MAINTENANCE AND REPAIRS ON THE WATER INTAKE OF JAGUARI HYDROPOWERPLANT AFFECTED BY AAR.

Edvaldo Fabio Carneiro[1]*; Julio Cesar Pinfari[1]; Tatiana P. Araripe Cappi[1]; Mauro H. L.Covre[1].

[1]CESP – Cia. Energética de São Paulo, São Paulo, SP, BRAZIL

Abstract

In 2001 alkali-aggregate reaction (AAR) was confirmed at Jaguari Hydropowerplant (HPP), that belongs to CESP-Companhia Energética de São Paulo, through petrographic analysis of specimens taken from the water intake, foundation block of a steel catwalk and concrete columns/beams that supports an overhead crane. Since the detection, instrumentation was installed; researches and repairs have been implemented aiming to assure the structural integrity and keeping a safe operability of the hydropower plant.

This paper presents the procedures, methodologies and results obtained after cracks repairs caused by AAR on the water intake, on the foundation block and columns that support the steel catwalk.

Keywords: Hydropowerplant, water intake, alkali-aggregate reaction, waterproofing

1 INTRODUCTION

The Jaguari Hydropowerplant (HPP) is equipped with two (2) 13.8MW generating units, each one has a function to generate energy and regulate flows of the Jaguarí River, a tributary of the Paraíba do Sul River. The structure of the water intake consists of a tower, 63.00 m high, driving the water stored in the reservoir to the powerhouse through a penstock 572.50 m long, through low pressure tunnel with 5.0 m diameter, located on the left abutment between the earth dam and the spillway. The water intake aqueduct was specified and constructed for a total flow for the penstock to 64.00 m^3/s, for the maximum reservoir level of 623.00 m. Access to the water intake structure is done through a steel catwalk, supported by two concrete columns and foundation blocks, both in reinforced concrete. In the Figures 1 and 2, we can see the water intake and access by a steel catwalk respectively.

FIGURE 1

FIGURE 2

FIGURES 1 and 2: View of water intake and steel catwalk access, columns/beams and foundation blocks.

According to CESP reports [4, 5] petrographic tests confirmed the deleterious phenomenon known as AAR (alkali-silica reaction) in the concrete structures of Jaguarí, due to the presence of silica (SiO_2) of the aggregate, being highly reactive with the cement alkalis (Na_2O and K_2O), causing an expansion in the structure and, as a consequence, the occurrence of cracks.

Since the appearance of the cracks caused by AAR, CESP has been monitoring the behavior of the entire structure of the dam, mainly the water intake through installed instruments and scheduled visual inspections.

* Correspondence to: edvaldo.carneiro@cesp.com.br

Over the years, preventive maintenance was performed, such as injections and repairs in cracks and joints, waterproofing products, aiming to increase durability and ensure a good performance of the hydroelectric power plant.

2 PREVENTIVE MAINTENANCE - MATERIALS AND METHODS

2.1 Internal structure of the water intake

In 2010, a shutdown of Jaguarí hydropower plant took place, to perform works like modernization and electromechanical equipment maintenance. The stop logs were installed, enabling to perform an inspection in the aqueduct and set the repair job on the inner walls of the ventilation tunnel. The external dimensions of structure tunnel is 1.00 m x 3.00 m, with an estimated length 20.00 m and thickness of wall-face in contact to the reservoir is 0.25 m. Repair jobs in the structure were carried out by the CESP team, as described in the report [6], in order to control and eliminate the infiltration through the joints and cracks. The Figure 3 shows an elevation of the water intake and ventilation tunnel respectively.

