CHAPTER 54

ON DESIGN OF WAVE PRESSURE ACTING ON STRUCTURES OF SLOPING TYPE

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ABSTRACT

In the paper some results of study of active external pressure of wind waves acting on structures of sloping type are presented in brief. The pressure developed by waves and acting on the inclined wall is divided into impact pressure and pressure remaining after shock. For determination of maximum water pressure remaining after shock a prof. N.N.Djunkovsky scheme is used (R.-I). Pressure distribution curve of water remaining after shock along the slope is determined by means of consideration of jet pressure acting on inclined wall. Design curve is compared with the data of laboratory wave flume tests. Measurement pressure data received at test zone in reservoir is statistically treated.

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The study of wave action on banks without protection and riverside hydraulic structures include a number of problems: wave transformation in riparian zone, determination of wave action, bottom velocities and so on.

In world literature sufficiently fully described were the problems connected with wave transformation on slope, shallow water and wave pressure acting on vertical wall.

In the Soviet Union in connection with a number of large storage dams, mainly earth dams with upstream faces which are covered with concrete coatings, a great attention was paid to wave pressure acting on such coatings.

N.N. Djunkovsky was the first in this field to suggest a theoretical scheme of determination of wave pressure on the slope at wave impact.

This scheme was experimentally based and further developed due to a large number of studies carried out by the wave Laboratory of Moscow Engineer Construction Institute headed by N.N. Djunkovsky. In addition to laboratory observations in the Soviet Union a number of design and scientific research institutions carry out systematic field measurements of wave agitation parameters, wave pressure distribution along the slops and a number of other characteristics of slope protection dehaviour in test zones located in a number of large reservoirs.

Pressure reoord of waves acting on the slope in the zone of wave breaking has a typical shape: sharp peak correeponidng to the shock, gently sloping part of pressure curve, corresponding to water pressure remaining after shook (jet), and a gradual drop of the curve up to minimum.

A problem of wave pressure acting on the slope due to water pressure remaining after shook (jet) is described below,

For the determination of maximum water pressure acting on a sloping wall different empirioal formulae are used. Most of them show maximum pressure as a linear function of wave height with different factors of proportionality.

The theory of similarity and dimension and theoretical scheme of determination of maximum pressure of swell breaking wave developed by prof. N.N. Djunkovsky (I) can be suooessfully adopted in the determination of maximum water pressure remaining after shock.

The formula of maximum pressure acting on the slope according to the theory of similarity and dimension is as follows:

$$P_{max} = f\left(\alpha, \frac{h}{\lambda}\right) \rho V^2 \qquad \text{(I)}$$

where P_{max} - maximum pressure,

α - angle of slope,

h - wave height,

λ - wave length,

ρ - water density,

V - characteristic velooity,

$f\left(\alpha, \frac{h}{\lambda}\right)$ - funotion of demensionless parameters α and $\frac{h}{\lambda}$.

Maximum pressure acting on the slope from the wave pressure remaining after shock can be expressed by the formula:

$$P_{max} = \rho \frac{V_B^2}{2} \qquad (2)$$

where - maximum velocity of wave particles falling on the slope in some point "B" in N.N. Djunkovsky's scheme (I).

Taking the orbit velocity as typical in the expression (I) and as an initial velocity at determination of velocity V_B, it is easy to receive the type of function $f\left(\alpha, \frac{h}{\lambda}\right)$ from the above given formulae (I) and (2).

Substituting the expression for the function $f(\alpha, \frac{h}{\lambda})$ into the formulae (I) the design formula for the détermination of P_{max} for the case of deep water yields:

$$P_{max} = \rho g \left[\frac{\pi}{4}\left(1+\frac{2}{m^2}\right)\frac{h}{\lambda} + \frac{y_0}{h} - \frac{\pi}{2}\frac{h}{\lambda}\frac{1}{m}\sqrt{\frac{1}{m^2} + \frac{2}{\pi}\frac{\lambda}{h}\frac{y_0}{h}}\right] \times h \qquad (3)$$

and accordingly for shallow water

$$P_{max} = \rho g \left[\frac{\pi}{4}\left(1+\frac{2}{m^2}\right)\frac{h}{\lambda} + \frac{y_0}{h} th \frac{2\pi H}{\lambda} - \frac{\pi}{2}\frac{h}{\lambda}\frac{1}{m}\sqrt{\frac{1}{m^2} + \frac{2}{\pi}\frac{\lambda}{h}\frac{y_0}{h} th \frac{2\pi H}{\lambda}}\right] \times h \qquad (4)$$

where m = $ctg\,\alpha$

y_0 - crest height above slope in the point of wave breating,

H - water depth in the reservoir,

Now we shall consider what pressure is taken by pressure pick-ups installed in the test section in the reservoir.

The pressure gauge in the point "x_0" of the slope will take higher or lower pressure due to wave parameters and in some cases if it proves to be in the zone of shock it will record maximum pressure. Thus time-pressure distribution $P(x_0, t)$ will be fixed in the record.

