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“A Simple Method of Ascertaining the Discharge of Rivers.”

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(Abstract.)

IN order to ascertain the discharge of a river by this method, a cross-section of it must be surveyed, and the velocity of the current in the same be measured. The velocity may be accurately observed by a current-meter, and for an exact calculation of the discharge must be measured in a sufficient number of vertical lines distributed all over the cross-section, and in several points of each line from the surface to the bottom. In rivers of moderate velocity and depth, such observations can be made with comparative facility and promptness; but in more rapid rivers, and of greater depth, they require much time and great pains. This, of course, also holds good in ascertaining the discharge of rivers of moderate size at the time of flood, when the observations are, however, unfavourably influenced by the water-level being commonly subject to frequent changes, for which reason the measurements should then be hurried as much as possible.

In case of the want of requisite measuring-appliances, it is expedient to measure the surface-velocity only; and then, of course, the discharge can only be calculated by means of certain proportional numbers. The discharge might be ascertained, in a very simple way, if an empirical formula could be found for the relation between the mean velocity U in the cross-section, and the greatest surface-velocity V , or the mean surface-velocity v_{ms} , which, however, has been proved to be impossible; the proportion $\frac{U}{V}$, as well as $\frac{U}{v_{ms}}$, appeared, on the contrary, to be subject to considerable changes, occasioned by the shape of the cross-section, as well as by irregularities of the river-bed, and also slightly by the roughness of the bottom.

It is impossible to form a direct estimate of the mean velocity at a cross-section by the observed surface-velocities; but there is a possibility of calculating the discharge, by finding a certain

relation between the mean velocity v_m in the verticals of a cross-section and the surface-velocity v_s . For this purpose the Authors have calculated the proportion $p = \frac{v_m}{v_s}$ for about three hundred vertical curves of velocity in twenty-eight measurements of discharge in Bohemian rivers, and in the Danube at Vienna. In all these measurements Harlacher's current-meter was used.¹ The mean surface-velocity v_{ms} in a certain cross-section was obtained by taking the measured v_s in the relative points of the level of the water as ordinates, and by laying from shore to shore a continuous curve through the points thus obtained, and dividing the area enclosed by this curve and the level of the water by the width of the latter. In the same manner the mean of all the v_m could be obtained.

From a calculation of all the v_m and v_s , for each of the twenty-eight measurements, the following values of the proportion p were obtained:—0.79 once, 0.82 twice, 0.83 six times, 0.84 six times, 0.85 five times, 0.86 once, 0.87 twice, 0.88 three times, 0.89 once, and 0.91 once.

Supposing the cross-section to have been taken, and the velocities to have been measured; on calculating the discharge, by the application of the mean value of p , a quantity will be obtained varying, but very slightly, from the discharge computed from all the velocities measured in the verticals of the section in question. In the different cross-sections of the rivers where these surveys were made, the highest velocity varied from 0.60 metre to 3.00 metres per second, the greatest depth from 0.80 metre to 8.00 metres, and the greatest width from 50 to 420 metres; the smaller velocities, however, were measured only in the sections of moderate depth. The nature of the bottom was very variable; for the most part the greatest value of p occurred with a sandy bottom, whereas the smaller values were found with gravel bottoms, the gravel being of the size of the fist in bottoms of the roughest nature. The proportion p in rivers not varying much in size, velocity, depth and nature of bottom, from the above-mentioned limits, may be taken at 0.85.

An almost identical result has been obtained from measurements of velocity in other places. Thus, in two hundred vertical curves of velocity surveyed by Swiss engineers, the mean value of p was found to be 0.835. In the measurements taken a few years ago in Holland, in the Rhine and its branches, the value of p was ascertained to be 0.87, and the probable error of that value,

¹ Minutes of Proceedings Inst. C.E. vol. lxxvii. p. 358.

ascertained by the application of the method of least squares, was proved to be insignificant.

The Authors have used bridges, from which the surface-velocity was measured by an electric current-meter let down on a small line. One great advantage in this mode of measurement is that neither boats nor any other appliances are wanted. Of course, only bridges with wide spans, those with iron superstructures, are suitable, and a proper position of the piers, lest the motion of the water in their vicinity may be affected by eddies.

The velocities having been measured all along the reach of the river at a sufficient number of points, 1, 2, 3 . . . of the section A C B, Fig. 1, between the piers of a bridge, the curve of the

FIG. 1.

surface-velocities A D B may be drawn. By calculating for the single points 1, 2, 3 . . . , and for a sufficient number of intermediate points, to be chosen in accordance with the formation of the bottom, the product of the surface-velocity v , by the corresponding depth t , and by plotting the values $v_s t$ as ordinates, the points are obtained by which the curves A E, F G, and H B bordering the hatched surfaces, are determined. The content of these surfaces multiplied by the proportion $p = 0.85$ gives the volume of water passed through the section. The Authors have taken successfully more than seventy measurements by the above method in Bohemian rivers, many of them being in the Elbe and the Moldau.

The Paper is illustrated by several diagrams, from which the Fig. in the text has been prepared.