EXPANSION SLOT CUTTING TO COUNTERACT ALKALI AGREGGATE REACTION AT PEDRA DAM

Alberto Jorge C. T. Cavalcanti [1*], Patrícia Neves Silva[1], Thais Amorim A. da Silva[1], Rodrigo C. Soares[2]

[1]Chesf - Companhia Hidro Elétrica do São Francisco, Recife, PE, BRAZIL

[2]Betonpoxi Engenharia , Recife, PE, BRAZIL

Abstract

The Pedra Dam, located in River de Contas, Bahia state in Brazil, was built between 1964 and 1968. In 1991 the presence of alkali-aggregate reaction (AAR) in concrete structures was detected by means of petrographic and electron microscopic analysis. The concrete expansion caused an internal tension on the end piers of the spillway transmitted by the adjoining blocks; this resulted in operating problems of the left end gate. In order to reduce the effects of the concrete expansion, four expansion slots were cut with diamond coated steel wires. A monitoring system – consisting of 24 joint meters was installed at eight joints between the concrete blocks, including the four expansion slots and the four slots next to them. The displacements measured during the cutting operations showed different behaviors at the left and the right abutments.

Keywords: Alkali-aggregate reaction, concrete dam, slot cutting, waterproofing

1 INTRODUCTION

The Pedra Dam is placed in de Contas River, Brazil. It was built during the 1964 – 1968 period. The dam is a 60 meter high buttress type structure with a total length of 408m. The structure has 17 non-overflowing abutment blocks and 7 central spillway sections.

The dam is made of 24 - 17 meters- wide blocks. In the excerpt from the right margin there are eleven blocks, with a total length of 187 m. The left margin has six blocks with a total length of 102 m., between these two portions there are seven spillway blocks with total length of 119 m (see figure 1) equipped with radial gates 9.0 m high and 12.50 m wide. The gates spans are separated by double 2.25 m-wide piers. The spillway flow capacity is 8,000 m³ with the reservoir level at 231.30 m.

The alkali-aggregate reaction has been causing concrete expansion, which has led to difficulties in operating the gate at the left end spillway block. The non-overflowing blocks, adjacent to the spillway sections were pushing the gates piers, causing the above mentioned gate operation problems [1]. The actual concrete expansion rate at the dam was unknown due to the lack of a monitoring system but it was judged to be moderate, based on visual inspection and petrographic examination of concrete samples. A monitoring system was designed and installed to follow the expansion rate.

The design of the slot cutting here presented was based on the predicted long term structural behavior of the dam, under concrete expansion. The main goal was to minimize the bending stresses caused by the concrete expansion and the consequent lateral deflection of the spillway end piers resulting in the gates clearance reduction. Further information on this can be found in [2].

Design modification of the spillway gates were also studied and are foreseen to be implemented later on, if necessary.

Several slot cutting location alternatives, with different slot depths, were studied through a three-dimensional mathematical model, including the concrete structure and the foundation rock mass. The model simulated the effects of concrete expansion in the whole dam, mainly at the spillway piers and surroundings. The alternative with 13 m depth slot cutting on joints between non-overflowing blocks was adopted. The final design for the corrective measures included four 10 mm wide slots, two at each spillway side, on the concrete buttresses contractions joints.

In order to monitor the slots behavior during the cutting operation, a system composed by 24 joint meters was installed at eight contraction joints between concrete blocks, including the four expansion slots and the four adjacent ones.

* Correspondence to: alberto@chesf.gov.br

2 SLOT CUTTING

2.1 General

Four expansion slots on the contraction joints at the left and right sides of spillway were part of this project. These expansion slots were located on the contraction joints between blocks B9/B10, B10/B11, B19/B20 and B20/B21 at the left and right sides of the spillway. The slots between the concrete buttresses have an upstream-downstream extension of 5.75 m. They are 13 m deep, 10 mm wide and an area of 66.90 square meters (See figures 3 and 4).