Thus the statistical analysis of pressure measurements at the point "x_0" yields the mathematical expectation of pressure:

$$\mathcal{M} P(x_0) = \sum P(x_0, t)\, p\,[P(x_0, t)] \qquad (5)$$

where $p[P(x_0,t)]$ - is probability.

As the relation of maximum pressure-wave height, the diagram of pressure distribution along the slope, and the function of wave-height-time distribution are known, the mathematical expectation of pressure in the given point can be determined:

$$\mathcal{M} P(x_0) = \sum P_{max}(h)\, f(x_0 - x_B)\, p(h) \qquad (6)$$

Here it is assumed that the pressure distribution along the slope can be represented in the function of P_{max}, that is

$$P(x_0) = P_{max}(h)\, f(x_0 - x_B) \qquad (7)$$

where "B" is the point of application of maximum pressure.

As P_{max} is linearly dependent of h (the parameter changes in a narrow range), the probability density function of maximum pressure is equal to the density function of wave height which shows the validity of formula (6). The formula (6) permits the treating of the data of the wave agitation on effect on slopes.

Experimental data of the observations of reservoir test zones were treated statistically (R.-3). In some points along the slope average values of maximum pressure and variation and assymetry factors were determined. The average maximum pressure diagram has the shape of a ourve gently sloping from $\rho g h$ in the deep water to P_{max} in the zone of impact with the gradual lowering up to zero at higher elevations. According to the test data

$$\bar{P}_{max} = 1{,}6\bar{h} \tag{8}$$

It should be noted that the treatment of field experimental data gives slightly higher results due to taking into consideration a part of impact pressure at the registering the maximum pressure. Besides the treatment shows a regular lowering of the average value beoause the maximum pressure point is a function of wave height. Variation faotor also shows regular increasing to 40-80 per cent in the wave impaot zone at the variation factor of wave height in the range of 20-40 per cent. The assymetry faotor changes is a rather wide range from 2.I to 3.5 or even to 5.5 for small pressure values in the upper part of a slope with variation faotors of wave height between 0.7 and I.3.

Pressure on the slope from remaining after shook water wave (jet) oan be regarded as a sum of dynamic and hydrostatic jet pressures.

To determine dynamic component of jet pressure hydromechanic as well as hydraulic methods were used.

In the first case that is when using the hydromeohanic method the ourve of pressure on the slope due to remaining after shock water wave (jet) is constructed according to coordinates, determined by parametric expressions (R.-4):

$$P_H = \rho g \left\{ \left[\frac{v_0^2}{2g} - \frac{m(1 \pm \sin\varphi)t}{2\sqrt{m^2+1}} \left(1 - \frac{1}{\chi^2}\right) + \frac{m(1 \pm \sin\varphi)t}{2\sqrt{m^2+1}} \right] \right\} \tag{9}$$

$$\xi = \frac{t}{\pi}\left(\ln\frac{\chi+1}{\chi-1} + \sin\varphi \ln\frac{\chi^2 - 2\chi\sin\varphi + 1}{\chi^2-1} + 2\cos\varphi \operatorname{arctg}\frac{\cos\varphi}{\chi - \sin\varphi} \right) \tag{10}$$

where the sing"+" is taken in constructing the curve branoh located up the slope from the point "B" ($\infty \geq \chi \geq$ I) and the sing "-" - in constructing the curve branoh down the slope from the point "B" ($-I \geq \chi \geq -\infty$).

In the second case a polygonal pressure curve is taken which is based on the following factors:

I. Maximum ordinate of piezometric pressure on the slope due to remaining after shock water wave is determined be the formula (2).

2. The length of the curve of the dynamic pressure distribution on the slope is similar to that of noted at the remaining after shock water wave in imponderable liquid, that is this curve length is equal to

$$\xi_1 + \xi_2 = 4t \cos\varphi \tag{II}$$

where the length of branches of the dynamic pressure curve is determined by the expression:

$$\xi_1 = 2t\,(\cos\varphi + 0{,}75\,\mathrm{tg}\,\varphi) \tag{I2}$$

$$\xi_2 = 2t\,(\cos\varphi - 0{,}75\,\mathrm{tg}\,\varphi) \tag{I3}$$

3. The pressure beyond the zone of the dynamic pressure of jet is equal to hydrostatic pressure and the curve ordinates p_1 and p_2 are correspondingly equal to

$$p_1 = \frac{\rho g m (1+\sin\varphi) t}{2\sqrt{m^2+1}} \tag{I4}$$

$$p_2 = \frac{\rho g m (1-\sin\varphi) t}{2\sqrt{m^2+1}} \tag{I5}$$

where φ - the angle between the tangent in the jet direction in the point "B" and the normal to the slope,

t - jet thickness, determined by the empirical formula of Khaskhachih G.D. (R.-5):

$$t = \left(0{,}75 - 0{,}06m - 1{,}5\,\frac{h}{\lambda}\right) h \tag{I6}$$

The pressure curves constructed by the afore-cited relations are compared with the results of measurements in wave flumes and in test zones. The comparison showed good agreement of the measured and theoretical values.

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