RIVER CLOSURE AND DAM CONSTRUCTION

CIVE 717 – River Mechanics
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Closure Dams or Cofferdams

- Closure dams are structures built to close a river, or the outlet from water sources and basin. The dam can be located on tidal or non-tidal rivers;
- A critical feature of all closure dams is that as the dams narrows as the dam is filled in, from the sides or as the sill is raised during construction, velocity increases and peaks just before the gap is completely filled;
- Velocity reduces to zero as soon as the dam in completely filled, i.e when the flow is completely stopped. Thereafter, substantial works continue to bring the dam to completion and full design strength;
- Closure dam design approaches are similar to that used for the design of breakwaters, rockfill dams, earth dams, etc. In some situations, coffer dams are used as temporary closure structure.

Design Issues

- Protection of erosion from wave action (run-up, run-down, dynamic wave pressure, overtopping);
- Bed protection, scouring of river bed during construction of closure dam, e.g. filter mats to prevent bed erosion;
- Seepage and river bed geology, width of sill, dam, seepage barrier;
- Sill location, elevation, width, material;
- Size of armor rock to withstand wave action;
- Rate of construction, construction must be done in the shortest time possible to prevent washout of partially constructed dam sections.

Design Issues

As the dam is filled vertically or horizontally the velocity becomes very large and the fine material used to fill previous sections of the dam can no longer be used and large diameter of stone must be used. The equations below is used to determine diameter of stone.

$$V_c = K_c[2 * g(G-1)]^{\frac{1}{2}} * d_s^{\frac{1}{2}}$$

$$d_s = \frac{1}{2 * g(G-1)} * \left(\frac{V_c}{K_c}\right)^2$$

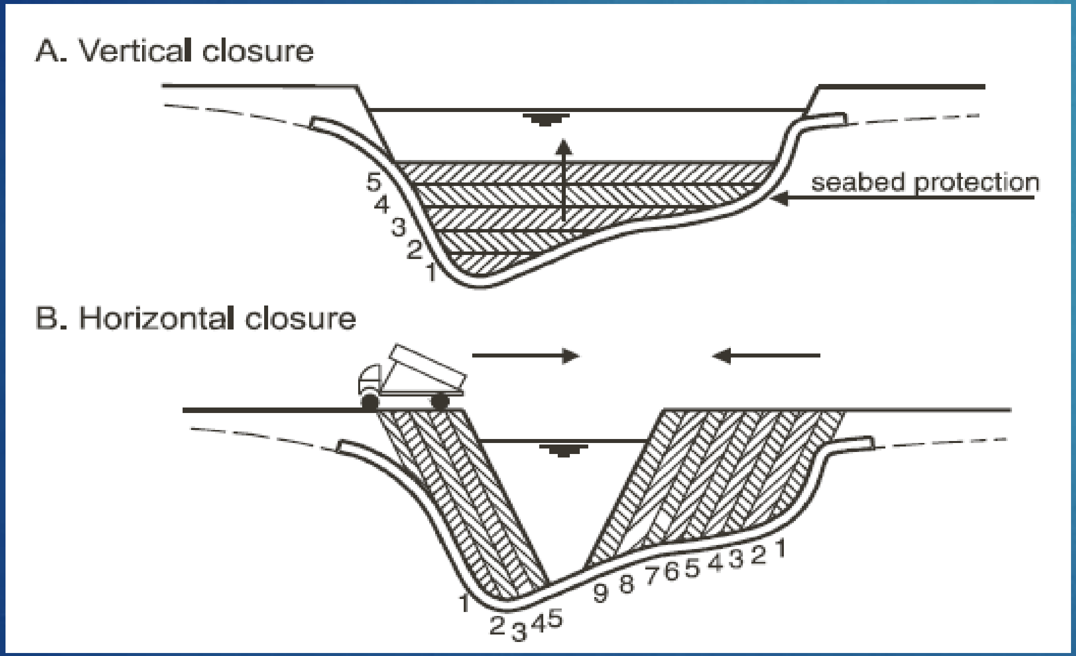
$$F_w = \gamma_s * \frac{\pi * d_s^3}{6}$$

