RAPID METHOD OF ESTIMATING LOAD DEVELOPED BY PROGRESSIVE WAVE ON SMALL BARRIER LOCATED ON SEA SHELF

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Rapid method for estimating hydrodynamic (wave) load on a barrier is worked out. The barrier has rectangular cross-section shape, and a smaller sizes. The construction is fixed to the basin (sea shelf) bottom.
Prompt estimation of both the wave relative length and velocity and acceleration of water particles within the construction shaft as a result of which inertial and speed wave loads as well as maximum load value are specified are conducted under approximating formulas earlier obtained by the author. Results obtained under both the above estimation and according to the construction norms and regulations show their reasonable compliance.

Key words**:** progressive wave, sea shelf, wave dampener, dynamic load, acceleration, coefficient of resistance.

Based on various studies it is determined that the wave load on the barrier (located on a sea shelf and fixed to the bottom) (fig. 1) consists of two components: the first is proportional to acceleration (it is called inertial load) and the second – to the established motion rate (it is called speed load). Their values and correlation between them depend on Dc/λ ratio (where Dc is size characteristic to the barrier cross-section, and λ -is a wave length) [1-3].

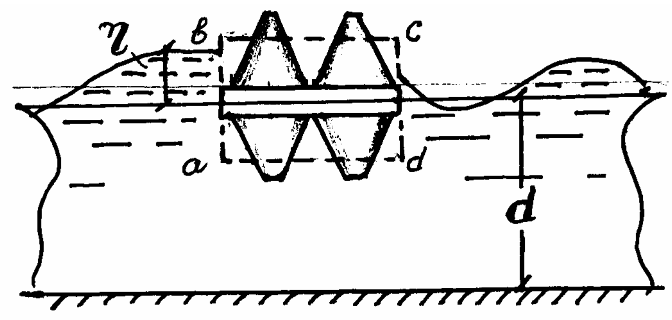

Fig. 1. Barrier placed on a see shelf and flowed over by waves abcd - the design scheme of construction

One of the basic ways to estimate the wave load is hydrodynamic method [1]. In engineering practice according to this method, it is basically accepted that the wave generated on water surface has periodic, the so called progressive, wave form (the shape and sizes of which do not change) [5]. The parameters characteristic to this wave are: T, σ and H (period, frequency and height)) [3,4].

In case $Dc/\lambda \leq 0,3$, the barrier belongs to the number of small constructions [1]. Total maximum horizontal (towards x-axis) load caused by the action of a progressive wave on the construction is estimated in a following way [1,5].

$$P_x = \rho(\delta_i C_i \Omega_{ab} \dot{V}_x h_c + \delta_D \frac{C_D}{2} V_x^2 \Omega), \tag{1}$$

Where ρ is water density, V_x and $\dot{V}_x$ - velocity and acceleration of water particle; Ω_{ab} – area of the barrier cross-section (in case of rectangular shape Ω_{ab}=a·b, where a and b are barrier width and length); Ω - area of the barrier cross-section which is transverse to the wave flow Ω_{ab} =b·h_c (where h_c is barrier height); δ_i and δ_D – coefficients considering the fact that inertial and speed components achieve maximum values at various time instant (π/2 phase difference); their estimation under the diagram method may be done in a following way: δ_i=0,7 and δ_D=0,5; C_D and C_i – empiric coefficients.

C_D coefficient is called coefficient of resistance which generally depends on Reynolds number [3]. According to the data obtained as a result of the experiments, in case of the barrier of rectangular cross-section shape, [1,6] it is taken C_D=1,6.

C_i coefficient value may be estimated as a result of processing the experiment data [1,3] with the dependence obtained by us.

$$C_i=2{,}5-0{,}084(6-N_{KC}), \quad \text{when} \quad 0 \le N_{KC} \le 6, \tag{2}$$

where $N_{KC}=V_x(T/D_c)$; V_x – calculation horizontal velocity of water particles.

Under the proposed prompt method for estimating the wave load, initially an average velocity V_x of the wave flow acting on the barrier is estimated according to the approximating formulas obtained by us or the diagram drafted based on accurate calculation formulas [5], (figure 2). Estimation of the acceleration value is possible by the following approximation formula:

$$\dot{V}_x = \frac{V_x}{\Delta t} = \frac{4V_x}{0{,}6T}, \quad \left(\Delta t = 0{,}6\frac{T}{4}\right). \tag{3}$$

Figure 2 illustrates $V_x^* = V_x \dfrac{T}{D_W} = f(kh)$ function diagrams, where kh=(2π/λ)h=2π/λ*, h is basin depth ; λ*=λ/h – relative wave length. Estimation of kh and D_w parameters is run under our approximation formulas [5], in particular:

$$kh = 0{,}86\frac{\sigma^2 h}{g} + 0{,}34, \text{ when } 0{,}35 < \frac{\sigma^2 h}{g} \le 3{,}0, \tag{4}$$

where $\sigma = \dfrac{2\pi}{T}$; g – acceleration of a free fall.

$$D_W = \left(\frac{1}{[H/D_W]_F}\right) \cdot H, \tag{5}$$

where

$$\left[\frac{H}{D_W}\right]_F = 1{,}27 + 0{,}72ht(kh - 1{,}3), \text{ when } 1{,}3 \le kh \le 4{,}0.$$

Thus, all the parameters necessary for calculating the wave load according to the formula (1) are specified.

