

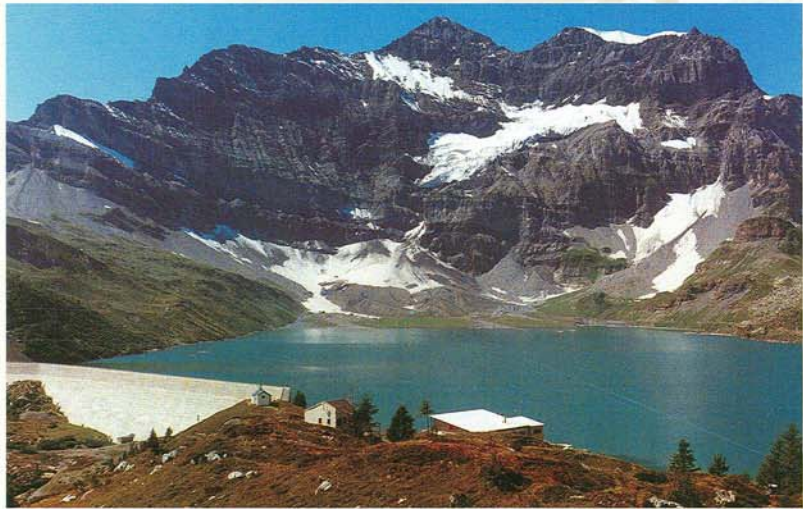
## Grouting works on a deep cut-off curtain in rock

### SALANFE DAM SWITZERLAND

#### Introduction

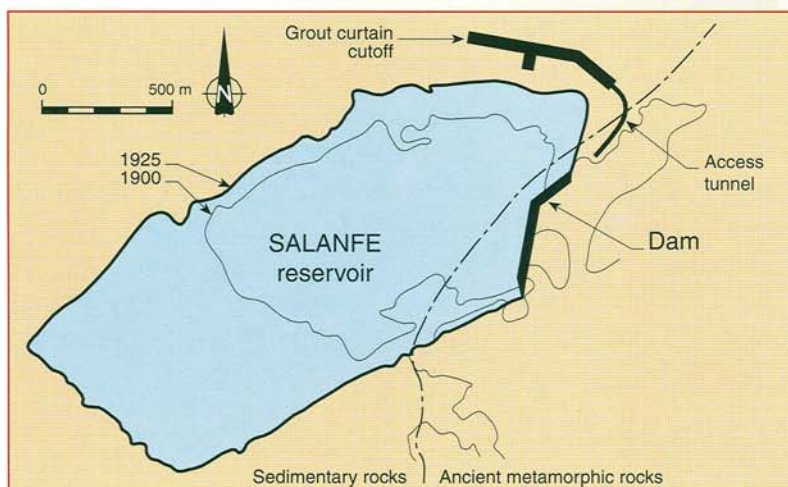
The Salanfe dam is situated in the Canton of Valais. Since it was commissioned 1952, large leaks have been continuously observed on the north flank of the reservoir and these appeared to be associated with the presence of layers of weathered Tertiary rocks. The bed of the reservoir remained watertight and the reservoir was operated at a reduced water level, 50% of its design volume, to avoid leakage.

The project is famous for the 1,470 m between the reservoir and its tail race discharge. To optimise the hydroelectric potential of the project, the owner designed a monolinear grout curtain cut-off to the leaking northern flank. A consortium of companies constructed a 215 m long access tunnel to a grouting tunnel, 620 m long.



