# RCC arch dam technique tested in Brazil

*The advent of roller-compacted concrete (RCC) in the construction of gravity dams has made them more time and cost-effective and a viable alternative to arch dams, and therefore the arch dam market tends to suffer from the competition of the RCC gravity dam. Since the beginning of 2002, Swiss consultant Stucky and Brazilian company Construtora Norberto Odebrecht with the support of international RCC expert Francisco Rodrigues Andriolo have collaborated on the development and testing of an innovative technique to apply RCC to double curvature arch dam construction, thus to make the arch dam more competitive.*

The partners have developed a novel approach to the problems and have been running full-scale tests on an RCC dam on the Picada dam in Brazil, about 200km north of Rio de Janeiro, since 2004. Besides proving the relevance and validity of an innovative construction method for arch dams (the STOD method), this technique also turns out to be more economic. It can bring about a 20% reduction in investment when compared with the traditional arch dam construction method, and very significant time saving too.

The Picada RCC dam under construction, view from downstream. Image: Stucky.

## Background

Arch dams are usually best-designed and optimised as double-curvature structures, which are built as a series of independent, adjacent blocks. The concrete is successively brought in place on the top of each formed block by means of a cable crane installed through the valley above the future dam crest level.

The concrete used is of conventional mass type, which has to be vibrated internally in order to be compacted dense, strong and watertight. After completion of the dam, the joints in between blocks have to be grouted to ensure watertightness and continuity of the structure, and the arch effect.

The first experiences of applying RCC to arch dam construction took place in the late 80s, but some key issues of arch dam had to be compromised to cope with the intrinsic properties of RCC. Some of the issues that have caused problems in the construction of the pioneer RCC arch dams include:

- Transversal joints (linked with the problems of grouting to transmit horizontal thrust forces, and cracking caused by cement hydration heat)
- The high concrete compressive strength required
- The double-curvature forming.

## STOD method

While working out their own RCC arch dam solution, the inventors of the STOD method have reversed the problem. Instead of compromising the well-established common practice of arch dam construction by giving up some crucial design concepts like those mentioned above, they have decided to adapt the RCC technology to the key features of arch dams. The technology uses RCC as a mere material impacting on the construction process only, while the key characteristics of arch dams are preserved. The design of the dam body remains largely unchanged, and therefore the STOD method turns out to be a construction method only, and not a new type of arch dam.

The RCC arch dam construction method proposed by the authors is defined by the following characteristics:

1. Upstream-downstream vertical joints are created while placing and compacting RCC across the entire dam section. To be effective, these joints have to be continuous and well delimited, capable of following a helical shape and groutable on completion of the dam. In addition, they must be as unobtrusive as possible to the RCC placing activities and rapid to form. The spacing between two transversal joints shall be in the range of 20-30m.
2. The numerous horizontal joints (every 30cm) are treated in a special form that provides the required shear strength between layers and does not create high permeability paths within the dam body.
3. RCC mixes with high strength characteristics are produced and used; these are able to reach up to 35-40MPa compressive strength. In addition, these RCC mixes must be watertight, similar to conventional vibrated concrete (CVC) mixes. Where demanded by local conditions, the concrete cooling issue is solved by implementing post-cooling, in the same way as it has been applied for decades in CVC arch dam construction.
4. To form the arch dam according to the optimal double-curvature shape, a special formwork panel, adapted to the particular requirements, has been developed by the partners. Thanks to the double-curvature shape, the thickness and consequently the concrete volume of the dam are reduced and the structural behaviour of the dam is optimised.

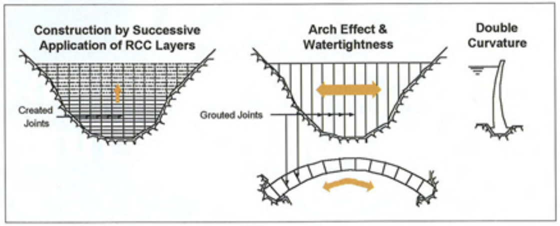


Figure 1: Key characteristics of the STOD RCC arch dam.

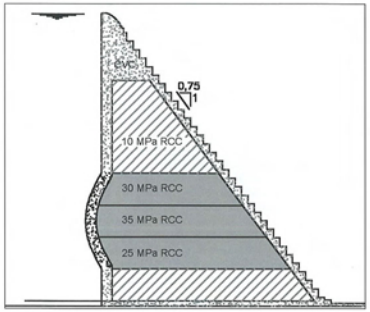


Figure 2: Picada RCC dam, cross-section with test section incorporated.

## Test project

To collect data and demonstrate beyond any doubt the feasibility, practicability and economy of the STOD RCC arch dam construction method, the partners embarked on a full-scale test in 2004-2005, in the framework of the construction of the Picada RCC gravity dam in Brazil, a hydroelectric scheme generating 50MW and owned by Votorantim.

The dam owner allowed the dam design to be slightly modified to incorporate the tests. The dam is 27m high, the crest length 97m, and the volumes of RCC around 13,000m$^3$ and CVC around 4000m$^3$, small in comparison with medium and large size arch dams, but it has been possible to carry out conclusive tests on the innovative technology.

- Testing of the following technical issues was deemed necessary to consolidate the STOD method:
- Double-curvature forming the dam face
- Formation of continuous transversal joints
- Grouting of these joints
- Vertical bond of successive RCC layers (shear strength on the horizontal joints)
- Use of high-resistance RCC and test of mechanical properties (tensile and compressive strengths, elasticity modulus, water tightness)
- RCC thermal properties (installation of post-cooling and dam body temperature monitoring).

## Test outcomes

The test results are currently being analysed and the construction method consolidated. However, in summary, the main conclusions reached after the test run at Picada Dam are:

The chief strength of the STOD method is to adapt the features of the existing RCC technology to the specific design and construction requirements of arch dams.

By using the proposed technology, the design of RCC arch dams remains essentially similar to conventional arch dams. This is an additional guarantee that can be credited to the proposed technology.

The STOD method is competitive in the arch dam market, allowing construction cost savings of about 20% compared with CVC arch dams, and time savings from several months up to one year.

The success of the STOD technology is greatly dependent on efficient site organisation. The logistics must be properly designed and tested in advance, as the construction process must be fast to be successful. This implies a strong pre-operational effort and upfront investment from the constructor that will later on pay-off during construction.

*Contact: Stucky Ltd*
*T: +41 21 637 15 13*
*E: awohnlich@stucky.ch*
*W: www.stucky.ch*