High velocity water jets: combined CFD and experimental approaches to characterize the scouring process

Summary

Dam's construction involves a significant local head increase at dam section, disturbing the equilibrium conditions between flow power and riverbed resistance, which took millennia to be reached. The abrupt change of the river energy line profile allows water storage for water supply and head for hydropower generation, among other uses. However, occurrence of flood events creates the challenge of safely passing extra flood water volumes downstream of the dam, which must be equipped with suitably designed spillways. As a rule dam spillways involve flows with energy that is incompatible with natural river bed resistance. The spillways design has to incorporate solutions for dissipating the flood flows excessive energy without damaging the dam itself, nor the downstream river bed and banks. Some solutions involve the reinforcement of the river bed resistance through concrete linings or heavy rip-rap protection, other an increase of the flow energy dissipation capacity introducing a deep water cushion (plunge pools) or increase of dissipation along the spillway chutes or channels (stepped spillways), other are based on the transfer of the erosion problem to a location where the unavoidable scour that will be produced in the natural river bed will not cause any operational or safety problems. Current knowledge of the scouring process allows a qualitative characterization, but there are still many quantitative aspects that need further research in order to better assess the potential scouring of the river bed produced by spillway operation. It is presently accepted that the jet energy is partially dissipated in the atmosphere due to turbulence and jet break-up, partially by hydraulic diffusion along the plunge pool and partially by the interaction with river bed rock mass. This interaction involves dynamic pressures on the water-rock interface, as well as inside underlying fissures of the cracked rock media. It is also generally accepted that scour starts by a progressive break-up of the rock fissures in a process involving pressure waves, resonance effects, transient flows and pressure amplifications, inducing strong vibrations and producing individual rock blocks from the rock mass which are, eventually, uplifted and ejected from the rock mass. The formed scour hole dimensions will then depend on the frequency, duration and discharges involved in the spillway operation. It is also generally accepted that, under constant hydraulic conditions, an equilibrium can be found involving an ultimate scour depth. However, it is very improbable that spillways will operate for design discharge. Moreover, it is even more improbable that spillways will operate for long enough periods under design discharge to reach the maximum scour. Therefore, to consider the conditions of maximum scour under design discharge for safety assessment of trajectory jet spillways is still a matter of debate, and a good justification for further research on the scouring process. The continuous line of research on trajectory jets scour can be tacked back to the middle of the twentieth century and has enabled a few different approaches for estimating the maximum scour. However, none of the proposed approaches allows a good estimation of the erosion progress for specific hydraulic conditions. More relevant, none of them considers in a detail the interaction between hydraulic conditions and rock resistance characteristics and heterogeneities nor allows an assessment of scour geometry.

Keywords

Trajectory jets scour, Lagrangian domain, velocity impact, transient flows, CFD, experimental research.

High velocity water jet experimental facility.

PhD student
António Maria de Afonseca Portela Roseira Muralha

PhD program
Civil Engineering (IST, University of Lisbon)

Supervisor
Helena Ramos (CERIS, IST, University of Lisbon)

Co-supervisor
José Falcão de Melo (LNEC)

Period
2018-2024

Funding
FCT-H2DOC scholarship (PD/BD/135593/2018)