INFLUENCE OF THE HYDROGRAPH SHAPE ON THE SCOUR DEVELOPMENT WITH TIME AT ENGINEERING STRUCTURES IN RIVER FLOW

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Transport system infrastructures, namely roads, bridges, dams, and water intakes in rivers are under permanent impacts of multiple floods. To estimate their safety and stability during scour at hydraulic structure foundations, a multidisciplinary approach, which will involve the principles of hydraulics, hydrology, morphology, geology, and so on, is required.

High floods in Europe during the last decade have destroyed a lot of engineering structures because of the scoured foundations; however, the EU Floods Directive 2007/60/EC does not take into account either increased loads of floods or damage risk estimation and management for engineering structure foundations in river flow.

In spite of the importance and complexity of the phenomena, the estimation and management of flood damage risks for engineering structure foundations in rivers has not yet been studied at all.

During the past few decades, the equilibrium and temporal depths of scour have been studied by different authors. In their studies, the flow parameters at the peak of the flood with unrestricted or restricted duration were used. However, in nature, the flow loads on engineering structures have the form of hydrograph and multiple floods form scour holes.

In the present study, the effects of probability, duration, sequence, and frequency of multiple floods on the safety and stability of engineering structures in river flow are studied. In frame of this study the impact of the floods with different shapes of hydrograph on the scour process is investigated.

The differential equation of equilibrium for the bed sediment movement in clear water conditions was used and the method for computing the scour development with time was elaborated. According to the method, the relative scour depth at the hydraulic structures depends on the following dimensionless parameters: the contraction rate of the flow, kinetic parameter of the open flow, kinetic flow parameter under the bridge, Froude number of open flow, Froude number/slope ratio, relative grain size of the bed material, relative depth of flow, relative local velocity, steady or unsteady flow conditions, relative depth of scour developed during the previous time, stratified bed conditions, as well as the time, probability, duration, frequency, and sequence of the multiple floods, sediment transport conditions, shape of the structures, slope of the wall side, and the angle of the flow crossing.

The tests where made in the conditions: $Fr_m = Fr_n$ (Froude number in models is equal to the Froude number in open flow conditions), horizontal scale was 50, and the time scale was equal to 7.

The method for estimating the scour development with time (Gjunsburgs et. al 2004) was used to perform computer modelling; it allows us to determine the influence the shape of the hydrograph on the scour process near engineering structures in river flow.

Two types of hydrograph shape were studied.

For the first type of hydrograph, the time periods of the rising and recession parts have different ratios, and where equal to 1:2, 1:3, 1:4, 1:6, and 1:8, where the first and second numbers are the rising and recession times of the flood, respectively, but with the same duration of the flood. In the second type of hydrograph the ratio between rising and recession parts was the same, but the time of rising part of the hydrograph remain constant, and duration of the floods was different. The probability of the floods was the same for both types of the hydrograph.

The results for scour development with time obtained in tests and calculations by using the above-mentioned method were similar, namely the rapid development at the start of the scour process and than the gradual reduction with time.

For the first type of the hydrograph, the influence of its shape on the final depth of scour was small, but the scour process was different at the initial stage. According to the calculation results, the scour depth development is more rapid for hydrograph with a higher slope of the rising limb.

For the second type, the rising part of floods was constant, but the recession part increased with every case. The greater the recession time of the floods and the less slope of the recession limb of hydrograph, the greater the depth of scour.

It was found that the shape of the hydrograph affects the depth, width, and volume of the scour hole developed during the floods. The ratio between the rising and recession cycles of the flood impacts the scour development with time. When the depth of scour at hydraulic structures increases, the safety and stability reduces, and if the depth of scour exceeds designed value, the structure can be damaged. The results obtained in this study are presented in tables and figures and confirm our conclusions.

The European flood forecasting system (De Roo, Bartholmes, Bates, et. al 2003) can be used together with the method of scour depth estimation with time (Gjunsburgs et. al 2004); as a result, it would be possible to estimate the safety and stability of the engineering structure foundations in river flow during the maintenance period or at the design stage and to avoid environmental damages and economical losses.

References

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