Salanfe dam

CLIENT : SALANFE S.A, E.O.S AND LONZA S.A  
PROJECT MANAGER : ENERGIE DE L'OUEST SUISSE  
GEOLOGIST : DR SCHNEIDER  
WORK CARRIED OUT BETWEEN SEPTEMBER 1992 AND JUNE 1994



Plan view of the Salanfe reservoir

#### Grouting Works

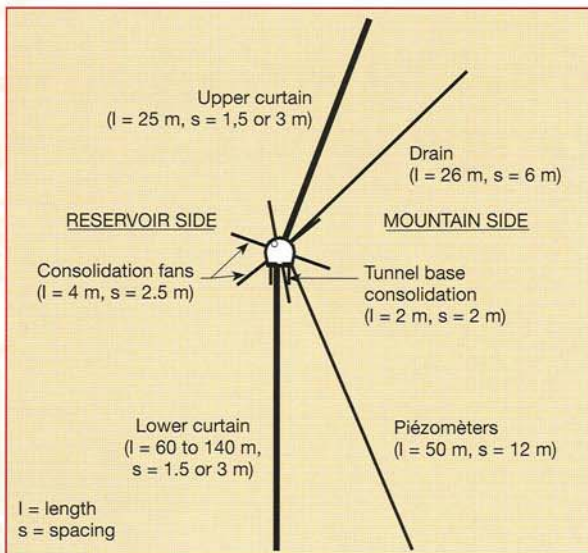
Consolidation grouting of the rock around the grouting tunnel was performed to deal with any relaxation and fissuring opened up during the excavation of the tunnel. This zone of consolidated rock acted as a link between the upper and lower grout curtains. Grout holes were drilled in radial fans, spaced 2.50 m apart, along the length of the grouting tunnel. These were injected at relatively low pressure with a high-penetration, anti-bleed grout. In addition, the base of the grout tunnel was further



SOLETANCHE BACHY



Underground injection plant managed by EPICEA



Grout curtain cut-off cross section

consolidated by injection of a high strength grout. This encouraged the re-establishment of appropriate hoop stresses around the tunnel which would have been reduced by damage to the rock near the tunnel perimeter during excavation.

The lower grout curtain had to penetrate the permeable Tertiary rocks through which leakage was occurring. For the first 406 m of the grout tunnel, this monolinear curtain was taken down to the underlying gneiss which was known to be watertight. For the remaining 215 m, the criteria for the final depth was determined by water testing. A limit of depth was set at a Lugeon test value of less than 2.

The treatment was carried out in a closure sequence including up to tertiary and, in some areas, quaternary holes depending on the average quality of the rocks encountered. Primary holes were spaced at 12 m centres. Ascending stage grouting was used with 5 m stage lengths in the limestones. Descending stage grouting with redrilling, in 10 m stages, was employed in the weathered rocks. The layout of the upper curtain was similar to the lower. Its upper limit was fixed at an elevation of +1,925 m which

corresponds to the spillway level of the reservoir. Grouting was carried out in 5 m upward stages as drilling progressed.

### High technology at high altitude

- Four types of bentonite-cement grout were injected, two of which designed to give high penetration :
- RHEOSIL S, a grout based on CLK cement with microsilica and propriety additive,
- C3S, a stable bentonite-cement grout designed also to have minimal bleed.
- Computerised management of grouting using EPICEA : from the control of the pumps to grouting data collection, analysis and presentation.
- Servo-control of the pumps to enable high pressure injection with small and controlled flows.
- Recording of drilling parameters and water test results to facilitate the delineation of the curtains.
- Measurement of hole deviation, processed by computer, to ensure continuity of the curtains.

### Equipment used

Drilling was carried out with 4 no. electrically-powered rotary percussion

drills and 1 no. survey unit was employed for deviation measurement. The grouting equipment included the grout mixing plant and Bachy's EPICEA system, which controlled an injection plant in the tunnel with 12 no. pumps and the capacity to work simultaneously with two different grouts. A computer network of 4 no. work stations enabled the site supervision to monitor and control all injection parameters.

### Work quantities

Total surface area	
of grout curtain	: 67,000 m <sup>2</sup>
- upper curtain	: 16,000 m <sup>2</sup>
- lower curtain	: 48,000 m <sup>2</sup>
- tunnel consolidation	: 3,000 m <sup>2</sup>
Height of upper curtain	: 25 m
Depth of lower curtain :	
Variable up to	140 m
Drilling	: 137,530 m
Coring	: 2,200 m
Drains	: 2,900 m
Piezometers	: 2,300 m
Volume of grout	: 9,440 m <sup>3</sup>