CHAPTER 167

About Conditions for the Wave Ripple Existence

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Abstract

For the prognostication of sediment flow during storm period an investigator has to know if there are any microforms at the bottom in a certain place and under certain wave conditions, and what are their characteristics.

On the basis of field and laboratory data we tried to determine the most universal range of conditions for the wave ripple existence.

In the nearshore zone the gradients of near-bottom velocities and shear stress values depend both on wave motion influence upon the erodible bottom and on the bottom form influence upon this motion. To estimate the dependence of hydrodynamical flow structure on the bottom microrelief it is very important to realize in

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what conditions microforms, usually called ripples, originate, exist and disappear.

The object of this work is to get quantitative estimation of ripple existence on a certain area of the underwater shore slope under the known parameters of surface waves.

It is generally accepted that ripples are formed when near-bottom velocities of water flow slightly exceed those required to set sediment in motion. M.Manohar (1955) estimates the ratio of this velocities as 1, 2 and other authors as 1, 1 (Carstens et al.,1969).

To evaluate the critical velocities for different phases of motion, the relations of the following type are often used:

$$U = K\sqrt{g\bar{d}} \qquad (1)$$

where $\bar{d}$ is the mean diameter of bed-sediment particles, g is gravitational acceleration and K is a constant with some dependence on $\bar{d}$. There is a great variety of similar formulae. Beugner (1980) alone gives a selection of 50 equations of this type.

All the criteria for the existence of wave induced ripples differ from similar formulae for progressive flow only in that the maximum value of nearfloor orbital velocity was taken into account rather than the nearfloor current velocity. However, some authors (Dingler, 1979; Komar, Miller, 1975; Vongvisessomjai, 1984 and others) indicate that to describe the behaviour of bed particles properly, specific features of the hydrodynamic regimes of various flow types should be considered, the influence of wave period (T) first of all.

Oscillating water masses affect the erodible floor most visibly when the nearfloor velocity (U) becomes maximal. The shorter the surface wave period, the longer the duration of the action of U during a storm. Moreover, the thickness of the nearfloor boundary layer of the wave flow is proportional to the square root of the wave period. Thus, waves with shorter periods create favourable conditions for the initiation of sediment motion.

Among the criteria for the initiation of the ripples formation accounting for T influence, the most common is the empirical equation of P.Komar and M.Miller (1975). It links sediment mobility parameter F with a ratio of nearbottom orbital diameter d_o to the sediment particle diameter $\bar{d}$.

$$F_b = b\sqrt{d_o/\bar{d}} \qquad (2)$$

where $F = \frac{\rho U_m}{(\rho_s - \rho) g d}$; $d_o = U_m T/\pi$; ρ_s and ρ are densities of solid particles and liquid, respectively. To calculate the beginning of ripple formation, the authors propose using a value of the dimensionless coefficient $b = 0.11$; a value of $b = 0.21$ is used to estimate the initiation of movement of developed ripples.

In some other papers the conditions for the ripple formation are given by the sediment mobility parameter F:

$$F_b = 3 \quad \text{(Brebner, 1980)} \qquad (3)$$

$$F_b = 0.89\,(d_o/\bar{d})^{1/3} \quad \text{(Vongvisessomjai, 1984)} \qquad (4)$$

$$F_b = 0.033\,(d_o/\bar{d})^{2/3} \quad \text{(Kos'yan, 1988)} \qquad (5)$$

$$F_b = 0.04\,(d_o/\bar{d})^{2/3}\left(\frac{g\bar{d}^3(\rho_s-\rho)}{\nu^2\rho}\right) \quad \text{(Dingler, 1979)} \qquad (6)$$

where ν is a kinematic viscosity coefficient.
The upper limit of ripple existence is controlled by the upper smooth phase of sediment movement when bedforms are obliterated and suspended sediment transport becomes very intensive. According to laboratory tests of Carstens Carstens and others (Carstens et al., 1969), ripples are disappearing when

$$d_o/\bar{d} = 34000 \qquad (7)$$

while S.Kennedy and M.Falcon (1965) on the basis of analysis of D.Inman in-situ measurements data (Inman, 1957) got the value:

