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A Study of Wave Force on Wharf Abutment Structure

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Abstract

The upper part of a pier wharf on the sea is usually made up of the horizontal panels with both longitudinal and transverse beams above the still water level. To estimate the wave force on the structures, many scholars have conducted theoretical and experimental researches, and proposed a lot of empirical equations concerning the wave force and corresponding pressure distribution. Nevertheless, due to the complex factors and changeable girder systems, the generation mechanism of wave uplifting forces has not been fully understood so far, and the discreteness and limitations of experimental data lead to vastly difference between various empirical formulas, which causes that the calculated wave forces using different formulas differ by ten times. Therefore, it is necessary to determine wave the uplifting force and horizontal force on girder structures by conducting physical model experiments. In the present study, the physical model experiments with a scale of 1:40 are used to measure the wave forces on the wharf platform, abutment and pile foundations under different combinations of water level and waves at Petrochemical Wharf, Haicang Harbor, Xiamen. The experiment results have already been adopted in practice by some design institutes.

Keywords: abutment; structure; wave force; model tests

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1. Introduction

With the development of offshore oil and shipping industries, the number of open wharf and offshore oil drilling platforms constructed in coastal and open waters is growing, and the estimation of the wave uplifting force on the perforated panels is one of the main issues needed to be studied in structural design. Japanese and Chinese scholars have conducted quite a few experimental and theoretical studies, and some calculation formulae have been obtained.

In the handbook for design of sea harbour (CCCC First Harbour Consultants Co., Ltd, 1994), the wave pressure the on structure panels, *p*, is approximated as the wave profile distribution, the overall wave uplifting force generated by waves is calculated as:

$$P = \int_{x_1}^{x_2} p\,\mathrm{d}x \tag{1}$$

where, the wave uplifting pressure p (kN/m^2) is $\beta\gamma(\eta - \Delta h)$, in which, β is the pressure reactive coefficient, when the width of the upper structure is smaller than 10 m, $\beta = 1.5$, on the contrary, when the width of the upper structure is rather larger, $\beta = 2.0$; Δh is the superelevation (m); η is the wave crest elevation above the still water level, which can be calculated with Eq. (2).

$$\eta = \frac{H}{2}\cos kx + \frac{\pi H^2}{2L}\left[\frac{\cosh\frac{2\pi h}{L}\left(\cosh\frac{4\pi h}{L^3}+2\right)}{4\left(\sinh\frac{2\pi h}{L}\right)}\right]\cos 2kx \tag{2}$$

where, H is the wave height, L is the wave length, k is the wave number ($k = 2\pi / L$), and x is the distance to the upper structure.

However, Goda et al. (1967) believed that the maximum uplifting force on the perforated panels is mainly the impact load, assuming that the wave pressure is uniformly distributed. The calculation length of pressure is $L/4$, and the overall uplifting force generated by waves is associated with the panel elevation, which can be expressed as:

$$P = \xi\gamma \cdot H \cdot \frac{L}{4} B \tanh\left(\frac{2\pi h}{L}\right)\cdot\left(\frac{H}{\Delta h_0} - \frac{\Delta h_0}{H}\right) \tag{3}$$

where, P is overall wave uplifting force on panels (t); ξ is the pressure correction coefficient, which is varied with the elevation of panel above the wave center line, and determined by experiments; γ is the density of water (t/m^3); B is the bridge board width (m); h is the water depth in front of the trestle; Δh_0 is the superelevation of the panel above the wave center line (m), which can be expressed as:

$$h_0 = \Delta h - \frac{\pi H^2}{L}\coth\left(\frac{2\pi h}{L}\right) \tag{4}$$

in which, Δh is the superelevation of the panel above the still water level.

Besides, Zhou et al. (2003, 2004a, 2004b, 2004c) and Song and Bai (1997) also conducted model experiments on perforated panels and high piled slabs, believing that the relationship between the wave uplifting force and the relative superelevation of the panel is an exponential function curve. However, these empirical formulae are characteristics of relatively simple structures, without consideration of the attacking angle, mostly functions of the superelevation and incident wave height.