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Temporary cofferdam at Caniçada Dam, Portugal

Batardeau temporaire au Barrage de Caniçada, Portugal

A. Pinto*
JETsj, Geotecnia, Lisbon, Portugal

L. Caldeira
LNEC, Lisbon, Portugal

F. Cerqueira, N. Plasencia
EDP S.A., Porto, Portugal

F. Gomes
Mota Engil, Porto, Portugal

**apinto@jetsj.com*

ABSTRACT: The execution of the Caniçada dam new complementary spillway, demanded the construction of a temporary cofferdam to allow the excavation of the discharge tunnel, at the dam south side. The cofferdam with about 20m height and 135m length, intersected weathered to very weathered granite, granite residual soils, fills and sands, with medium average hydraulic conductivity. This scenario led to the execution of a hybrid cofferdam solution: 7m concrete gravity wall over a 30m maximum depth cut-off curtain, using micropiles (tube à manchette) combined with 1m diameter, spaced 0.70m, double row jet grouting columns. The main design and execution criteria are presented, as well as the main QC/QA procedures.

RÉSUMÉ: L'exécution du nouveau déversoir d'inondation complémentaire du barrage de Caniçada, a exigé la construction d'un batardeau temporaire pour permettre l'excavation du tunnel de déchargeur, du côté sud du barrage. Le batardeau, d'une hauteur d'environ 20 m et d'une longueur de 135m, a recoupé des granites altérés à très altérés, des sols résiduels granitiques et des sables, avec une perméabilité moyenne. Ce scénario a conduit à la réalisation d'une solution de batardeau hybride: un mur de gravité, en béton non armée, de 7m de hauteur, sur un écran d' étanchéité de 30 m de profondeur maximale, à l'aide de micropieux (tube à manchette) combinés avec colonnes de jet grouting 1m de diamètre, double rangée et espacés de 0.70m. Les principaux critères de conception et d'exécution sont présentés, ainsi que les principales procédures de CQ/QA.

Keywords: Cofferdam; jet grouting; micropiles; cut-off.

1 INTRODUCTION

The Caniçada dam is a double curvature concrete arch dam with a height of 76m above the foundation level and a crest length of 246m, located at the Cávado river, Peneda Gerês National Park, at Braga District, North of Portugal. The dam was built in 1955 and is resting over the granite bedrock (Figures 1 and 2).

The execution of the Caniçada dam new complementary spillway, demanded the construction of a cofferdam to allow the excavation of the new discharge tunnel portal, at the left abutment of the dam. With this objective, the cofferdam was built with about 20m height and 135m length using a hybrid solution: a concrete gravity wall over a cut-off curtain constituted by jet grouting columns (type 2) and micropiles.

Figure 1. Caniçada dam location.

Figure 2. Construction of Caniçada dam reinforced concrete arch over granite bed rock (courtesy of Rodio).

2 GEOLOGICAL SCENARIO

The geological scenario at the Caniçada dam new complementary spillway is very heterogeneous. After an intensive geological and geotechnical campaign, the following four geotechnical zones were established, from the surface (Figure 3 and 4):

- ZG4 – Fluvial beach sands and heterogeneous fills, with medium to high average permeability.
- ZG3 – Granite residual soil with boulders, with medium permeability.
- ZG2 – Granite rock mass (W3-4 and F3-2 to F3-4) with low average permeability.
- ZG1 – Granite rock mass (W2-3 and F2-3).

Figure 3. View of granite boulders at the Caniçada slopes.