$$d_o/\bar{d} = 16000 \qquad (8)$$

J.Dingler defined the upper limit of ripple existence by mobility factor as:

$$F_c = 240 \qquad (9)$$

Having analysed the effect of wave period, S.Vongvisessomjai (1984) obtained:

$$F_c = 12.7(d_o/\bar{d})^{1/3} \qquad (10)$$

In the Kos'yan's paper it was obtained:

$$F_c = 0.54(d_o/\bar{d})^{2/3} \qquad (11)$$

The equations (2) - (11) describe the peculiarities of ripple formation more completely than the equation (1) does. But in some cases such limitations may be wrong, as at constant U_m and T values, the nature of the bed sediment motion can vary considerably due to artificial damping or increasing of nearbottom turbulence of floor roughness.

The value of the bed tangential stress (τ) takes turbulence and floor roughness into account so it seems logical to use this parameter to characterize the specific interaction between moving water masses and sediment.

The conditions for ripple existence can be determined, for example, by Shield's parameter value (Ψ). This parameter expresses the relationship between maximum nearbottom shearing force and the force resisting the wave movement:

$$\Psi = \frac{\tau \bar{d}^2}{(\rho_s - \rho)\, g \bar{d}^3} = \frac{0.5 f_T \rho U_m^2}{(\rho_s - \rho)\, g \bar{d}} = 0.5 f_T F \qquad (12)$$

where f_T is a wave friction factor.

According to Nielsen, Shield's parameter, describing the existence of wave ripples varies:

from $\Psi_b = 0.04$ to $\Psi_c = 1.0$ (13)

There are another expressions using Shield's parameter for the determination of the upper limit of ripple existence in wave flow:

$$\Psi_c = 4.4\,(U_m \bar{d}/\nu)^{-1/3} \qquad \text{(Komar, Miller, 1975)} \qquad (14)$$

$$\Psi_c = 0.5 - 0.6 \qquad \text{(Horikawa et al., 1982)} \qquad (15)$$

To verify the criteria for conditions of wave ripple existence and to deduce our own one we used our own laboratory tests and field observations results and those available from literature.

Variation ranges of laboratory test characteristics (Antsyferov et al., 1977; Keremetchiev, private report; Manohar, 1955; Miller, Komar, 1980b; Nielsen, 1979) is given in table 1.

Variation ranges of field observation parameters (Inman, 1957; Kos'yan, 1988; Miller, Komar, 1980a; Nielsen, 1984; Tanner, 1971) are summarized in table 2.

In all the tests the fact of ripple existence under certain parameters of surface waves and of solid particles and liquid characteristics was noted. For all this, the ripple characteristics and forms were not taken into account. In Manohar's experiments (Manohar, 1955) some measurements were made in the moments of ripple disappearance.

V. Tanner (1974) carried out sea works under low waves, when the maximal nearbottom velocities were wittingly less than the shifting ones. In this case only passive ripples were observed, therefore sea data obtained by V. Tanner were not used in this paper. Only his observations in lakes were used. The selection of experimental data obtained by M. Miller and P. Komar (1980a) was made according to their recommendations.

Amplitudes of nearbottom orbital velocities during ripple observations were calculated using the Airy wave theory, when analyzing the data of sea investigations the values of significant (calculated from the height of mean from one third of the largest waves of a group) orbital velocities were taken into account. According to existing estimates (Kos'yan, 1985; Miller, Komar, 1980a; Nielsen, 1981) parameters of these particular waves determine the nature of sediment movement, when waves are irregular. Using these parameters one may

Table 1.

