

Raising a silted reservoir as an alternative to dredging: The example of Ghrib dam, Algeria

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A problem of sedimentation at the Ghrib dam in Algeria was recently mitigated by increasing the reservoir storage capacity using fusegates. The reasons for the choice of this solution, and a brief description of the scheme, are given here.

Algeria is a semi-arid to arid country, where water is scarce and valuable. Accounting for more than 37 per cent of the total mobilized resources, surface water plays an important role for irrigation, industrial and domestic uses. But it is jeopardized by sedimentation that reaches critical levels in most of the reservoirs.

Fig. 1. Original plan view of the dam.

The young mountain ranges of the Maghreb are characterized by steep slopes and heavily degraded

plant cover, as well as by unfavourable geology (clay layers, marls and soft sandstone or schist alternate with hard limestone or sandstone strata). These factors contribute to high sediment deposition from Algerian streams, thus reducing the storage capacity of most dams. In Algeria, deposition of sediments in dams is estimated at $32 \times 10^6 \text{ m}^3$ per year, on average. This translates to a 0.6 per cent annual loss of storage capacity from a total capacity estimated at $5.2 \times 10^9 \text{ m}^3$.

The extent and rates of alluvial deposit and dam siltation can sometimes reach even more worrying levels. For example, the Beni Amrane dam, used for the supply of water to Algiers, lost more than 50 per cent of its original storage capacity ($11.6 \times 10^6 \text{ m}^3$) in only 15 years, before it was heightened in 2003.

This situation has prompted a number of attempts to retrieve the lost storage capacities. Associated with catchment-level efforts to reduce sediment load in the streams, the dredging of reservoirs has been the main solution considered. In Algeria, however, dredging is often limited by the lack of available water needed for its implementation (approximately three times the volume of silt is required). It is also increasingly discarded as a result of environmental constraints and cost considerations.

Range of options

The State Agency, ANBT (Agence Nationale des Barrages et Transferts), has implemented an attractive solution at Ghrib dam to cope with the critical sedimentation level of the reservoir by raising the permanent pool elevation. Ghrib dam is located approximately 130 km southwest of Algiers, and provides water for irrigation purposes in the area and for drinking water supply to Algiers and Medea regions. Considered as a strategic structure, the dam and appurtenants are operated and maintained with the utmost care.

Constructed between 1933 and 1943 with an initial capacity of $228 \times 10^6 \text{ m}^3$, the Ghrib dam consists of a 70 m-high, 250m-long rockfill embankment and a 185m-long free overflow spillway on its right abutment (see Fig. 1). The reservoir is prone to silting; bathymetric studies have shown that, by 1994, the reservoir had already lost 31 per cent of its original capacity. Another important feature is that there are wide variations in the dam's annual inflow regime, one of the widest observed in Algeria. Between 1933 and 1993, annual inflows ranged from 20 to $500 \times 10^6 \text{ m}^3$.

Retrieving the original storage capacity of the Ghrib reservoir falls within the scope of Algeria's programme to better harness the available surface water

