EFFECT OF TRANSVERSE DISCONTINUOUS STRUCTURES
ON THE STABILITY OF PEBBLE BEACHES

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The intense development of the coastal zone of the Black Sea coast of the Caucasus predetermined the construction of health-resort complexes within the existing beaches. Such structures include aerariums, solariums, boat houses, climate pavilions, etc. To eliminate their negative effect on pebble beaches, the supports of these structures were installed on separately standing masses, usually of a rectangular shape. As a result a transverse discontinuous (open) structure was formed, which, in the opinion of the designers, as a consequence of their openness should not have an effect on the longshore movement of the beach pebble material.

However, an analysis of the on-site data on the state of beaches near constructed transverse structures indicates the existence of their effect on processes occurring in the coastal zone. Despite the considerable openness, the discontinuous structures displayed a “jetty” effect, as a result of which the interception and accumulation of sediments was noted on the upstream side (relative to the direction of the dominant movement of sediments), which was the cause of the occurrence of “downstream” erosion and led to the need to take measures to restore the beaches.

The need to construct health-resort complexes is increasing under conditions of intense development of the coastal zone. This necessitated investigations to evaluate the effect of discontinuous transverse structures on pebble beaches and to determine the optimal layout and shape of the support masses eliminating the occurrence of negative phenomena. Since it is difficult to conduct experiments under natural conditions, they were conducted in a wave basin on a three-dimensional model.

Modeling was carried out at a scale of 1:25 with respect to the Froude number. Sediments with a median diameter $d_{50} = 2.1$ mm were used as the beach-forming material. The model beach was subjected to the same regular two-dimensional wave regime with a wave height along the line of breaking $h_{cr} = 10$ cm (2.5 m), period $\tau = 1.8$ sec (9.0 sec), with their angle of approach to the shore $\alpha = 15^\circ$; the depth of filling the basin with water was $H_0 = 50$ cm (12.5 m) (in parentheses are given data corresponding to the prototype). The time of subjecting the model to waves in all experiments was the same.

The effect of the transverse discontinuous structures on the beach was estimated from the results of comparing the initial data with the relief of the “free” (without the structure) beach. The relief of the beach was analyzed with respect to characteristic points of the profile of the pebble beach — location of the beach ridge, water line, step-off (place of breaking of the waves), and end of the model of the beach. Fixation of these points of the profile was carried out by means of a ruler from a constant origin with mandatory reflection of all changes in the beach relief. Along with observations of the change in the relief, the quantity of material removed during beach drifting under the effect of diagonally approaching waves was determined in the lower part of the model every 15 min.

The laboratory investigations to evaluate the effect of transverse discontinuous structures on shore processes were carried out for two shapes of the support masses — rectangular and circular. The rectangular support masses measuring $8 \times 12$ cm ($2 \times 3$ m) with an elevation of the top relative to the average water level $\Delta H = +1.6$ cm (0.6 m), which are an analog of those being used under the prototype conditions, were installed in one or two rows. In the case of the two-row layout of the masses, the length of one row was 202 cm (50.5 m) and of the other 146 cm (36.5 m) with a distance between them of 14 cm (3.5 m). The distance between the masses in the row successively changed from 8 to 32 cm (2-8 m). In the case of the one-row layout, the length of the section was taken equal to 202 cm. Between the masses at the level of the elevation of their top ($+1.6$ cm) were installed three rows of longitudinal beams with a cross section of $1 \times 1.6$ cm (0.25 $\times$ 0.40 m) intended, under prototype conditions, for supporting the flooring. In the center of the support masses were installed $2 \times 2$-cm ($0.5 \times 0.5$-m) posts on which the structure was constructed. A general view of the model with a distance between masses equal to 16 cm (4 m) is shown in Fig. 1.
The possible effect of each of the models of the open structures on the stability of the beach was evaluated for three different conditions: 1) with the presence on the model of a beach and supply of sediments to the upstream part every 15 min in a quantity equal to the volume removed from the model during beach drifting, thereby a beach with a through-going saturated flow of sediments was simulated; 2) with the original beach as in the first case but with no delivery of sediments, under conditions of beach erosion; 3) in the absence on the model of the original beach and delivery of sediments to the upstream part in a volume which the given waves can transport.

The investigated models of the structures were placed at a distance of 4 m (100 m) from a sediment trap, which made it possible to evaluate the effect of the structure on stability of the "downstream" stretch of the beach.

The design of the sediment trap made it possible, without stopping the experiment, to determine the quantity of removed beach material and to return it to the upstream part of the model at any time intervals.

The data obtained indicate that in comparison with conditions of a "free" beach, the effect of the structure was manifested in accumulation of part of the beach material in front of the structure, and along with this "downstream" erosion is noted immediately behind the structure (Fig. 2).

The effect of the discontinuous structure was manifested not only within the length of the structure itself but also its "head" mass, which was reflected in the formation of a relief in the form of an alluvial fan. Observations showed that the formation of the fan occurred due to transverse drifting of beach material, i.e., as a result of drawing the sediments seaward. In this case, longshore drifting of the beach material along the shoreline of the forming fan was not noted. The seaward formation of the "head" mass of the underwater relief in the form of a fan is related to a change in the hydraulics of the bottom layer that occurred on the "free" beach after installing the structure. As indicated by the experiments, in the presence of diagonally approaching waves bottom outflowing currents directed seaward occur near the structure similar to rip currents with a velocity sufficient for transporting the pebble material. The occurring currents and eddies forming as a result of the run-up flowing past the individually standing rectangular support masses lead to a decrease of the sediment-transporting capacity of the waves through the free spaces in the structure. This is the cause of the accumulation and drawing of the sediments seaward. As a result of this, the transverse open structure displays a "jetty" effect.

Thus an analysis of the data of laboratory experiments shows that despite openness, a transverse discontinuous structure consisting of two rows of rectangular support masses presently used in hydrotechnical construction practice substantially affects littoral processes occurring on pebble beaches.

Further laboratory investigations were aimed at elucidating the effect of a change in the distance between rectangular support masses, their layout and shape on the stability of the pebble beach adjacent to the structure. All experiments were conducted in the presence on the model of a beach and return of the removed sediments to the upstream part, which most completely corresponds to natural conditions.