Wave Load and Stability of the Port Mole Wall in the Period of Construction

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Abstract **– Some of failure have been occurred during stage of construction of the sea port due to calculation of the wave load in the period of construction is not given enough attention such as in the period of operation, Therefore, in this article, the wave loads on the reflecting wall of the sea port mole at the various stages of construction has been studied by numerical and experimental methods. The authors have been calculated a specific project with a mathematical model using input data in the field measurements, calculations show that this mathematical model is possible to use in practice to determine the maximum total wave force impacted on the sea port mole.**

Keywords **- Port mole wall; wave load; steel sheet-pile wall**

I. INTRODUCTION

In recent years, in Russia the construction of sea ports with the structures of fencing moles is increasing. For modern sea port projects with fencing mole have a considerable depth of 20-30 m and have a significant extent. The use of pile construction with a screen created by steel sheet-pile wall in the front of the port is also popular. However, in recent years there have been several accidents in the construction phase of such deep structures (Geoport in Novorossyisk, port Mzimta in Sochi). The problem is related to the stability of buildings under construction. The paper considers two questions. First: what are the characteristics of the steel sheet-pile wall, the wave loads can be calculated based on the diffraction of waves behind a wall? Second: how water transfers along the front wall during oblique waves with the short crest coming in? And what are the risks of loss of stability associated with such flows.

II. GEOPORT, NOVOROSSYISK

The object used for this investigation is briefly described as follows: Geoport in Novorossyisk in Russia located at Csemess bay, Black Sea coast- this is deepwater mole port.

The deepwater part of the Eastern breakwater designed to protect the area from wave action and provide parking place for ships on the inside of the mole port. The length of the protective breakwater (phase 2 of port development) is 650m. Structure of the mole port is a pier on bored piles d = 1420mm, vertical steel sheet piling wall and reinforced concrete superstructure. Pile foundation is a system of two bored oblique piles (10 / 1); longitudinal rows of diameter 1420mm; step 4.86 m; depth of piling up to -40 ...-45m. The structure of the mole port is shown in fig. 1.

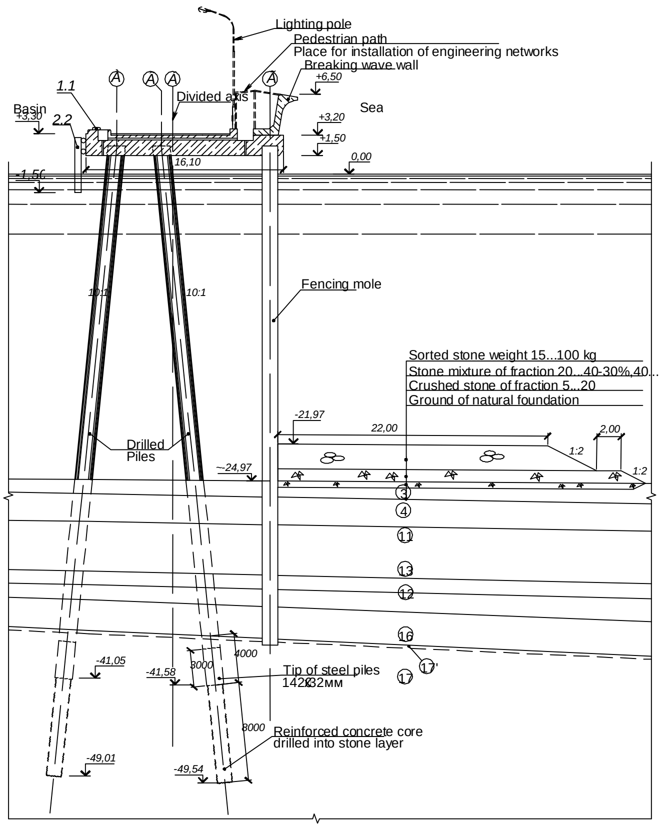

Figure 1. The mole structure

III. RESULTS OF THE STORM, NOV.4-5, 2009

During storm dated Nov.4-5, 2009, large part of mole wall was instable, fig. 2 shows that steel sheet piles oblique away approximately 8 degree in vertical direction. Noting on site given parameters of wave taken as follows: height of wave 4.0 m, length of wave 76.0, and period of wave 7.09 s. These parameters were regarded in the design but instability of construction still occurred.