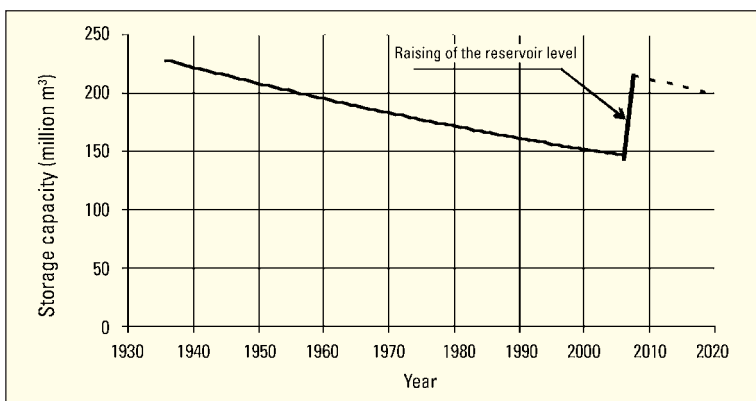
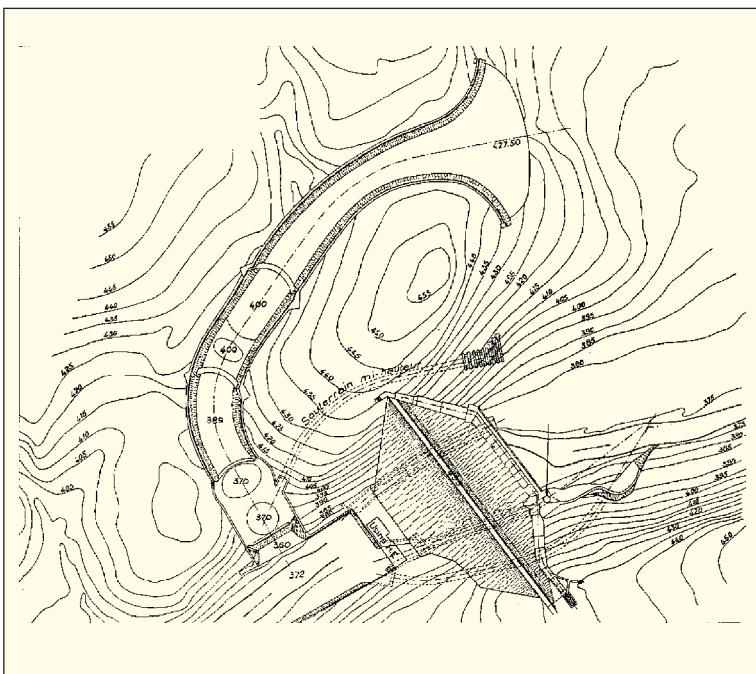


Fig. 2. The reduction in storage capacity as a result of silting, and the effect of heightening

resources by ensuring the long-term safety and serviceability of its existing dams.

The preliminary feasibility studies undertaken quickly showed that conventional approaches (dredging and flushing) would be very expensive mainly because of the large volumes of silt, long-distance haulage, and water-supply costs. Consideration was then given to taking advantage of the particularly high freeboard to raise the permanent pool elevation by 4.5 m (thus increasing in the storage capacity by $70 \times 10^6 \text{ m}^3$) without impacting the maximum water level for extreme flood events (see Fig. 2). Following a preliminary evaluation of cost and technical factors, the following options were considered:

- Raising the overall spillway sill and building a parapet wall across the dam crest. This would have required an increase in the maximum water level (MWL) which would not have been acceptable.
- Raising the spillway with a fixed labyrinth weir. To discharge the design flood with sufficient dry freeboard, the labyrinth weir would have consisted of very long walls (40 m from upstream to downstream) and would have required major excavation work.
- Installing a gated spillway system. In addition to cost considerations, this approach would have involved the risk of malfunctioning in the event of earthquakes or blackouts.
- Combining Fusegates and gates. By removing the risk associated with the use of a gated spillway and reducing the overall project cost, this option was found to be by far the most cost-effective alternative, and was consequently selected.

An effective solution

The selected option offers the benefits of a gated spillway with regard to operational flexibility and of a fusegated spillway with regard to safety during extreme flood conditions.

- One of the main benefits of gated spillways is their ability to manage the reservoir level with precision. This advantage is even more important in the light of a recommendation by the consulting firm, ISL Ingénierie, to increase the permanent pool elevation in stages because of the geological characteristics of the hill located between the dam and the spillway.
- On the other hand, fusegates are very reliable during extreme flood events; in addition, they do not require human intervention or a source of power to operate. This system provides an ultimate dam safety feature, since the design flood is passed with the design freeboard, even without operation of the gates.

Combining the two spillway control systems greatly reduces the probability of the fusegates tipping. As such, no fusegates overturns until a flood with a return period in excess of 1 in 2900 years is reached; whereas this probability would drop to 1 in 100 years with no gates.