2.2 Cutting operations

The expansion slots cutting at Pedra dam was performed in October of 2009. Because of its overall length, each cut was broken down into segments made in sequence. Each segment had a maximum height of 3m. It was necessary to drill horizontal relief holes across the massif to prevent the wire from getting stuck during the cutting operation. The wire can seize due to the high internal compressive stresses caused by the alkali aggregate reaction. The holes were drilled with 5 cm diamond drill bits.

The slots were cut with a 10 mm diameter diamond coated steel wire. The equipment used was the Wire Saw, SK-SD model, Hydrostress (Tyrolit) brand, driven by a hydraulic PPH20 unit (see figures 5 and 6). Depending on the characteristics of crop area as described above, the first slice of cross section was trimmed with the "diving" cutting method, where the wire cuts from top to bottom. For rest of the slices, the "loop" method was used, with the wire passing through the relief holes and running toward the upper bound.

To make the cuts between the elevations of 219 m and 232 m, the reservoir was drawn down to El 217.5 m. The joint B9/B10 was cut into 3 steps and the joint B10/B11 in 2 steps due to interference with the reservoir water level (see Table 1 and Figure 10).

3 SLOT MONITORING RESULTS

A system of 24 measuring devices to monitor the slots behavior during the cutting operation was installed at eight contraction joints between concrete blocks. The four expansion slots and the four slots adjacent to the expansion lots were included in these measurements). Joint meters were installed at the dam crest and in the El. 225.50 m downstream gallery, measuring the differences in shifts between blocks along the normal and tangential directions (see table 2).

Figures 12 and 13 present the slots gap graphics monitored by the joint meters, from August to October of 2009. It is noted that: in joints 8/9 and 21/22, neighboring joints from the slots cut, showed no movement; joints 11/12 and 18/19, between the spillway and the internal left and right abutment extreme blocks, presented large dispersion in the readings which varied between -0.5 mm and 0.5 mm. Joints cuts 9/10, 10/11, 19/20 and 20/21 showed a clear trend towards closing the joints gaps. These closures were greater at the left abutment joints, about 1.5 mm, while at the right abutment joints were of about of 1 mm

4 SLOTS WATERPROOFING

The waterproofing of the expansion slots was designed through a exposed geomembrane drain system supplied and installed by Carpi Brasil Ltda. The system is composed of a polyvinyl chloride (PVC) geocomposite laid over a flexible PVC geomembrane antipuncturing double layer, fixed along the perimeter with stainless steel batten strips and chemically anchored bolts . Each geomembrane system covers 1 m wide by 14 m high surface on the upstream face of the expansion slots.

This installation was performed in four weeks. The work was done overran area of 56.0 m^2 (14.0 m high, between the elevations levels of 218 and 232m. The antipuncturing flexible PVC geomembrane support layers are fixed to the concrete along both sides with stainless steel profiles and impact bolts (see figure 9).

5 CONCLUSIONS

The implementation of the expansion slots cuts proved to be efficient to mitigate the effects of the concrete expansion on the spillway gates at its ends. An operation test, held after the conclusion of the slots cutting, showed no difficulties in opening and closing the gates.

The closing of expansion slots, measured during the cutting operation, was less than those calculated in mathematical models simulations, but confirmed the pattern to be greater in the dam left shoulder.

6 REFERENCES

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TABLE 1: Slot cutting operation sequence.