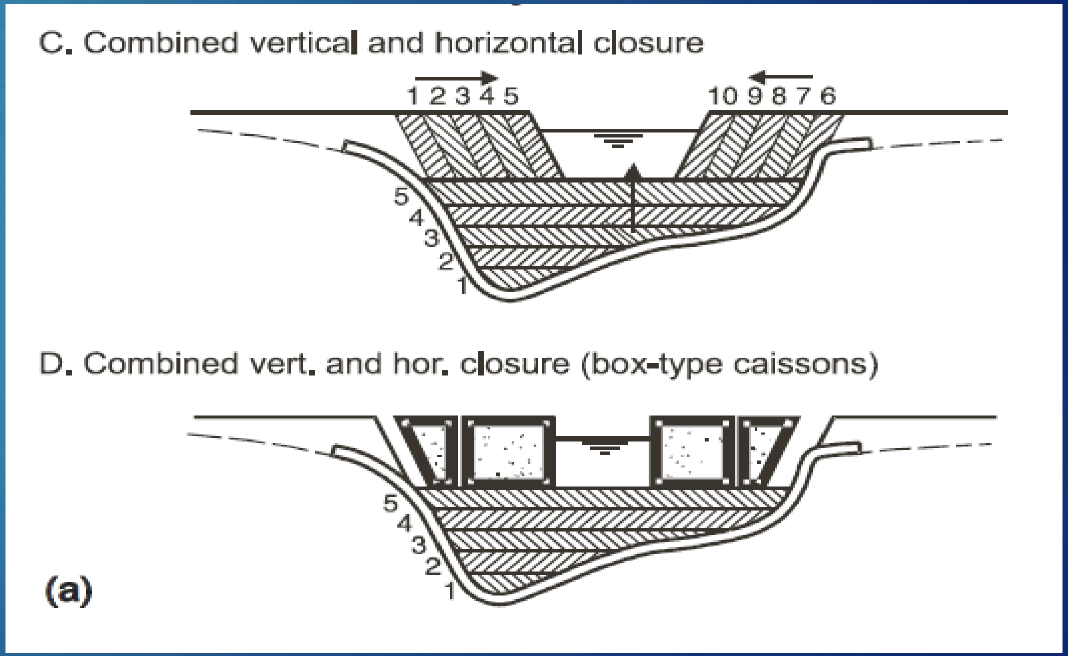
$d_s = diameter\ of\ stone$
$F_w = weight\ of\ stone$
$V_c = critical\ velocity$
$K_c = 1.2\ for\ river\ closure; 0.86\ for\ stilling\ basins$

Source: River Mechanics, Julien 2010

Methods of Construction

Vertical and horizontal closure are the two basic methods. A combination of these two methods along with other techniques may be employed. e.g. dumping from bridge to raise sill across the channel





Source: Design of Closure Dams, Delft Hydraulics

Examples of closure dam construction

Example: vertical closure (heavy equipment)

Source: H.J. Verhagen, TUDelft (lecture)

Example: vertical /horizontal closure (manual labor)

Source: Dhaka Tribune

Construction Issues

- Construction Logistics;
- Evaluate features that are site specific;
- Logistics , man, machine and materials, can be a major restraint on construction. Example: to build the Feni closure dam in Bangladesh in 1980's no large construction machinery was available, so 1000 workers was mobilized to place sand bags for the closure;
- Improper or inappropriate design can lead to recurring repairs in the long term;
- Availability of materials ,equipment, may determine type /design of closure dam.