Figure 2. incline of the segment of the sheet-pile after storm

The special tests have been carried out in the wave basin to study the interaction between incoming waves and the various length sheets piling wall (5, 10, 20 and 40 m in natural scale). The results of tests used to obtain the criteria of the conditions of wave diffraction theory application.

IV. MATHEMATICAL MODEL

In the opinion of the authors, the wave load on the sheet pile wall at the construction stage with various lengths could be considered as local obstacle. A calculation method can be used Russian technical standard for determining load impact on the port structure [1], based on nonlinear wave theory but this method is very cumbersome and complex. Thus writing a program for direct calculation of the maximum horizontal wave force is necessary and it is much easier to use in practice. Based on the horizontal speed and acceleration of the water follow determined by Lappo (1990) [2], the maximum total horizontal wave force is directly determined by the following equation:

$$dF_T = dF_D + dF_I \tag{1}$$

In which, dF_D and dF_I components speed force and acceleration force. Integral of dF along the whole submerged section of the wall, the maximum total horizontal wave force can be expressed as:

$$F = C_v.\rho(L\sin\alpha + b\cos\alpha)\left(\frac{v_x.|v_x|}{2}\right) + C_i.\rho(L\sin\alpha + b\cos\alpha)b.w_x \tag{2}$$

Where

- ρ density of water
- α the angle of the waves
- b and L width and length of sheet pile walls
- C_v and C_i coefficients of speed and inertial resistance, which are determined by experiments
- v_x and w_x horizontal speed and acceleration of the water follow, which can be determined as following equations :

$$v_x = a\sqrt{g.k.thkd}.\frac{chk(d-z)}{shkd}\cos k(x-ct) + \frac{3}{4}\frac{a^2k}{sh^4kd}\sqrt{g.k.thkd}.ch2k(d-z)\cos 2k(x-ct) + \frac{3}{64}.\frac{a^3.k^2}{sh^7kd}\sqrt{gkthkd\left[13-4ch^2\right]}.ch3k(d-z)\cos 3k\cos 3k(x-ct) \tag{3}$$

$$w_x = akc\sqrt{g.k.thkd}.\frac{chk(d-z)}{shkd}\sin k(x-ct) + 3\frac{a^2k^2.g}{sh^2kd}\frac{ch2k(d-z)}{sh2kd}.\sin 2k(x-ct) + \frac{9}{32}.\frac{a^3.k^3.g}{sh^5kd}\frac{\left[13-4ch^2kd\right]}{sh2kd}.ch3k(d-z)\sin 3k(x-ct) \tag{4}$$

Where

- a wave amplitude
- k wave number, $k=2\pi/\lambda$
- λ wave length
- d depth of water
- x, y and z coordinate point of water
- t time of wave motion
- c determined as following equation

$$c = \sqrt{\frac{g}{k}thkd}.\left[1 + \frac{a^2k^2}{16sh^4kd}(8ch^4kd - 8ch^2kd + 9)\right] \tag{5}$$

The calculation of the total horizontal force for the specified construction were carried out by authors [3], figure 3 shows an example of calculating the horizontal wave force acting on a short wall sheet pile wall as the local obstacle.

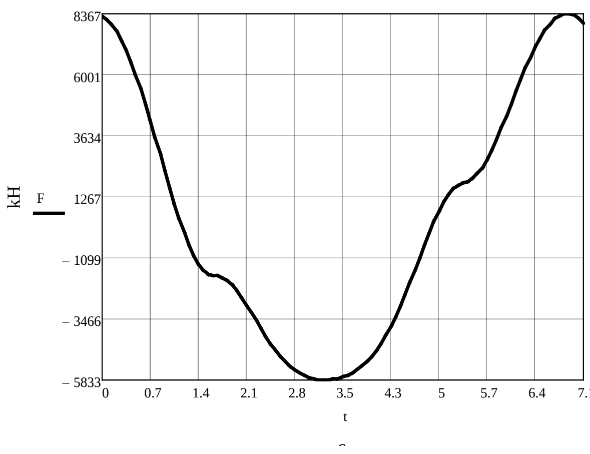

Figure 3. An example of a direct calculation of the horizontal force of the waves on the short wall sheet-pile

V. CONCLUSION

To ensure the stability of the mole port under construction, two following questions have to answer exactly during design. First: what are the characteristics of the steel sheet-pile wall, the wave loads can be calculated based on the diffraction of waves behind a wall? Second: how water transfers along the front wall during oblique waves with the short crest coming in? And what are the risks of loss of stability associated with such flows. The solution for these questions is pointed in this paper by authors.

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