NEW METHOD OF DETERMINING THE PARAMETERS OF WAVE BREAKERS

V. P. Mal’tsev

One of the basic elements of marine hydraulic construction (and often the only one) is the wave breaker (or wave absorber). The wave breaker functions by decreasing wave loads and acting on hydraulic structures, ameliorating water roughness in ports, protecting the shoreline against erosion, increasing the dynamic stability of beaches, etc. The wave breakers used in the construction of hydraulic facilities are revetments of various configurations, berms made from stone rubble or profiled masses, underwater or overwater breakwaters, natural or man-made beaches, etc. The last decade has witnessed the ever-increasing use of chambered wave breakers in worldwide hydraulic construction practice; they are built in the form of barriers open to the sea and impermeable on the shoreline side, separated by a wave chamber, which is covered on top by a slab. Such wave breakers are the most effective both in operation and in cost engineering indices, especially in hydraulic structures, where they perform not only their own functions, but also those of an entire structure (protection of breakwaters, quays, or shorelines). New prefabricated hydraulic structures of this type are described in [1, 2].

Although wave breakers have been a part of human activity since time immemorial, the only reliable method of determining their optimal parameters has been by experimental investigations using hydraulic models. Analytical methods based on well-known wave theories often yield conflicting results and cannot be used for practical purposes. This problem is attributable to the lack of a physically justified and simple mathematical model that takes into account the operating mechanism of wave breakers and is capable of drawing on a wealth of practical experience in hydraulic calculations of structures.

The method proposed here for the analysis of wave breakers is based on theoretical and experimental studies of the velocities [3], asymmetry [4], and mode conversion [5] of a regular traveling wave in the nearshore zone, along with mode conversion on the shoreface with an underwater obstruction [6]. These studies have helped to uncover the operating mechanism of wave breakers and to develop an engineering method for evaluating their effectiveness. For example, experimental studies [3] have established that points of a low-water wave profile and, accordingly, the shapes of the constituent wave elements (crests and troughs) move with unequal velocities. This phenomenon is attributable to the fact that the velocities of these points depend not only on the water depth $d$, but also on their position $\gamma$ relative to the equilibrium state of the water and the curvature of the waveform $\frac{\partial^2 \eta}{\partial x^2}$.

In [4] a wave on the shoreface is regarded as consisting of positive (crest) and negative (trough) displacement waves relative to the mean level of the wave surface (calculated level). The profiles of these components of a regular traveling wave are reduced to nominal horizontal step waves, so that when the countercurrent method is used, each motion of the wave can be treated as steady-state horizontal motion with its own constant depths and velocities corresponding to the time of passage of the crest or trough of the nominal wave. The postulated model (Fig. 1) could be used to investigate theoretically the asymmetry of a regular traveling wave.

A comparison of the experimental and calculated characteristics of the nominal wave discloses satisfactory agreement between them. This consistency confirms that the method developed in the paper can be used in practice to determine the asymmetry of a regular traveling wave in any given range of the shoreface at relative depths $d/h \leq 5$.

In a later paper [5] the regular traveling wave model has been used to investigate the mode conversion of waves in the nearshore part of the low-water zone (Fig. 2). From the investigations it has been established that in the mode conversion of regular traveling waves the specific volumes or areas of their crests and troughs remain essentially constant and equal up to the point where the waves break. The mode conversion of regular waves in the nearshore zone is regarded as an interrelated change in the geometrical and kinematic elements of the wave crests and troughs under the influence of decreasing water depth, but without any change in their specific volume. The numerical values of the geometrical and kinematic wave elements in any given range are characterized by the specific...
volume of the wave crest $W$, its degree of deformation $K_d$, the water depth $d$, and the wave period $T$:

$$W = K_d \sqrt{2gd^{3/2}T};$$  \hspace{1cm} (1)
$$K_d = 0.705 \frac{C_{cr} T_{cr}}{\sqrt{gd}} \frac{\bar{h}_{cr}}{T}.$$ \hspace{1cm} (2)

where $C_{cr}$, $T_{cr}$, and $\bar{h}_{cr}$ are the velocity, period, and mean elevation of the crest of the real wave above the mean level of the wave surface (Fig. 1).

The method developed in the paper for determining the asymmetry and mode conversion of waves on the shoreface [4, 5] can be used to calculate the height of a regular wave and, accordingly, all the constituent geometrical and kinematic elements of its crest and trough in any part of the nearshore zone with a known depth and bottom inclination from the given values of the relative height $h/d$, period $T$, and bottom inclination $\partial_{bot}$ in some part of the same zone. It can also be used to determine the point at which the wave breaks on the shoreface and its height at that point.

This method has been used in hydraulic modeling practice to generate regular and irregular waves with specified parameters in wave tanks and flumes [7] and has served as the basis of an engineering method for calculating the mode conversion of waves on the shoreface with underwater obstructions in the form of a breakwater or bottom trench [8]. The latest theoretical and experimental studies have shown that the proposed method can also be used to evaluate the effectiveness of wave breakers [8].

From the results of an analysis of previous investigations we have determined the mechanism underlying the operation of wave breakers.

A characteristic feature of the steady-state motion of a fluid as distinct from transient (time-dependent) wave motion is that in the former the condition of continuity is maintained by the equality of the volumetric flow rates in the cross sections, whereas in transient, oscillatory wave motion the volumes of fluid flowing past the cross sections under the crest and under the trough of the wave in opposite directions are also equal. The total fluid flow in transient oscillatory motion, as in steady-state motion, does not vary from cross section to the next. However, the magnitude of this flow is always equal to zero (eliminating the waves in the flow). Variations of the geometrical and kinematic elements of the wave, the actual breaking of the wave, and the elevation of the mean level of the wave