EXPERIMENTAL STUDIES ON LOCALIZED SCOUR DOWNSTREAM A SLUICE GATE

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The phenomenon of localized scour is one of the most frequent problems to be faced by those who design structures in streams where a complex interaction water-structure-soil is produced. Along several decades, advances have been achieved in knowledge about this interaction, giving special attention to certain common cases; nevertheless, we are not dealing with a concluded theme and research studies —mainly experimental— continue to advance and assemble. In the present study the phenomenon of localized scour due to a horizontal water jet flowing submerged over a rigid apron towards a movable bed has been studied. It is a particular case that will permit to deepen on some aspects of scour phenomenon in general, based on advances done so far.

The results obtained on the research of localized scour phenomena due to a horizontal water jet that flows submerged over a rigid apron towards a movable bed of non-cohesive soil are presented. The jet is produced by the flow through a sluice gate and submergence is controlled regulating the level of water downstream of this gate. A theoretical analysis has been done based on several studies of localized scour phenomena developed by other researchers, and tests have been executed on a physical model specially designed which permitted verification of the hypothesis outlined.

The variables manipulated during the tests are: length of the rigid apron, sluice gate opening, mean velocity of the horizontal water jet as it is issued through the sluice gate, depth of submergence, and movable bed characteristics. Even if at first it was considered that the movable bed soil would be represented by two parameters: geometric mean and geometric standard deviation from this mean of the grains that compose the sediment mixture, tests have strengthen, the same as in other research works, that non uniform mixtures may be represented solely by the d_{95} diameter, that is, the non-uniform mixture would have the same limiting scour as a uniform mixture of diameter d_{50} equal to the diameter d_{95} of the non-uniform mixture.

Otherwise, tests verified that the length of the rigid apron has only the effect of attenuating the jet velocity since the flow pattern over the apron is that of a diffusion jet with physical behavior similar to that of a free jet. The latter has been extensively studied and the equations that describe it are used in the present study. Then, knowing the decrease of velocity due to the length of the rigid apron, the case may be treated as one of a horizontal jet without a rigid apron previous to the movable bed.

This reasonings allowed simplification on the treatment of experimental data and it was found possible to obtain a unique relation between dimensionless parameters which would describe the case studied and also indicate which are the variables that reign the process of localized scour downstream of a sluice gate with rigid apron.

A total of 124 tests or runs were executed, which correspond to 42 flow schemes, each of them for time intervals in the following range: 4, 8, 16, 32, 64, 128 and 192 minutes. Two soil types were used, both with the same geometric mean diameter of 1,19 mm but with different geometric standard deviation. The result of each test is a two-dimensional scour hole that was measured on its middle axis. The efflux velocity of the jet has been computed and measurements have been done to determine the conditions for initiation of motion of movable bed particles.

A function has been obtained which is intimately related to the analysis presented by Marion Carstens in 1966 who evaluated several cases of localized scour introducing the *sediment number* which is practically equivalent to the *densimetric particle Froude number* used nowadays. Using all the results, the following expression for specific transport capacity was obtained:

$$\frac{q_s}{\left(F_{95}^2 - F_{95c}^2\right)^{5/2} U_{m_o} d_{95}} = 0{,}00009\left(\frac{s}{b}\right)^{-2{,}6899}$$

The term on the left is Carstens' dimensionless parameter using densimetric Froude number and d_{95} diameter. Integrating and considering $s = 0$ for $t = 0$, the following has been found:

$$\frac{s}{b} = \left(3{,}729.10^{-5}\left(F_{95}^2 - F_{95c}^2\right)^{5/2}\left(\frac{d_{95}}{b}\right)\left(\frac{U_{m_o} t}{b}\right)\right)^{0{,}213}$$

An inconvenience in the expression deduced is that the equilibrium maximum scour depth can't be obtained from it, showing that equilibrium is reached in an infinite time interval. Also, it considers a gradual and ordered process that doesn't always occur in nature. Studies already mentioned indicate that the process of scour shows phases and equilibrium is reached in a finite time interval.

It has been found during the tests some dependence of the scour on the depth of submergence, though its effect has not been studied. Even if it is considered that the submergence depth has an effect that may be additional cause of the scattering of data, this has not been analyzed.

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