Case Study - São José Dam - Brazil

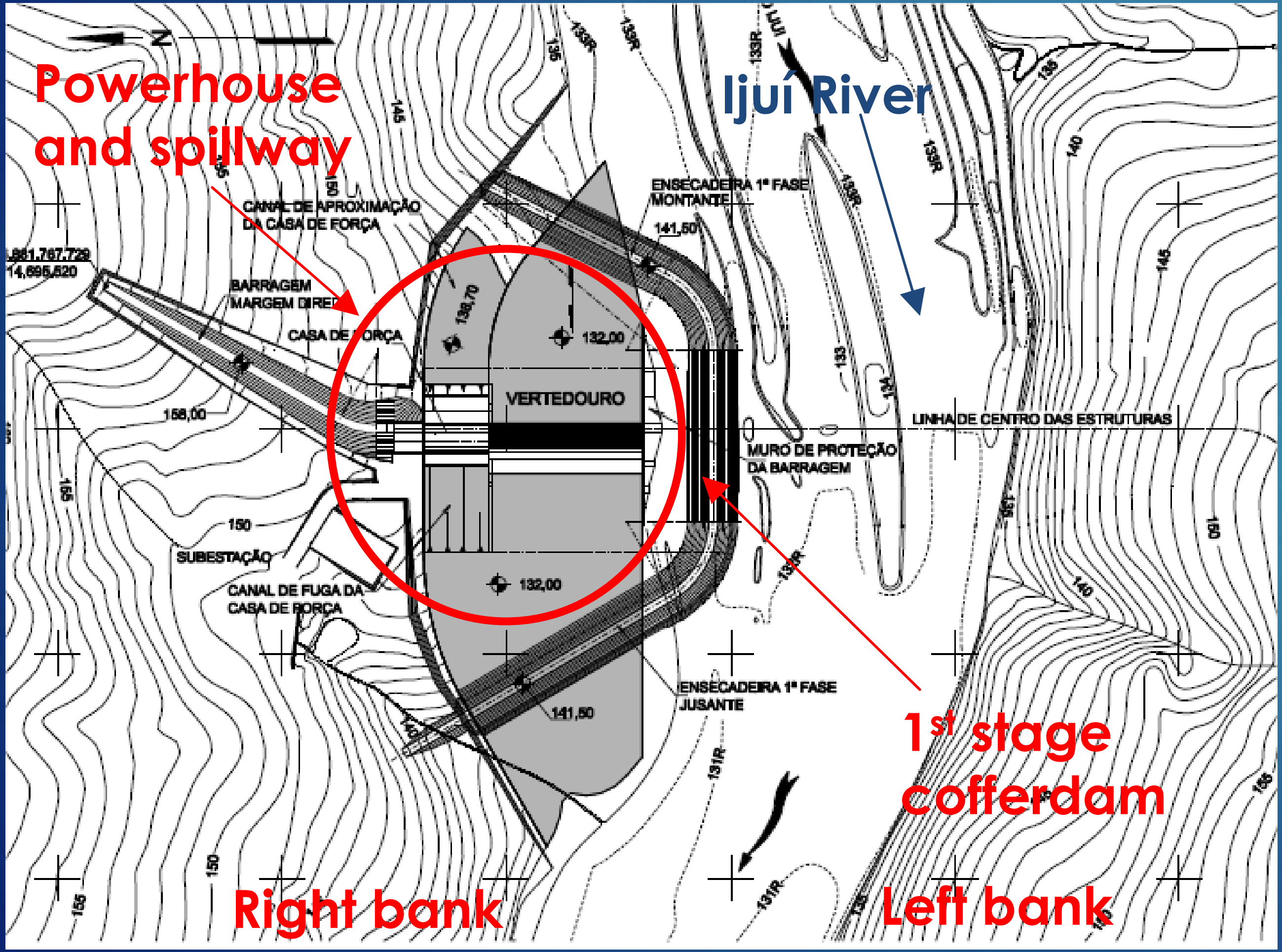
The next slides present a case study of São José Dam, located in Ijuí River, in the State of Rio Grande do Sul, south of Brazil. The owner of this dam is the Ijuí Energia – S.A and the design was made by Engevix Engeneering – Brazil.

The slides present the evolution of the dam construction and the river closure.