FIRST PASS JOINT	CUT AREA (m2)	CUT DEPTH (m)	CUT SEQUENCE	TIME PERIOD
B9/B10	8.24	1.60	FIRST STAGE	2/8/09 - 12/8/09
B10/B11	49.95	9.70	FIRST STAGE	13/8/09 - 24/8/09
B09/B10	41.71	8.10	SECOND STAGE	25/8/09 - 4/9/09
B19/B20	66.90	13.00	COMPLETE	7/9/09 - 17/9/09
B20/B21	66.90	13.00	COMPLETE	20/9/09 - 27/9/09
B10/B11	16.95	3.30	SECOND STAGE	29/9/09 - 2/10/09
B09/B10	16.95	3.30	THIRD STAGE	3/10/09 - 4/10/09
SECOND PASS JOINT	CUT AREA (m2)	CUT DEPTH (m)	CUT SEQUENCE	TIME PERIOD
B9/B10	66.90	13.00	COMPLETE	13/10/09
B10/B11	66.90	13.00	COMPLETE	11/10/9 - 12/10/9
B19/B20	66.90	13.00	COMPLETE	6/10/09 - 7/10/09
B20/B21	66.90	13.00	COMPLETE	8/10/09 - 9/10/09

TABLE 2: Joint meter bases location.

JOINT	JOINT METER BASES		
	DAM CREST	EL. 225.50 m GALLERY	EL. 227.50 m
B8/ B9	BA-1 / BA-2	BA-3	-
B9/ B10	BA-4 / BA-5	BA-6	-
B10/ B11	BA-7 / BA-8	BA-9	-
B11/ B12	BA-10 / BA-11	-	BA-12
B18/ B19	BA-13 / BA-14	-	BA-15
B19/ B20	BA-16 / BA-17	BA-18	-
B20/ B21	BA-19 / BA-20	BA-21	-
B21/ B22	BA-22 / BA-23	BA-24	-

FIGURE 1: Downstream view of Pedra Dam and slots location.

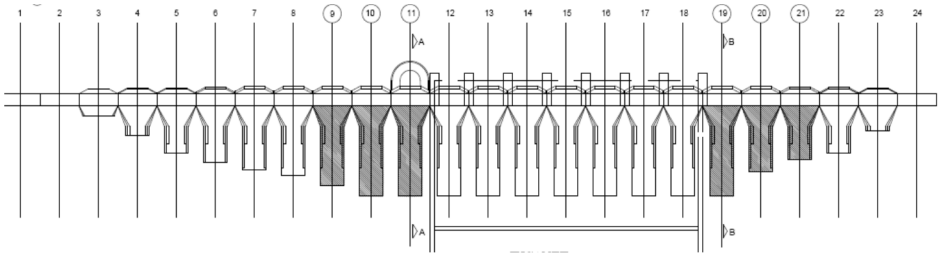

FIGURE 2: Dam plan view with numbered blocks.

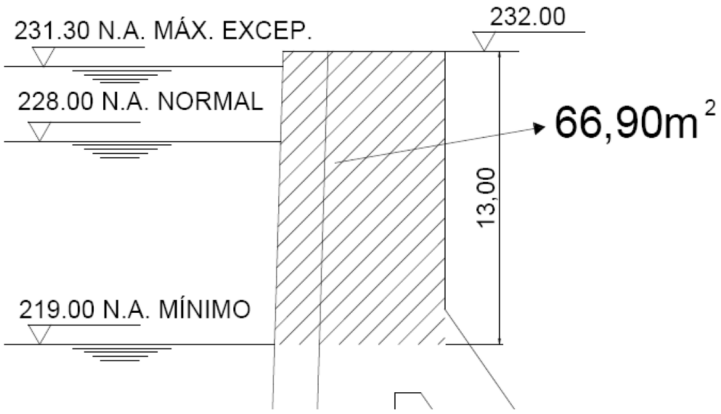

FIGURE 3: Slot cutting area.