U_m cm/sec	T sec	H m	$\bar{d}$ mm	d_o cm	h_r cm	Number of measuring	Author
8.0-42.0	1.0-1.5	0.1-0.5	0.2-0.3	6.5-24.0	1.5-5.5	383	Keremetchiev, private report
20.0-23.0	1.8-2.4	0.6-0.7	0.24	16.0-18.0	4.5-5.0	6	Antsyferov et al., 1977
34.5-69.7	1.9-10.1	-	0.28-1.06	4.6-33.6	0.1-1.9	196	Manohar, 1955
30.1-50.2	3.0-5.0	0.3	0.17	0.13-16.0	-	4	Miller, Komar, 1980
10.3-41.5	1.0-1.7	0.4	0.08-0.55	2.5-16.6	0.41-2.7	89	Nielsen, 1979
14.0-90.0	1.7-13.9	0.12-0.657	00.127-0.646	4.0-139.5	0.1-13.5		Dingler, 1974

Table 2

U_m cm/sec	T sec	H m	$\bar{d}$ mm	d_o cm	h_r cm	Number of measuring	Author
16.0-95.0	2.7-6.3	0.7-18	0.08-1.45	5.0-300	0.5-50	89	Kos'yan, 1988
6.1-73.1	0.7-16.0	0.05-33.5	0.081-0.913	2.0-155	0-19.8	89	Inman, 1957
13.3-158.1	0-18.2	3.1-21.3	0.17-0.29	7.6-27.1	-	27	Miller, Komar, 1980
51.0-102.0	5.7-12.9	1.3-1.8	0.11-0.61	35-80	4.3-15	30	Nielsen, 1984
15.9-53.0	0.8-6.2	0.2-0.6	0.13-0.71	3.5-14.6	0.5-3.4	6	Tanner, 1971

compare the results of field works with laboratory tests data, obtained under monochromatical waves.

Equations (1) - (15) limiting the area of wave ripple existence were verified by experimental data. The results of some verifications were published earlier in the works of Kos'yan, 1978; Kos'yan, Pykhov, 1991. Figures 1 - 3 show the typical examples of such verified comparisons of measured and calculated values.

On the basis of accomplished comparisons we can make some conclusions:

1. Various boundary conditions of ripple existence differ greatly from each other, which might result, possibly, from the fact that each author, while deducing his own equation, used a relatively small number of data on ripple observation.

2. The results of verifications show that such criteria as equations (2), (4), (6), (8), (10), (14), (15) are not fulfilled as a great number of test points lie beyond the limits of ripple existence.

3. Almost all of the observation results remain in the range of equations (1), (3), (7), (9), (13). But overwhelming majority of test points lie far from the curves described by these equations. Therefore these criteria may be used only for a rough evaluation of the conditions for ripple formation and flattening.

4. All experimental points, corresponding to the conditions for ripple existence on any coordinate systems occupy the surface contoured on the every side, while the given criteria contour it partially only on one side.

Combining criteria of all authors which give satisfactory results when being compared with field observation data, one can get a range of conditions for ripple existence. In this case this range will be described by the systems of equations which roughly contours the

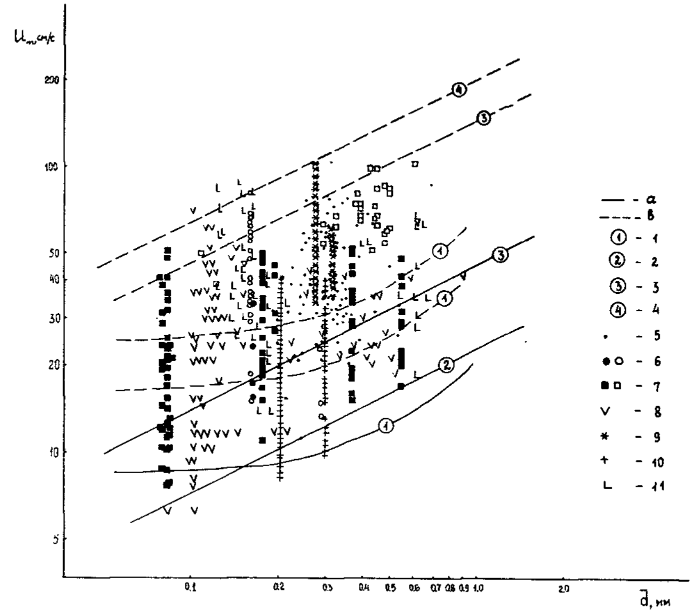

Figure 1. Verified comparison of measured and calculated values a) ripple formation; b) ripple flattening. 1 - Murina, Halfin, 1981; 2 - Brebner, 1980; 3 - Vongvisessomjai, 1984; 4 - Dingler, 1974; 5 - Kos'yan, 1988; 6 - Miller, Komar, 1980; 7 - Nielsen, 1979, 1984; 8 - Inman, 1957; 9 - Manohar, 1955; 10 - Keremetchiev, private report; 11 - Dingler, 1974.