São José Dam - Brazil

River Diversion Design

São José Dam – Ijuí River – Brazil.
River Diversion Design – 1st Stage

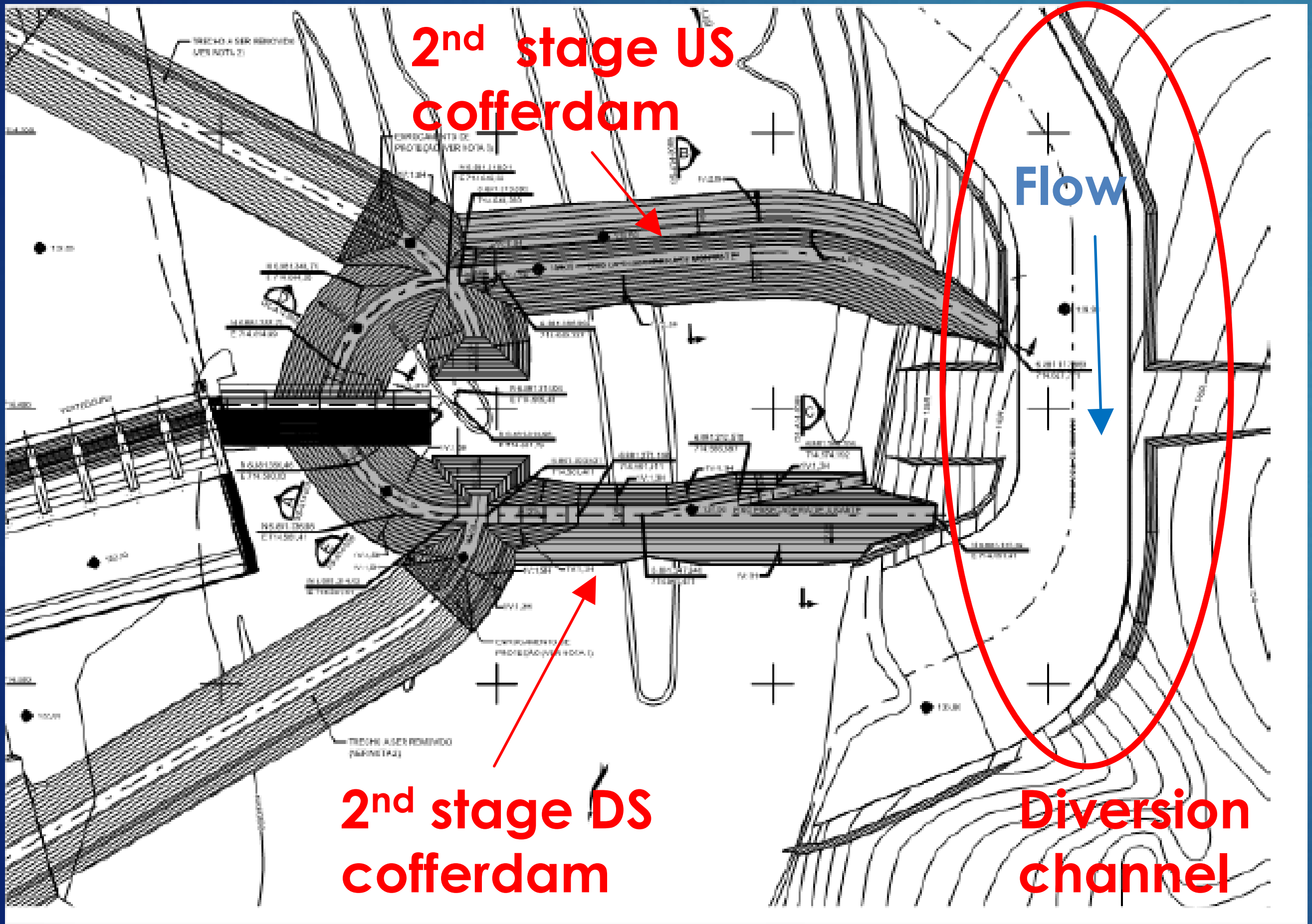


The first river diversion stage considers the construction of a cofferdam with protection for a return period of 100 years, partially closing the river.

This cofferdam protected the construction of the powerhouse and the spillway.

River Diversion Design

São José Dam – Ijuí River – Brazil.
River Diversion Design – 2nd Stage



The second river diversion stage considers the construction of a cofferdam for total closure of the river and the construction of a diversion channel excavated in rock in the right bank.

The protection of this cofferdam is for a return period of 10 years, and it protected the construction of the roller compacted concrete dam.

The diversion channel features are:

- Flood design Q = 1.800 m³/s (10 yr flood);
- Width = 40 m;
- Depth = 10 m;
- Velocity ≈ 4.5 m/s

Studies on physical model

Physical model of 1st stage of Ijuí River diversion
Geometric scale 1:75

The figure shows the physical model studies about the first stage deviation of the Ijuí River. These studies were carried out in the laboratory CEHPAR / LACTEC in Brazil.

During the experiments the water levels and flow velocities were measured in order to provide a proper dimensioning of protection blocks around the cofferdam to preventing erosion.