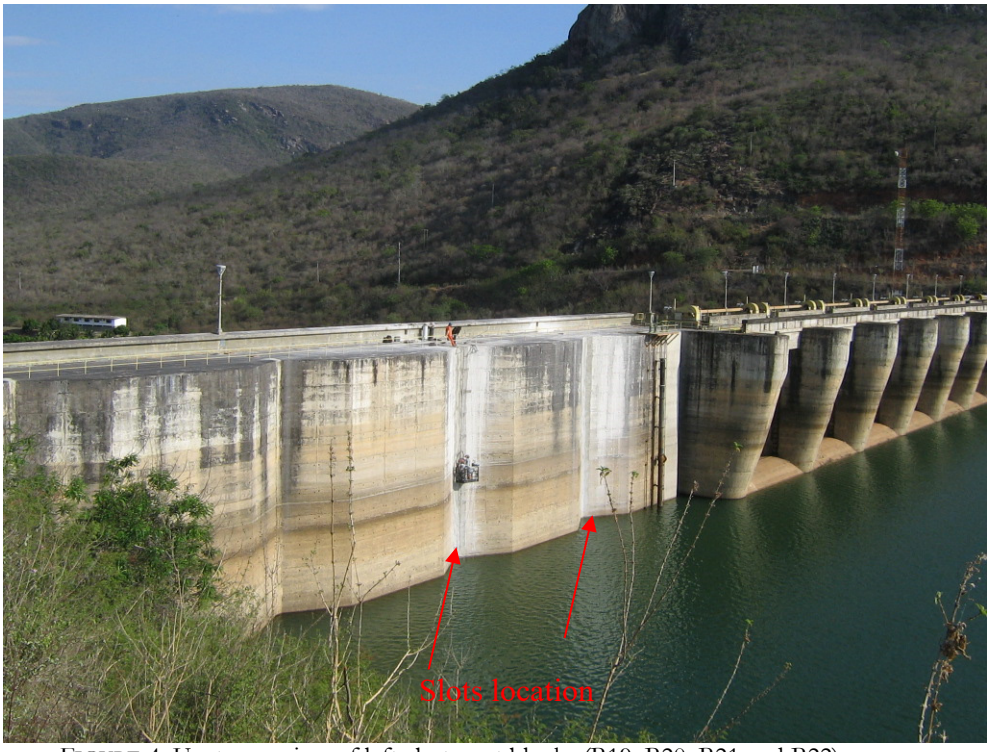

FIGURE 4: Upstream view of left abutment blocks (B19, B20, B21 and B22).

FIGURE 5: Cutting equipment at dam crest near downstream parapet wall.

FIGURE 6: Detail of diamond coated cable and water cooling system.

FIGURE 7: Relief hole horizontal drilling.

FIGURE 8: Cable guiding system and suspended working platform.

FIGURE 9: Slot and geomembrane sealing system after completion.

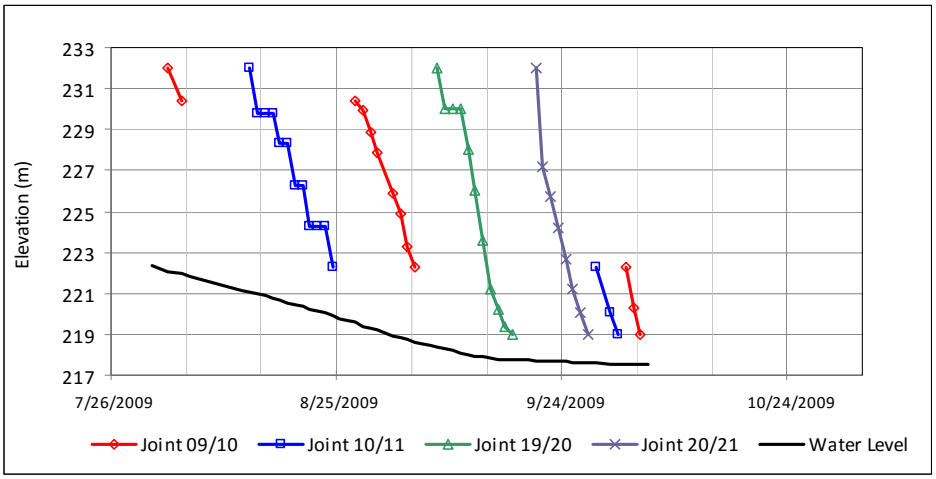

FIGURE 10: Slot cutting and reservoir drawdown chronology.