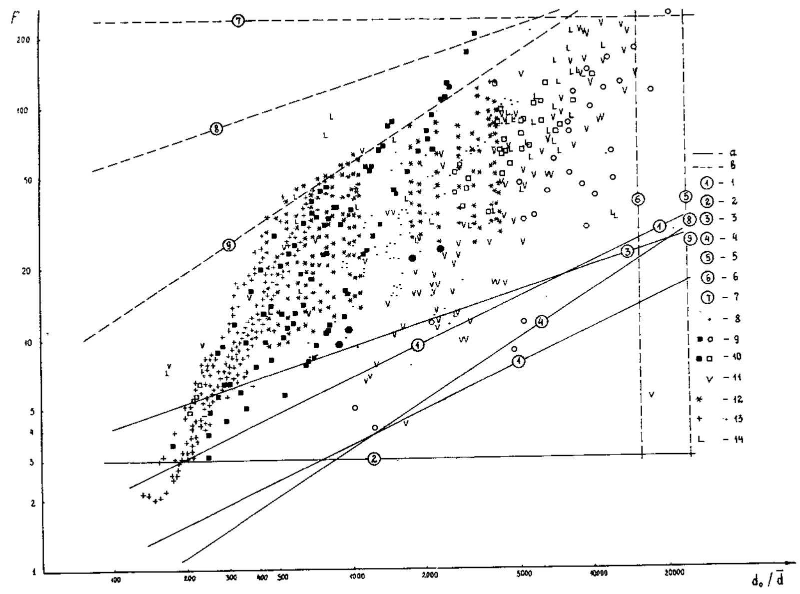

Figure 2. Verified comparison of measured and calculated values a) ripple formation; b) ripple flattening; 1 - Miller, Komar, 1980; 2 - Brebner, 1980; 3 - Vongvisessomjai, 1984; 4 - Kos'yan, 1988; 5 - Carstens et al., 1969; 6 - Kennedy, Falcon, 1965; 7 - Dingler, 1974; 8 - Kos'yan, 1988; 9 - Miller, Komar, 1980; 10 - Nielsen, 1979 and 1984; 11 - Inman, 1957; 12 - Manohar, 1955; 13 - Keremetchiev, private report; 14 - Dingler, 1974.