River Diversion 1st Stage

These aerial photos present the first stage cofferdam and the construction of the spillway and the power house

July 2009

River Diversion 2nd Stage and dam construction

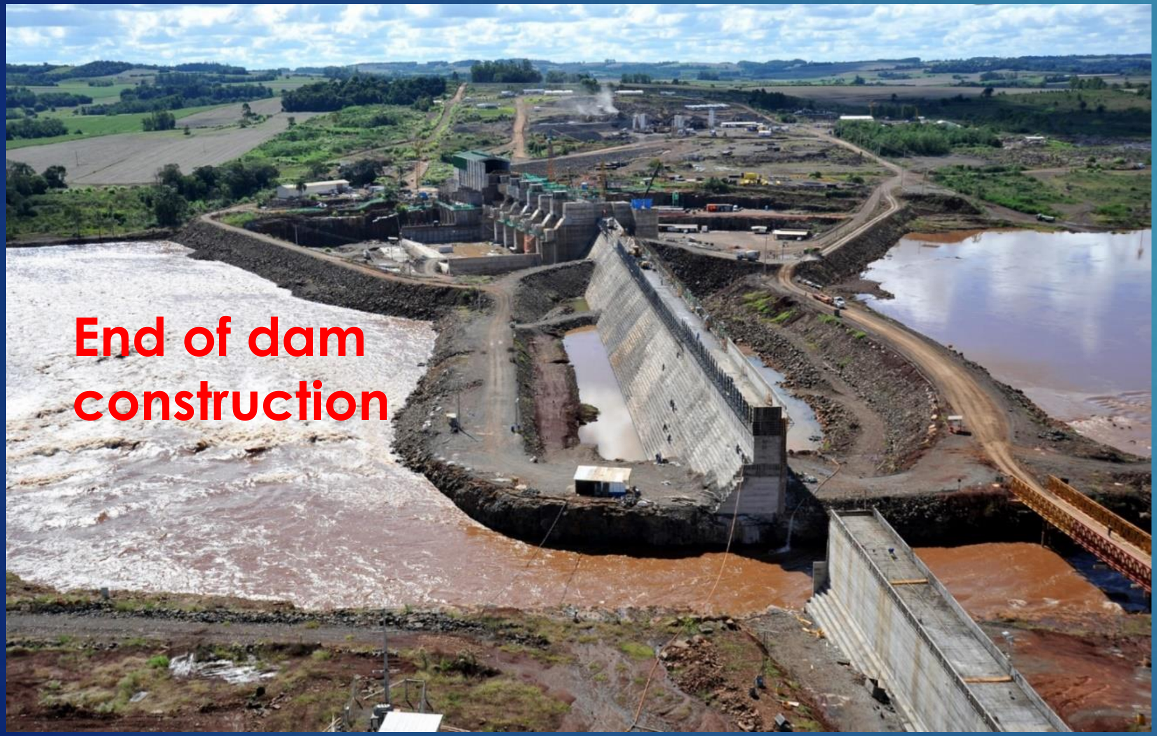
These aerial photos present the second stage cofferdam, the diversion channel and the beginning of construction of the roller compacted dam

August 2009

December 2009

Dam construction

These aerial photos present the end of dam construction



July 2010

Studies on physical model

The figure shows the physical model studies (CEHPAR lab) about the river closure. It is possible to see the dry channel in the physical model and the running of an experiment.

Studies on physical model

Due to high flow velocity during the river closure, big rock blocks were required to close the channel, which was a difficult for the constructors.

Results from physical model:

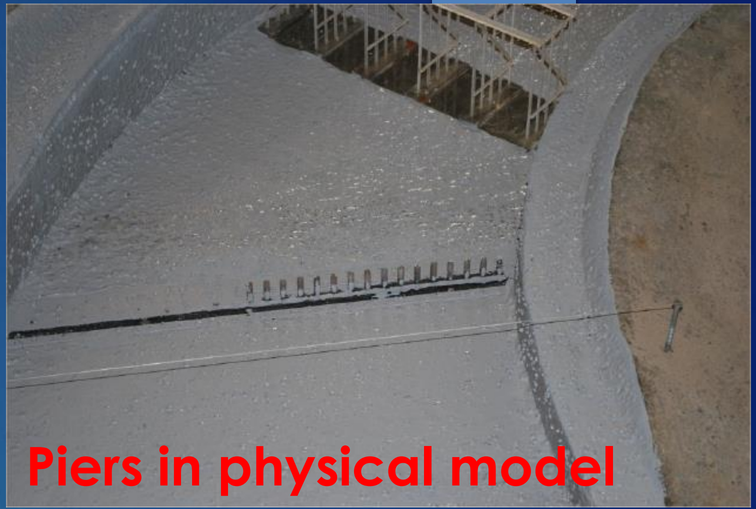
- Maximum discharge = 500 m^3/s
- Flow velocity≈10 m/s;
- Simplified Izbash formulation:

$$D_{critical} \approx \frac{V^{2}}{40} = \frac{10^{2}}{40} = 2.50\,m$$

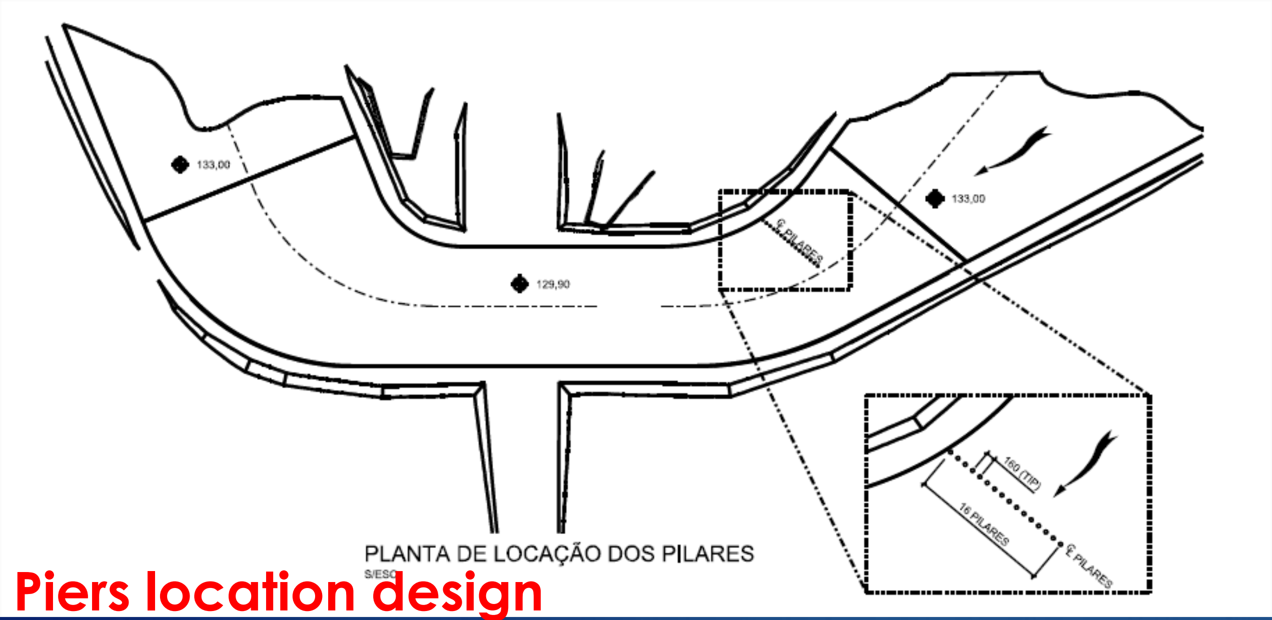
- Thus, the diameter of blocs required was D ≈ 2.50 m;

Studies on physical model

The solution was construct anchored concrete piers (1m diameter and 2 m high) upstream, close to the right wall of the channel (that was the critical zone to the closure) in order to hold the blocks and then reduce the block size.



Piers in physical model



Piers location design

Piers in the construction site

River Closure

The following slides show the evolution of the river closure following an end-dumping procedure

August 2010

River Closure

With the concrete piers it was possible to close the river with blocks with the maximum diameter around of 1.50 m

August 2010

River Closure

The river is finally closed and the flow went through the spillway. After the conclusion of the dam, the spillway gates were closed and the reservoir was filled.

August 2010

Conclusion

- For a proper design of a dam is fundamental the knowledge of river closure techniques;
- The knowledge about the type of material available on the construction site is crucial to the development of the project;
- The type of river closure technique must be in accordance with local topographical features and the availability of constructor's equipment;

About the São José Dam river closure case:

The river close operation was successful. The studies in physical model and equations to estimate the size of the blocks had a good agreement with what was observed in the prototype.

After the closing of the channel the river was diverted temporarily to the spillway. After the conclusion of the dam the spillway gates were closed for filling the reservoir, which was concluded in February 2011.

THE END

February 2011