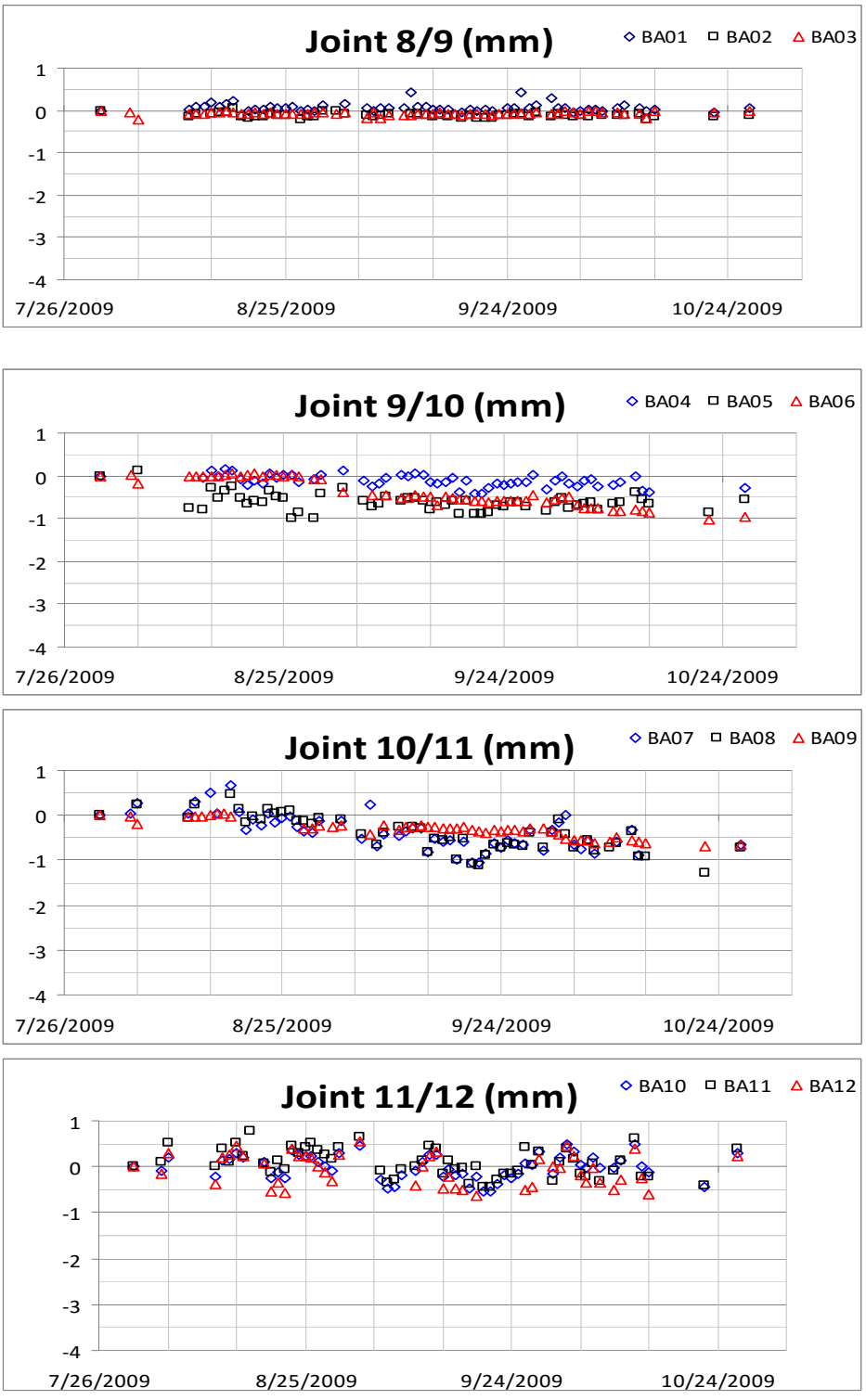

FIGURE 11: Right abutment joints gap monitoring.