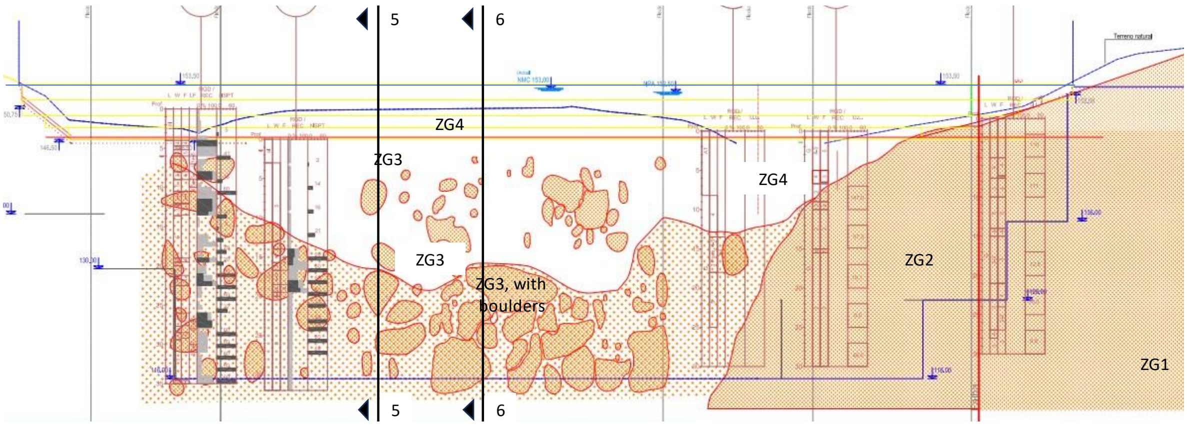

Figure 4. Geological profile (from upstream).

3 COFFERDAM SOLUTION

Considering the geological and hydrogeological complexity, as well as both cofferdam geometry and temporary nature, a cut-off curtain solution, combining jet grouting columns (Croce and Modoni, 2007) and injection micropiles (tube à manchette) with 30m maximum depth was built. A concrete gravity wall was built over the cut-off curtain with its crest level 0.5m above the dam maximum water level.

At the cofferdam most representative cross section (ZG3 intersection), the following solutions were adopted, with the double function of cut-off curtain and gravity wall foundation (Figures 5, 6 and 7):

- At the downstream side: two rows of ϕ1000mm jet grouting columns, spaced, respectively, 0.70m and 0.80m in the longitudinal and transversal alignments, with triangular distribution, were built. The micropiles were installed at the jet grouting columns intersections with sleeves at each 1m.
- At the upstream side: one alignment of inclined micropiles (HEB160 steel profiles) and vertical micropiles (HEB140 steel profiles), both spaced 1.6m.

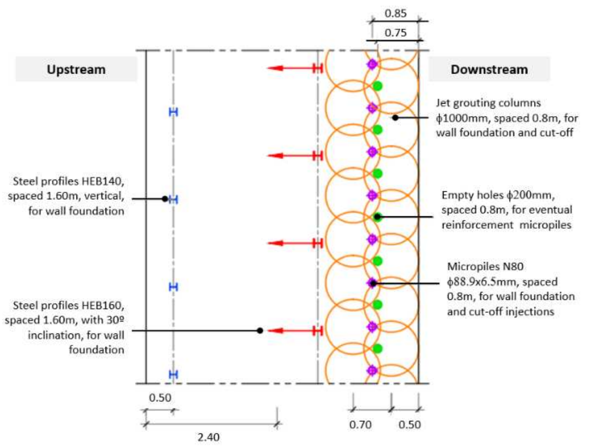

Figure 5. Plan distribution of HEB profiles and cut-off jet grouting and micropiles at the gravity wall foundation.

