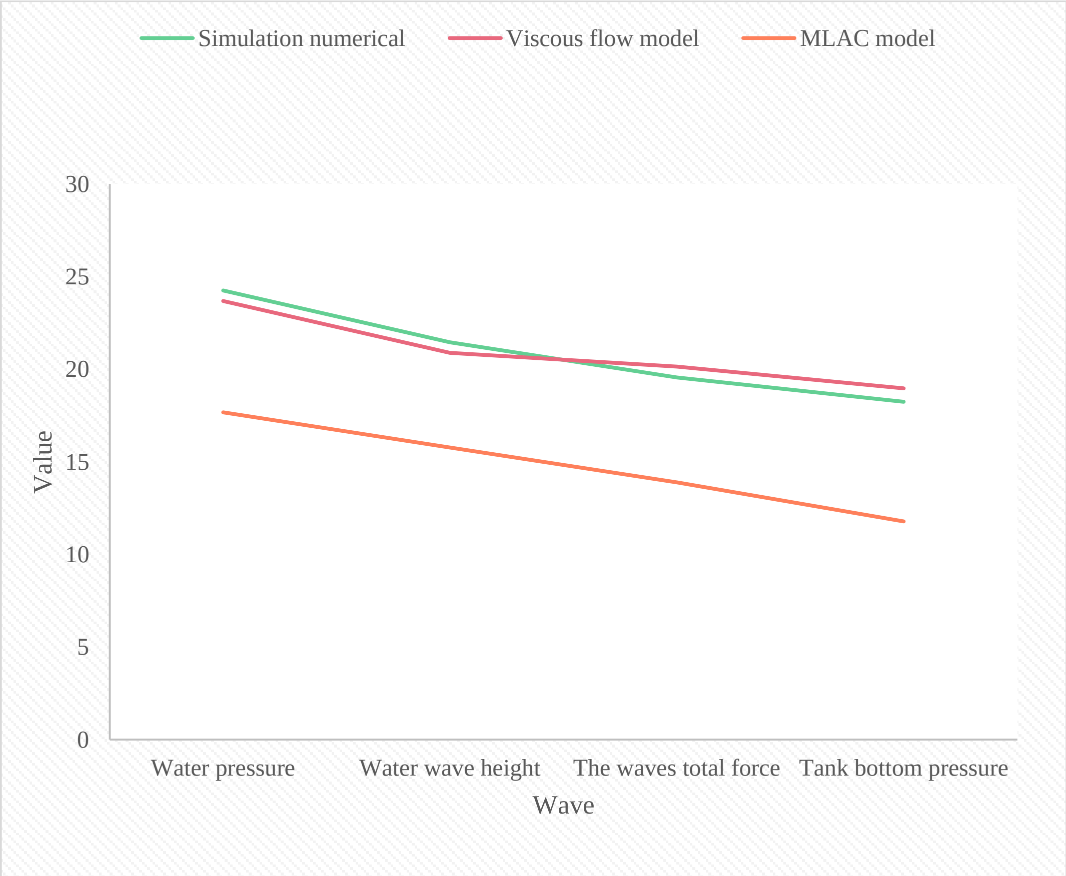

Figure 2. Comparison of simulated and average analytical values

This is shown in Figure 2,the data show that in the simulated flume engineering, the average analytical value of the wave force, the water wave height, the total wave force and the intensity of the flume bottom pressure are compared with the test results of the MLAC model simulation value and the viscous flow model simulation value. The simulation value of the flow model is closer to the average analytical value of the water wave pressure, water wave height, total wave force and tank bottom pressure of the breakwater wave force, in which the average analytical value of the water wave pressure intensity is 24.25, and the simulation value of the MLAC model is 17.67. The error is relatively large. The simulation error value of the viscous flow model is 23.69, which is closer to the average analytical value, and the error is within 0.4%. The simulated values are all within 10% error, while the MLAC model simulated numerical errors are larger. Therefore, it can be seen that the viscous flow model has better calculation accuracy for the simulation value of wave force.

5. Conclusion

Therefore, in order to enrich the research on breakwater wave force in marine engineering based on viscous flow model, this paper first briefly introduces the structure type of breakwater wave force and the concept of viscous flow model function equation, and then discusses the application of viscous flow model in marine engineering. On the basis of the analysis and discussion on the wave force technology of breakwaters in 2008, the data simulation and calculation parameters of the wave force of breakwaters in marine engineering based on the viscous flow model are investigated and designed. Secondly, the viscous flow model is used to design and analyze the structure of the breakwater wave force in marine engineering. Finally, the experimental data is analyzed for the application of the viscous flow model designed in this paper to the breakwater wave force in marine engineering. The final experimental results verify this paper. The superiority of viscous flow model for breakwater wave force in marine engineering.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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