B. Goguel, 2002.06.01 - **Malpasset presentation to ICOLD visitors 2022, May 31**

Fig. 1 : dam plan view and downstream elevation, summarizing the construction schedule Coyne was attracted by the narrow Malpasset gorge, he located there a classical thin arch dam.

Fig. 2 : radial section on the outlet gate (block IJ), and reservoir impounding *at same vertical scale*

Fig. 3 : deflection monitoring (geodetic targets grid) ; and nothing in the foundation : no drains, no piezometers, as usual at that time.
Post-failure investigations : 1960 L/B gallery, and 1962 lower R/B gallery below block FG

Fig. 4 : general views of the ruins, with radial joints and some other identified details.

The upper left *wing wall* aimed at protecting the Thrust Block form direct reservoir pressure. This *gravity block* (half of which, i.e. block PQ, fell below, afer the upper arches collapse) was drained, as evidenced by the large pipe outlet visible close to joint Q.

The dam axis is on joint H, at short distance from block IJ containing the bottom outlet. The concrete/rock limit is at joint K. An enormous part of the left abutment is missing, exposing the "*L/B dihedral*" scar.

Fig. 5 : Right Bank upstream side, where a large open vertical crack resulted from the general Rotation, as evidenced by the topographic survey of the remains displacements : rotation like a solid body (+ additional movement of the upper L/B overloaded Thrust Block).

Fig. 6 : Blocks found downstream having been identified, in altitude only (upper elevation) or completely located (lower elevation) ; and *typical shapes of cantilever failures*, evidencing a contrast between the L/B side (lower parts of cantilevers KL and LM carried away by the rock wedge movement) and the R/B side (upper parts of cantilevers toppled down).

Fig. 7 : Developped elevation, locating the river passages : no diversion tunnel (a simple temporary opening, at lower enlarged joint K, permitted to pass the river ; before being relayed by the low level outlet). After the failure, the river could flow below block FG ; its course was facilitated by the *1962 investigation Adit* under the block FG, and the abundant sediments (sand and gravels) transport over the years. The lower section of that block, 800 m^3 approx., was seen detached in 2014 by around 5 cm ; it fell down by few meters during a flood on 1rst december 2019.

Fig. 8 : COYNE and other's french arch dams, from 1935 to 1975

Malpasset dam was designed 70 years ago, in 1952, by a 60 years old famous arch dams designer who had been twice (6 years) ICOLD President. The 180 m high Tignes arch dam he had designed was just completed.

André Coyne was perfectly aware of uplift in gravity dam body : as evidenced by Maurice Levy 1895 explanation of Bouzey second failure (see note in Fig. 12), further gravity dam failures (Fergoug / Habra / Perregaux 1927), and his strengthening of gravity dams with tensioned cables anchored in the foundation (Marèges RB 1935 and Cheurfas 1936).

But he ignored / did not consider / uplift in arch dams, and at depth in their foundations. He recognized immediately his own responsability, and passsed away without having understood

Fig. 9 : The catastrophic Malpasset failure triggered intensive researches and developments in Rock Mechanics (a concept ignored before the dam design). First International Congress in Rock Mechanics was held in 1966 at Lisbonne, Portugal, shortly after Vajon / Langarone drama (Oct. 1963… when the Mont Toc falled into the reservoir, the arch resisted). Refer also to ICOLD Q. 28 & 33 at 1964 & 1967 congresses.

We (French COLD experts) belong to the second generation of engineers, having been teached by the first generation, Pierre Londe and colleagues, from the Bureau and others (EDF and Pierre Habib) who explained the failure, and provided lessons for designing safe dams.

Fig. 10 : Pierre Londe, author of a Special Bulletin ("*the small orange book*", 1973), updated in 1993 and then numbered as ICOLD Bulletin 88. The first one should be on line soon.

Londe vulgarized the 3D rock abutment stability analysis. The 1959 Malpasset Drama, and the October 1963 Vajont-Langarone Tragedy marked our profession. These years correspond also to the completion of Coyne's Kariba Dam construction on Zambezi River, and its full impounding.

Uplift *at depth in the foundation* was a major explanatory factor of Malpasset left abutment failure ; combined with the downstream fault, with the gneiss permeability sensitivity to stress (having created an underground impervious dam, adversely located without any drainage),and with the rock mass excessive deformability (low elasticity modulus).

Fig. 11 : Proposed failure mechanisms, and main lesson : grouting and drainage layout.

Fig. 12 : Last thinkings (Post and Bonazzi, 1987), Main Lessons (Alain Carrère, 2010).

Fig. 13 : The CFBR 2022 paper is summarizing previous works and abundant documentation ; of which some significant selected papers are made available here : *http://malpasset.bgl.ovh*

Geological details : refer to Bernard Couturier explanations given from the upper Rigth Bank. Watch the **CFBR 2020 *Recommandations pour l'étude géologique d'un site de barrage*** (written by Bernard Couturier and Pierre Antoine).

Bernard Goguel presentation : son of Jean Goguel, head of the French Geological Survey and teacher of applied geology for engineers, who joined the first inquiry committee (for the Owner, Ministry of Agriculture).

Whole professional life since Nov. 1970 with *Coyne et Bellier Consulting Engineers,* successors in 1962 of ACJB, *André Coyne and Jean Bellier* (created in 1947 parallelly to EDF). Renamed as *TRACTEBEL Enginnering* France in 2009.

CFBR (French COLD) member since 1979, ICOLD T.C. Dam Surveillance Chairman (2003-2009).

Kariba Dam follow up from 1987 to 2010, having advised for securing the Plunge Pool and the gated spillway. Familiar with technico-historical studies.

Born on Nov 7, 1945. Ing. Ecole Centrale de Paris (1969), retired in Saint-Malo since 2014.

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