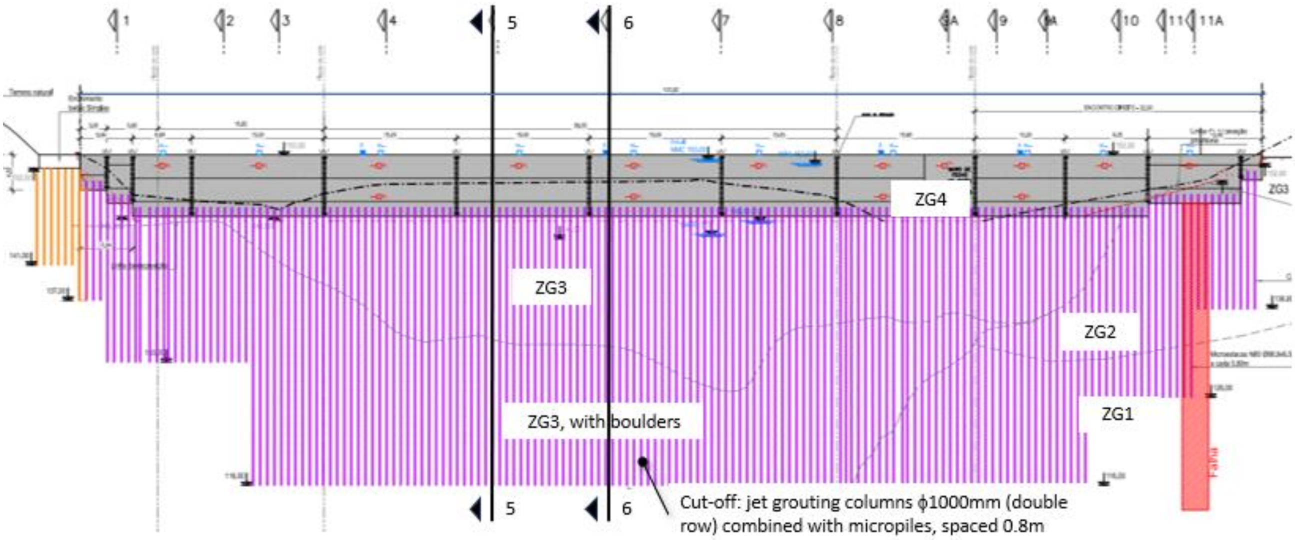

Figure 6. Cofferdam solution elevation (from upstream).

The excavation works inside protected by the cofferdam were performed with 1.25(h):1.00(v) slopes lined with shotcrete, nailed, and drained (Figures 7 and 8).

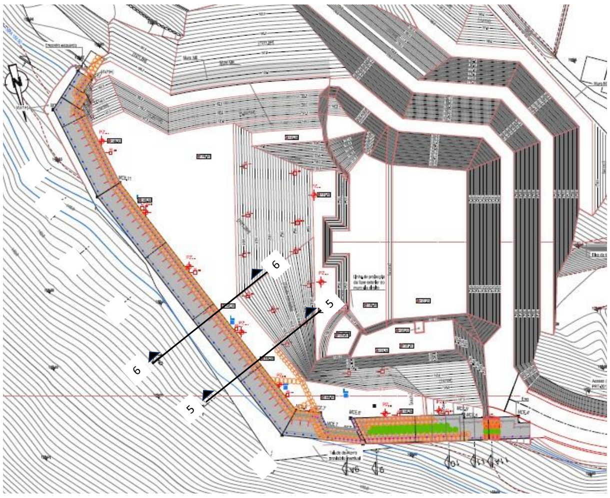

Figure 7. Cofferdam plan with the excavation slopes.

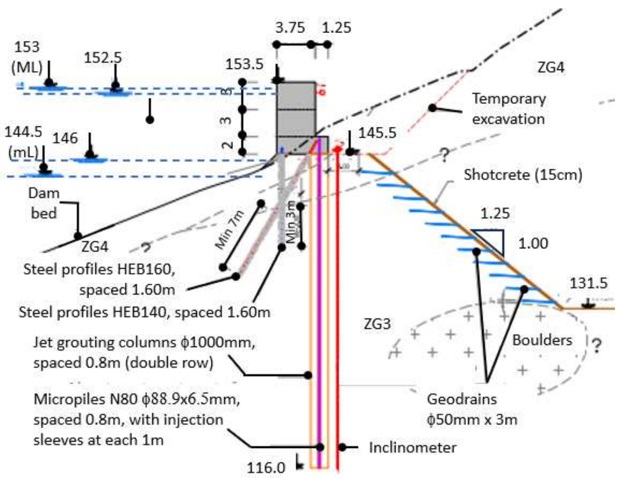

Figure 8. Cofferdam cross section 6-6 (ZG3 intersection).

