shear characteristics obtained can be used when calculating seismic effects on slope stability.

The aforementioned characteristics of assigning slope parameters indicate their substantial factor of safety against sliding for a rather considerable period of operation of the slope with small volumes of annual erosion, which, as a rule, are taken into account in their cost.

LITERATURE CITED


DETERMINATION OF THE PARAMETERS OF SHIP WAVES AT BANKS

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When solving the problems of determining the wave resistance to the movement of ships [1, 2] it was found that with distance from the ship the wave profiles are transformed into a system of diverging and transverse waves (Fig. 1) and the heights of the waves gradually decrease. The parameters of the waves depend on the speed of the ship, its size, and external boundary conditions.

In the standard literature [3, 4] the following relation is given for calculating the height $h_s$ of a ship wave at the banks of canals:

$$h_s = \frac{v_s^2}{g} \sqrt{\frac{T}{A}}$$

where $v_s$ is the speed of the ship; $T$, $L$, and $b$ are the draft, length, and block coefficient of the ship; $A$ is a parameter taking into account the effect of the canal, which in the standard instructions [3] is determined by the relation

$$A = \frac{1.6}{1 - \left(\frac{B'}{\delta_1}\right)}$$

where $B$ and $\delta_1$ are the beam and midship section coefficient of the ship; $\Omega$ is the cross-sectional area of the canal.

In the standards [4] this parameter is expressed by the formula

$$A = 2.5e^{-(gH/2v_s)}$$

where $H$ is the depth of the water.

The different representation of parameter $A$ leads to substantial differences when determining the wave height, and the absence of specific recommendations on determining the length of the diverging waves and their angle of approach to the bank reduces the reliability of calculating the effect of their force on the banks. Equation (1) cannot be used for small ships moving at high speeds, since this leads to an overestimation of the calculated values of the wave height.

In the proposed approximate method of determining the parameters of ship waves for various conditions of movement of the ships it is assumed that wave motion at a certain distance from the ship represents two groups of regular traveling gravity waves — transverse and diverging. The bottom is assumed horizontal, and the effect of the banks on the conditions of wave formation and transformation of waves is not taken into account. It is known

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Fig. 1. Schematic diagram illustrating calculation: 1) Ship; 2) diverging waves; 3) transverse waves; 4) bank.

Fig. 2. Coefficients of generation \( m_d \) (curves 1, 2, and 3) and \( m_t \) (curve 4) as a function of the Froude number for values of \( v/\sqrt{gH} \): curve 1) 1.5; curve 2) 1.0; curves 3 and 4) < 0.7.

[5] that between the specific water volume being expelled by the wave generator and the specific volume of the crest of the waves being generated there is a functional relation, which as applied to the investigated problem can be represented in the form

\[
\frac{h_l}{\lambda} = m_t BT_d; \\
\frac{h_d}{\lambda} = m_d BT_d,
\]

where \( h_l \) and \( \lambda_l \) are the height and length of the transverse wave near the ship; \( h_d \) and \( \lambda_d \), height and length of the diverging wave near the ship; \( m_t \) and \( m_d \), coefficients of generation, respectively, of transverse and diverging waves, which depend on the speed of the ship.

The coefficients of generation are interrelated by the following energy condition:

\[
m^2_d + m^2_d + m^2_d = 1,
\]

where \( m_d \) is the coefficient of dissipative losses.

We will use also the kinetic conditions of the "ship-wave" system. The propagation velocity of the transverse waves is equal to the speed of the ship, i.e.,

\[
\left(\frac{g\lambda}{2n}\right) \text{th} 2n(H/\lambda) = v^2.
\]

The propagation velocity of the diverging waves depends on the regime of movement of the ship. If the generation of diverging waves occurs without rip currents and partial breaking of the wave surface, then in this case we can assume that the time of generation of the wave crest corresponds to the time of passage of the ship's bow of length \( L_b \) through a fixed vertical section, hence follows

\[
\left(\frac{n\lambda_d}{2g}\right) \text{ch} 2n(H/\lambda_d) = L_b/v^2.
\]

However, in practice the speed of a ship is often such that partial breaking of the water surface occurs at its bow. Condition (7) in this case is violated, and the diverging wave at the initial instant has the maximum steepness of its existence regardless of a further increase of ship speed. Thus the maximum ratio of the height and length of the diverging wave can be assumed equal to

\[
h_d/\lambda_d = 1/7,
\]

as was experimentally established for a system of traveling gravity waves.

The values of the wave height \( h_d \) calculated by Eq. (5) with consideration of (8) should be used when they are smaller than the values of \( h_d \) calculated by (5) with consideration of (8').

The decrease of wave height as it moves away from the ship is related to the group reconstruction of the waves and their spreading. The value of the wave height \( h_s \) at distance \( l \) from the ship can be taken approximately according to the exponential law [1] in the form

\[
h_s = h_{t,d} e^{-l/\lambda_d},
\]