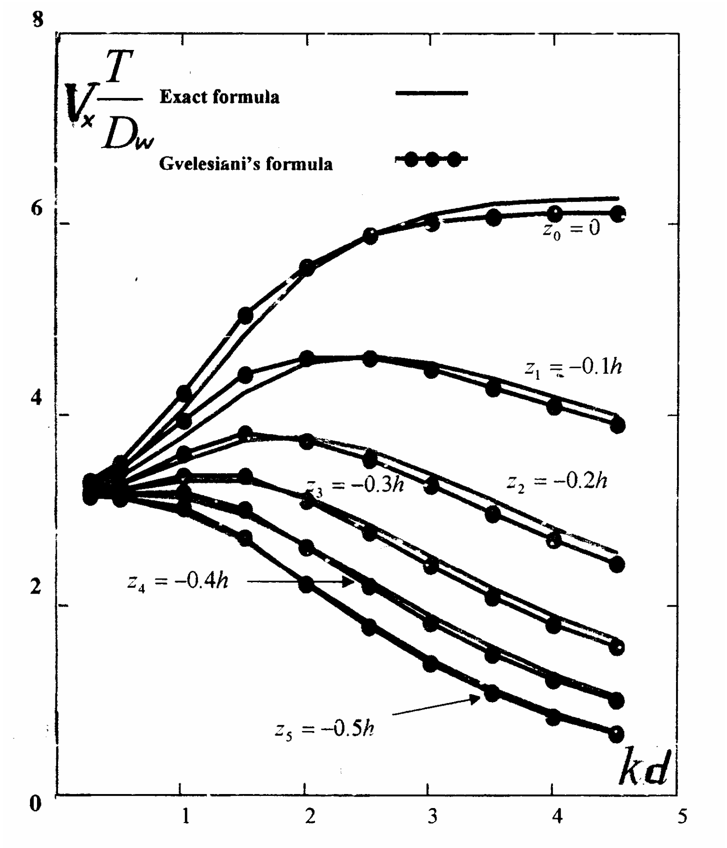

Fig. 2. Relationship between the relative maximum horizontal velocity of water particle and kh parameter for different submergence depths

Example: let's estimate maximum load caused by the progressive wave on abcd rectangular cross-section construction (fig. 1) floating on water surface and fixed to the see bottom at h=30 m depth by the cables. The construction dimensions are: b=6,5 m, a=3,5 m, h_c=3,5 m. The wave parameter values are: H=6,0 m; T=6,2 sec and water density ρ=1000 kg/m^3.

$\sigma = \frac{2\pi}{T} \approx 1$ (1/sec) and $\frac{\sigma^2 h}{g} = 3{,}0$ are estimated first and kh=3,0 is obtained according to the formula (4). Then, $\left[\frac{H}{D_W}\right]_F = 1{,}94$ and D_W=3,1 m are calculated according to the formulas (6) and (5). Based on figure 2, we can determine, that when z=0 and -1,75 m, respective velocities are $(V_x)_z$=3,1 and 2,45 m/sec. By means of extrapolation it is found that when z=hc/2=3,5/2=1,75, then $(V_x)_z$=1,25$(V_x)_z$=0=1,25·3,1=3,9 m/sec. According to this, an average (calculation) velocity is estimated as V_x=3,2 m/sec. Since Δt=0,6(T/4)=0,9 sec,

$\dot{V}_x = 3{,}2/0{,}9 = 3{,}6$ m/sec^2. Parameter N_{KC}=V_x(T/b)=3,2 and under the formula (2) C_i=2,23 is obtained. Given the above, we obtain C_D=1,6.

Cross-section areas characteristic to the construction are:

$\Omega_{ab} = a \cdot b = 3{,}5 \cdot 6{,}5 = 22{,}8$ m^2; $\Omega = b \cdot h_c = 6{,}5 \cdot 3{,}5 = 22{,}8$ m^2.

Finally, the following is estimated under the formula (1):

$$P_x = 0{,}71 \cdot 640{,}6 + 0{,}5 \cdot 186{,}8 = 454{,}9 + 93{,}4 = 548{,}3\text{kg} \cdot \text{N}.$$

According to the norms [7], we obtain P_x=531,6 kg·N, which is slightly different from the above obtained results.

Vertical component (P_z) of the wave load can be estimated in a similar way.

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