4 DESIGN

4.1 Cofferdam overall stability

The cofferdam overall stability, including the excavation slope, was checked for several cross sections using SLIDE software, FEM with seepage analysis (Figure 9).

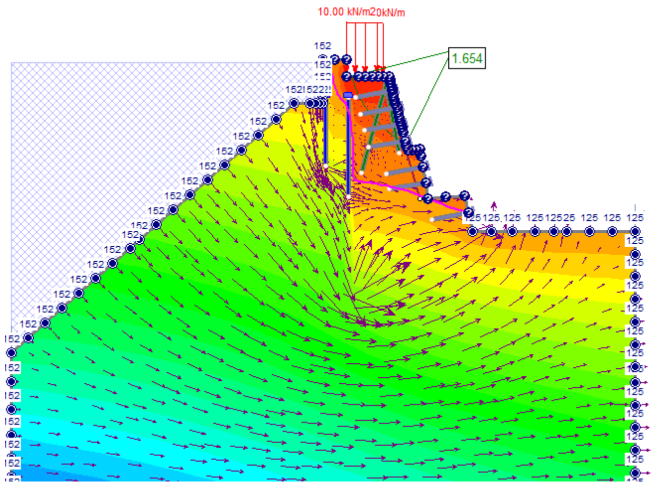

Figure 9. Safety factor for global stabiliy (1.654) at the final excavation level, considering the water inflow, cross-section 5-5.

4.2 Cofferdam hydraulic stability

The cofferdam hydraulic stability, mainly against internal erosion at the excavation base, was also checked for several cross sections using SLIDE software, FEM with seepage analysis. The safety factor for internal erosion was estimated considering the ratio between the critical hydraulic gradient (approximately 1.0) and the estimated hydraulic gradient at the excavation base exit (Figure 10).

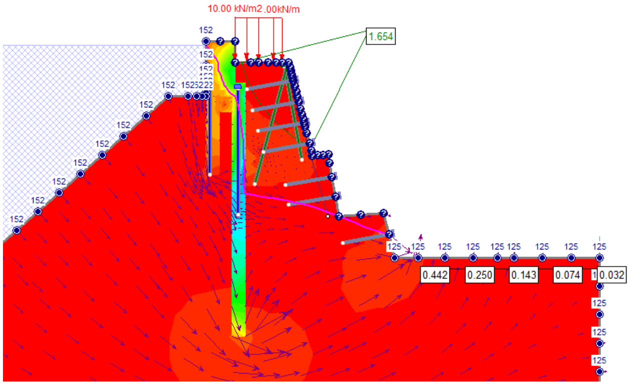

Figure 10. Hydraulic gradients at the excavation base, cross section 5-5.

Figure 12. View of jet grouting excavated around columns.

5 JET GROUTING QUALIY CONTROL AND QUALITY ASSURANCE

5.1 Trial columns

Trial columns were performed to check both the columns geometry and strength at the ZG4 and ZG3. The columns strength and deformability (Young's modulus) were confirmed through UCS tests, performed at 28 days cores and compared with the design parameters: 4MPa and 1GPa, respectively, for 450kg/m^3 of cement consumption (Figure 11).

Figure 11. Trial column's view.

5.2 Execution parameters

All jet grouting execution parameters were recorded using automatic devices and compared with those established based on the trial columns.

5.3 Columns position and verticality

All jet grouting columns position and verticality were confirmed using GPS and digital inclinometer devices.

5.4 Columns integrity

Jet grouting columns integrity was checked by excavation (Figure 12), coring about 5% of the columns, sounding, cross- hole and Lugeon tests.

6 FINAL REMARKS

The presented case study allowed to confirm the advantages of water cut-off solutions for temporary cofferdams using jet grouting columns combined with micropiles in complex geological and hydrogeological scenarios. As main advantages, compared with more conventional solutions, such as diaphragm walls, can be pointed out the following: minimum ground extraction, behaviour predictability and ease demolition (Figure 13).

Figure 13. View of the excavation final works.

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