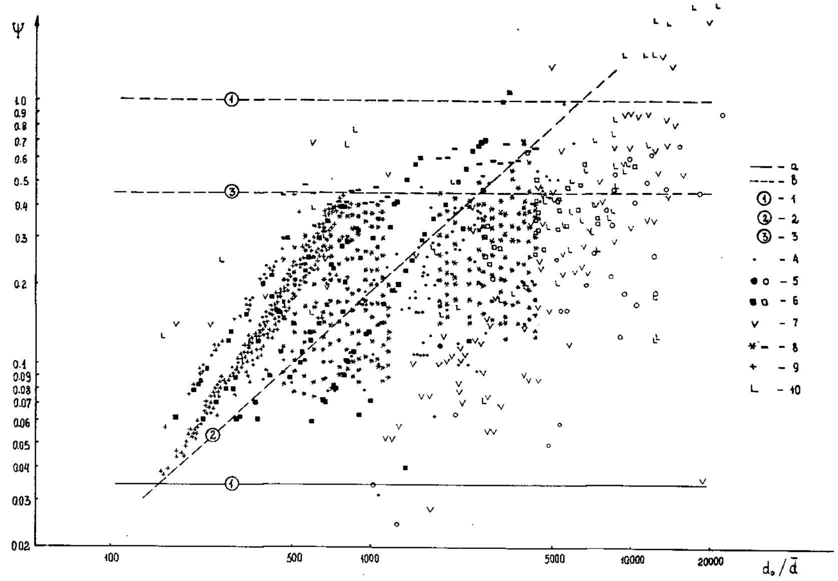

Figure 3. Verified comparison of measured and calculated values

a) ripple formation; b) ripple flattening
1 - Nielsen, 1979; 2 - Kos'yan, 1990; 3 - Horikawa et al., 1982;
4 - Kos'yan, 1988; 5 - Miller, Komar, 1980; 6 - Nielsen, 1979 and 1984;
7 - Inman, 1957; 8 - Manohar, 1955; 9 - Keremetchiev, private report;
10 - Dingler, 1974.

field of points from every side (Kos'yan, Pykhov, 1991).

Let's try to express conditions for ripple existence by the single equation which contours the entire observation field as close as possible.

Universal conditions for bottom form existence accounting for the influence of both the wave period and roughness of bottom may be obtained in the coordinate system of Ψ , $d_o/\bar{d}$. Best of all the whole field of experimental points is contoured by the ellipsis eguation with the following parameters:

$$\frac{(-5.80+0.88\ln d_o/\bar{d}+0.47\ln G)^2}{8.41}+\frac{(5-0.47\ln d_o/\bar{d}+0.88\ln G)^2}{1.69}=1 \quad (16)$$

This expression may be simplified and reduced to typical square equation.

In fig. 4 one can see a comparison of experimental data with those calculated by the formula (16). Here the curve (16) contours the absolute majority of test points (~98,8%) very closely from every side. Besides the curve (16) shows a good agreement with results obtained by Manohar for ripple flattening.

Should new results of ripple observations appears, some correction of eqn. (16) parameters determining the dimensions of the ellipsis and its incline to coordinate axes will become possible. But we believe that such a correction will be insignificant.

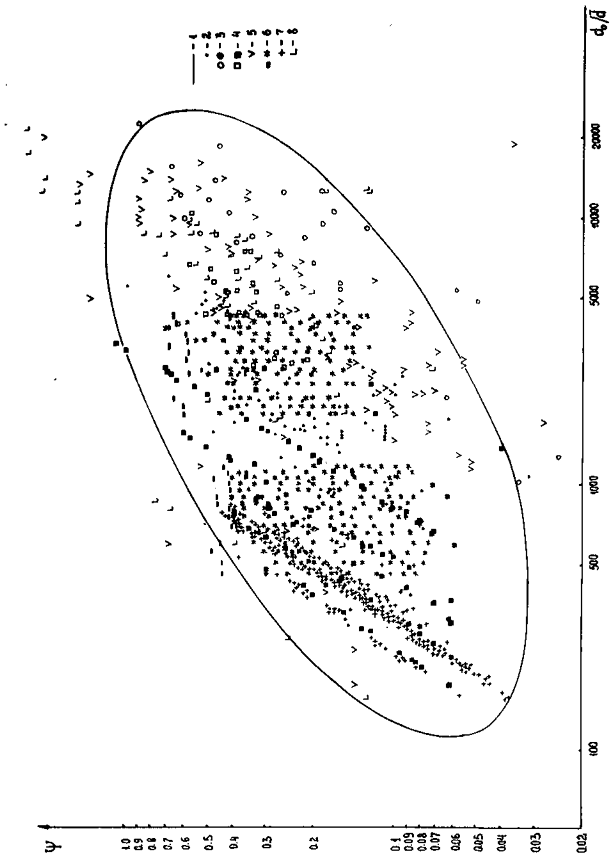

Figure 4. Field of experimental points contoured by the equation (16)
1 - equation (16); 2 - Kos'yan, 1988; 3 - Miller, Komar, 1980;
4 - Nielsen, 1979 and 1984; 5 - Inman, 1957; 6 - Manohar, 1955;
7 - Keremetchiev, private report; 8 - Dingler, 1974.

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