“Erosion of rocky riverbeds by impact of jets: interaction between falling jet, pool geometry and fissure characteristics,based on hydrodynamic pressures”
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Problem statement

High-velocity plunging water jets issued from hydraulic structures as dams spillways and orifices can result in scouring of the rocky riverbed dam foundation downstream. Assessment of the extent of such scour is necessary to ensure the safety of the toe of the dam and associated appurtenant works, as well as the stability of its abutments (Figure 1).

Scour is often predicted by empirical or semi-empirical formulae, developed from physical models or prototype observations. These formulae are not fully representative of the physical effects involved. A physically based model for scour assessment was developed at the Laboratory of Hydraulic Constructions (LCH) that considers the characteristics of pressure wave propagation in the fissures of the jointed rock mass and is based on experimental measurements of fluctuating pressures in simplified one-dimensional joint configurations. In order to render the modelling tool more realistic, some of the physical processes involved need further enlightenment.

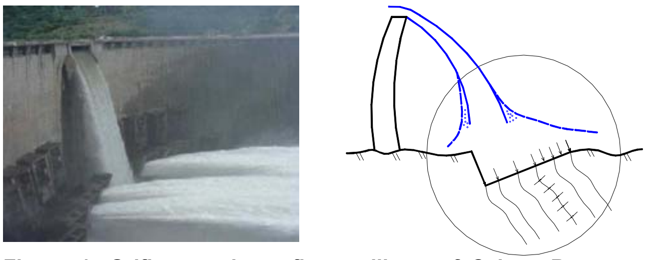

Figure 1: Orifices and overflow spillway of Cabora-Bassa dam (Mz). Sketch of physical processes involved in fissured rock scour downstream of dams.

Objectives

The present research study aims, firstly, at evaluating the interaction between the evolving pool geometry and the falling jet. Indeed, the pressure fluctuations inside the rock joints are caused by the pressure excitation of the jet at the joint entrance. This excitation depends on the form of the plunge pool and associated macro-turbulent flow pattern. Its spatial distribution and statistical characteristics are unknown for real plunge pool geometries. Up to now only the effect of an increasing tailwater level has been considered (Figure 2). Secondly, the response of prototype fissures should be better assessed by evaluation of progressively more realistic fissures. Fissure properties like thickness, angles, cavities, etc. should be investigated so to evaluate their interference with pressure propagation inside the fissures. In a later stage, investigating the dynamic response of network of fissures is also envisaged.

Thirdly, the process of dynamic up-lifting of the blocks will be further studied in order to correlate the pool’s flow pattern with the rock blocks formed by crack propagation. Spatial and temporal characteristics of the turbulent flow will be correlated with typical size block.

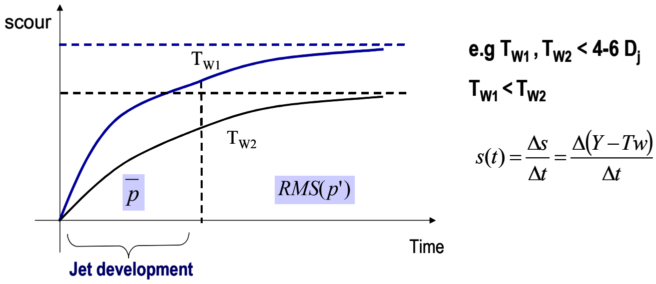

Figure 2: Scour progression s(t) for two initial tailwater levels Tw_1 and Tw_2. Mean pressure are considered the main scouring agent up to Tw = 4-6 Dj. Beyond that, scouring would be driven by pressure fluctuations. Jet lateral confinement is thought to render this evolution more complex.

Last but not the least, the influence of air either in the free surface turbulent pool flow or inside the fissures is object of persistent discussion. Experimental measurements have been done for low pool velocities but not for high prototype velocities. What’s more, the effect of air inside the fissures has been deduced from theoretical laws but an experimental confirmation is needed.

Methodology

The physical processes mentioned above will be investigated experimentally by means of a laboratorial set-up, which represents the three main component of the rock scouring process: the falling jet, the plunge pool and the fissured rock mass. The existing facility at the LCH can reproduce prototype velocities up to 30 m/s, allowing for real scale evaluation of the dynamic pressure fluctuations. This facility will be subsequently modified in order to study the jet characteristics at the issuing nozzle (turbulence intensity, etc.), different unlined plunge pool configurations (conical, depth-wise, biased, Figure 3) and different fissure characteristics. The latter will be investigated either isolated, for assessment of the particular effect of each tested parameter, and coupled. Micro-pressure transducers of the piezoresistive type are used for dynamic pressures measurement. The experimental results shall be integrated in the modelling tool, allowing a more comprehensive simulation of the fissured rock scour process throughout time.

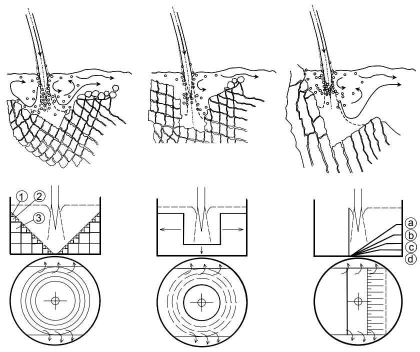

Figure 3: Three different shapes of plunge pool bottoms in nature and their corresponding experimental layouts.

Key words: fissured rock scour, falling jets, dynamic pressures, turbulent 2-phase flow, pool geometry, time.