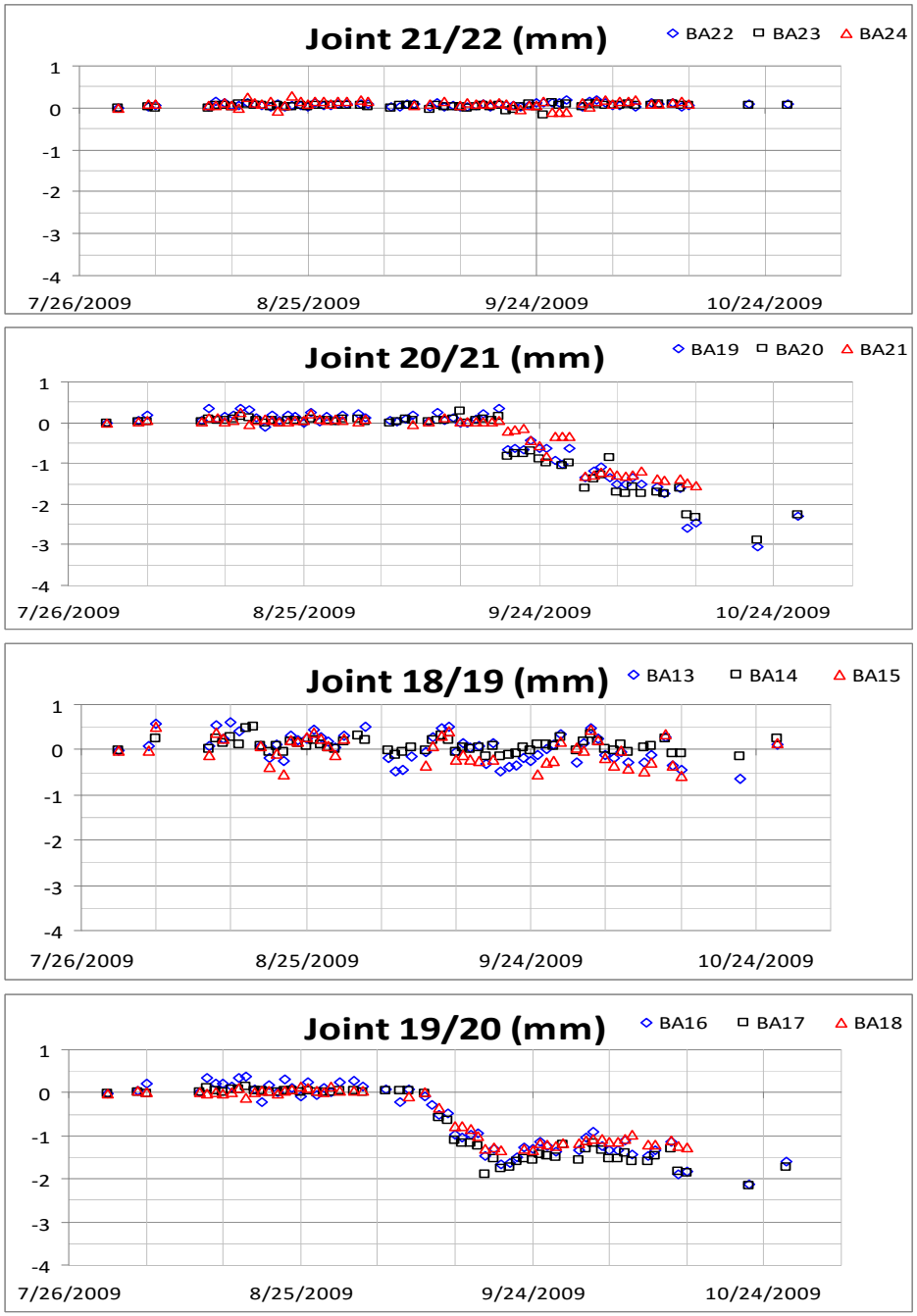

FIGURE 12: Left abutment joints gap monitoring.