Details of the project

A contract was awarded to Hydroplus in July 2005 amounting to approximately €10 million, 40 per cent of which corresponds to the construction of the Fusegates and 60 per cent to other appurtenant works.

The project implementation was planned in several phases, with a total 16 month overall duration and with a completion date expected by early 2007. The short implementation duration is another benefit resulting from raising the permanent pool level as compared to dredging.

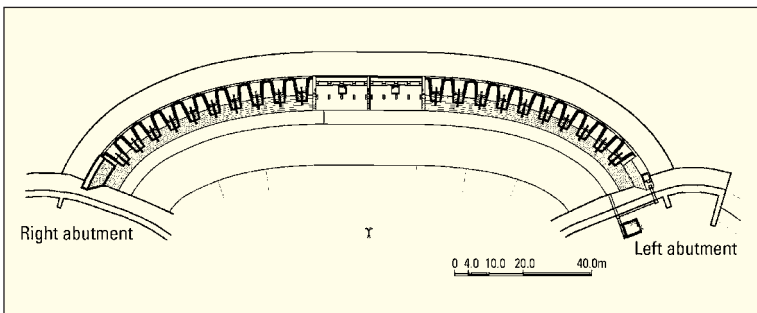


Fig. 3. Plan view of the spillway sill.

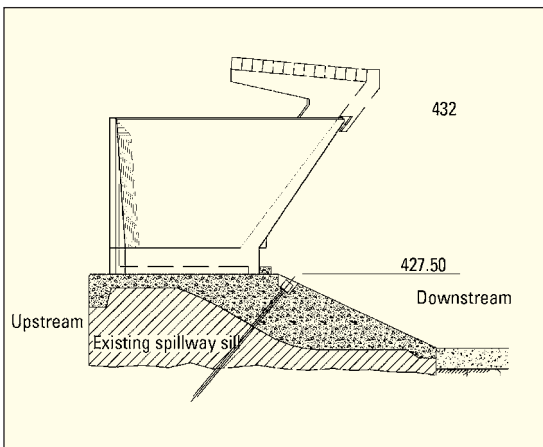


Fig. 4. Typical cross section of a Fusegate.

The project began with a feasibility study, which covers the definition of the configuration to be adopted at the spillway sill and the modifications of other dam structures. Flow through the modified spillway was then studied using finite element analyses, and model tests were performed at 1:20 and 1:50 scales at the NIEES hydro laboratory in Moscow.

The adopted spillway configuration involves the installation of two steel flap-gates, each 15 m wide and 4.5 m high at the centre of the spillway sill and the construction of twenty labyrinth-crested Fusegates each 6.75 m wide and 4.5 m high. The Fusegates are made of cast-in-situ concrete (see Figs. 3 and 4).

In addition to the construction of the spillway control systems, the project requires the modification of the original sill to form a platform on which the Fusegates can be accommodated. Other structures to be constructed included a drainage cover, the consolidation of the spillway chute and implementation of post-ten-

Work in progress at the spillway in September 2006.



sioned anchors as well as protection of the upper part of the upstream side of the dam embankment.

French and Algerian companies have been undertaking the construction. Sharing know-how and experience between the teams during construction has made this partnership a valuable learning environment for all the parties involved.

Conclusion

Tocope with the sedimentation at the Ghrib reservoir, the ANBT has developed an attractive approach to retrieve the original storage capacity by raising the permanent pool by 4.5 m. The selection process considering various cost and technical factors led to the adoption of the alternative involving Fusegates combined with flap gates.

Compared with dredging techniques, the raising of the permanent pool, if feasible, is much quicker to implement and is very cost effective. For instance, the cost per cubic meter of water recovered at Ghrib dam is in the range of €0.15. The only main drawback of the raising approach is that it can be implemented only once on a given project.

Since the heightening of the Beni Amerane and of Fom El Gueiss dams, this project will be the third one implemented in Algeria with the use of Fusegates and could serve as a benchmark for future sedimentation remediation projects worldwide. ◇



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