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Hydrodynamic pressures in rock fissures due to high velocity jets

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Introduction

High velocity plunging water jets, appearing for example at the downstream end of spillways of dams, create local erosion of the rock bed. The prediction of these scouring effects is necessary to ensure the safety of the toe of the dam as well as the stability of its abutments. Traditionally, downstream scour has been predicted on the basis of empirical or semi-empirical formulae, mostly developed from physical models. These approaches are nevertheless unreliable and not fully representative because they are not taking into account all of the physical effects involved. The full understanding of the development of scour and the interaction of the various agents of this process is still incomplete and a more reliable theoretical solution to the problem is actually missing. Above all, the relationship between the dynamic water pressure in the fissures of the jointed media and the jet characteristics is unknown. A better physical understanding of dynamic water pressures in fissures due to high velocity water jets is the key for the development of numerical methods capable to simulate local erosion and scouring processes in fissured media.

Main purposes

The purpose of the research project is to close up this gap by investigating dynamic water pressure phenomena in fissures due to high velocity jets. The detailed objectives are as follows:

- Analysis of the physical parameters involved
- Experimental investigation of dynamic water pressures in different fissure configurations. These experiments consider several jet and fissure characteristics and will be done with velocities on prototype scale (up to 35 m/s)
- Formulation of a general relationship between jet characteristics and dynamic water pressures based on the results of physical modelling and theoretical approaches
- Application of a dynamic pressure solicitation pattern on rock mass failure criteria resulting in the formation of rock entities. Probabilistic evaluation of the dislodgement and displacement of these entities

Theoretical developments

Analysis of scouring is complicated by the multitude of hydraulic and geo-mechanical conditions. An accurate evaluation of the parameters determining the erosion resistance of rock is difficult, as is the estimation of the erosive power of a plunging aerated water jet. Nevertheless, scouring can be described by a consecution of physical and mechanical processes, as showed in fig.1. Macro-turbulent flow in plunge pools is the major cause of pressure fluctuations on the rock interface and is highly dependant on aeration phenomena and plunge pool and jet geometry characteristics. Theoretical developments have mainly been focussed on two-dimensional vertical jet diffusion. Nevertheless, a lot of experimental knowledge on dynamic pressures has been acquired on hydraulic jump and plunging jet model tests.

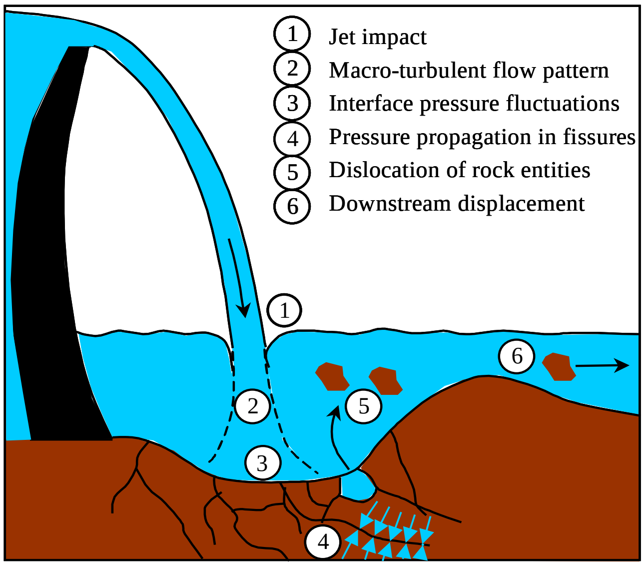


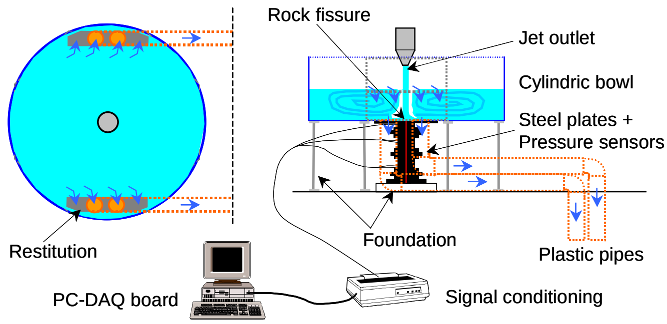
Fig.1: Physical processes involved

This allowed development of statistics and spatial distribution of the resulting interface pressure fluctuations, as well as the energy dissipation within the plunge pool. However, a large number of plunge pool characteristics are still mystery. The main research goal is therefore based on a relation between pressures at the entrance of discontinuities and pressures propagating inside of these discontinuities and, in result, doesn't need to consider the real flow turbulence pattern.

Pressure propagations in fissured media have been investigated in the field of uplift phenomena of concrete slabs of stilling basins. However, these studies didn't take into account the damping, resonance and water hammer effects that appear in both open and closed fissures when subjected to dynamic pressures. Following transient flow theory, the inside pressure pattern can in that way attain values up to several times the at the entry injected pressures.

Experimental installation

Fig. 2: Experimental installation



The experimental installation consists of a 3m diameter plastic cylindrical bowl, placed on two 100mm thick steel plates (1 m^2) that are pre-stressed with a third, 1mm narrow steel strip between them. The form of the latter entirely determines the fissure configuration and will be changed during the experiments. 8 pressure sensors are linked with a simultaneous DAQ system allowing a filtered A-D conversion up to 15 kHz per channel. The other parameters that will be modified during the test runs are the jet outlet velocity and diameter, the plunge pool depth and the fissure width. The first test results are expected for spring 2000.