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What modern rock mechanics owe to the Malpasset arch dam failure

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1 INTRODUCTION

Since the most ancient construction works a rock foundation was enough for safely building on it. On December 2, 1959, the Malpasset arch dam, close to the French Côte d'Azur, suddenly broke and released 50 hm^3, with huge destructions and more than 400 fatalities. About this time, hundreds of arch dams had already been built in the US, Japan, and Europe and hundreds have been built since, higher and higher, without any more accidents. The event initiated a lot of analyses and studies, both in situ and at labs, in France and worldwide. Clearly, ISRM was born from this failure.

2 THE FAILURE

Designed for water storage by famous Consulting Engineer A. Coyne, and built 1952–1954 in a narrow gneiss gorge, the 60 m high dam has never been filled up before the occurrence of huge rains in November 1959. The failure was assigned to water pressure through a unique combination of features:

i) high sensitivity of rock permeability to stress, creating a deep impervious barrier below the dam;
ii) high deformability of rock, helping open a deep crevice behind the dam heel (Fig. 1);
iii) a fault dipping upstream ca.20 m downstream of the dam;
iv) lack of boreholes for foundation drainage.

It must be added that the monitoring and supervision of the dam were rather poor, as it was left unused by lack of any water distribution network (nobody noticed a slight move of the dam towards left side); lastly, the construction works of a motorway bridge was glad no water could flow through.

For having taken part himself in the investigations on many dam sites in France at the same time (1948–1955), the author bears witness that the rules of art had been followed: As stated the technical literature, main dam site problems were bedrock depth below the valley floor, and bedrock imperviousness, Of course all rules were quickly changed after the event: more site investigations became mandatory, how sound the rock may look; uplift drainage under gravity dams was extended to arch dams; and the State control on all dams over 15 m height was reinforced.

Figure 1. Remains of Malpasset arch dam: a conspicuous crevice appears along the concrete shell; the whole river discharge is flowing below the dam (photo P. Duffaut, 1960).

3 MAIN LESSONS

Two traps had mistaken the people in charge: the rock mass "look", as seen by many visitors, was treacherous, and the administrative status was rather low; nobody had realized this dangerous object had been left without convenient control.

The main lesson from Malpasset failure was that, inside a dam foundation, water forces may be the same order of magnitude that dead weight and dam thrust. All dams are only gravity dams under condition to include the weight of ground abutments and engineers are the only ones, in the geotechnical field, to be fully aware of water force, a true revolution following the long time needed to understand uplift inside rock mass.

Before, only mining engineers had begun to formalize a meager corpus of rock mechanics. Since, civil engineering and geological schools, labs and bureaus, as well public as private, developed an array of new concepts and methods, which first appeared at the 8th ICOLD conference in 1964 and later at ISRM ones, beginning in Lisbon, 1966. Civil engineers met petroleum and mining engineers to build together a comprehensive Rock Mechanics.