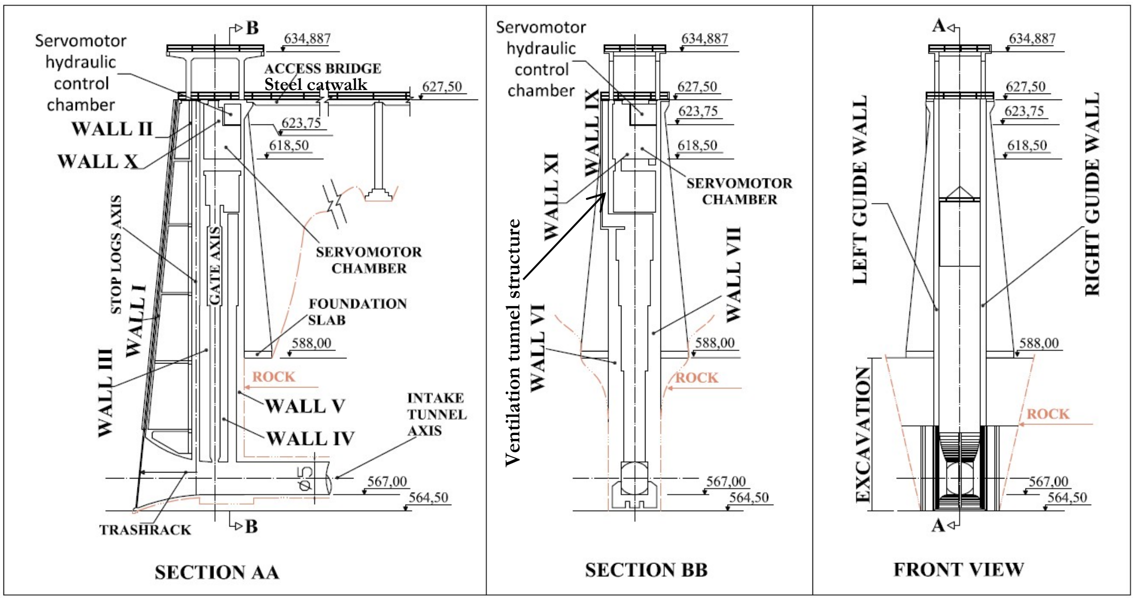

FIGURE 3: Jaguari HPP water intake showing front view and sections.

With the aim of improving the tunnel access conditions, divers conducted the first services of slant joints and some cavities in the water intake of the ventilation tunnel structure, with application of epoxy. However, the result of applying, didn't answer the objective of reducing significantly the infiltrations, depending on the water pressure of the reservoir to the inner side of the tunnel.

FIGURE 4

FIGURE 5

FIGURES 4 and 5: Infiltration through cracks of wall ventilation tunnel.

The exhaustion of the supply aqueduct, allowed access to the inner walls of the tunnel, and repairs were started in the joints, cracks and cavities with higher water percolations at the level 615. 00 m. In this way this leak was controlled in the joints next to the slab.

To achieve satisfactory results within the structure, the services were performed, by associating the jobs of quick picks, cements for caulk and products for grouting such as polyurethane and acrylic resin.

There was also the need to eliminate the water infiltrations affecting the work of the team of mechanical maintenance at level 608. 00 m. The activities to stop the water infiltration were performed by the careful drilling of concrete, with special procedures depending on the thickness of the wall, cleaning the area to be repaired with hydro jet and steel brush, caulk the joints with quick set cement and grouting with the products mentioned above, see Figures 6 to 8.

FIGURE 6

FIGURE 7

FIGURES 6 and 7: Cleaning the area to be repaired and use of quick set cement, to stop the infiltration.

FIGURE 8

FIGURE 9

FIGURES 8 and 9: Installation of nozzles and injection with polyurethane and acrylic resin.

The service was run by CESP, for 22 days at the plant. In this period of work the quantities indicated in table 1 were applied.

TABLE 1: Quantities of products used in the services.

PRODUCT	QUANTITY
Polyurethane	40 l
Acrylic resin	54.5 Kg
Quick set cement	50.0 Kg
Cement powder – (Hey'di)	85.0 Kg
Injection nozzles	168.0 units

2.2 Structure of concrete columns and Foundation blocks of steel catwalk

In the second half of 2014, according to the CESP report [2] a routine visual inspection in concrete structures of water intake was performed. The level of the reservoir was 609.70 m, the lowest registered in recent years, due to a drought in the Southeast, leaving exposed the Foundation blocks and concrete columns of the steel catwalk, located in level 612.00m, approximately. On that occasion it was found that the blocks were very cracked and leaching. Figure 10 presents a schematic drawing of the dimensions of the blocks and concrete columns. Figure 11 presents the illustration of the steel catwalk and concrete columns on the Foundation blocks.

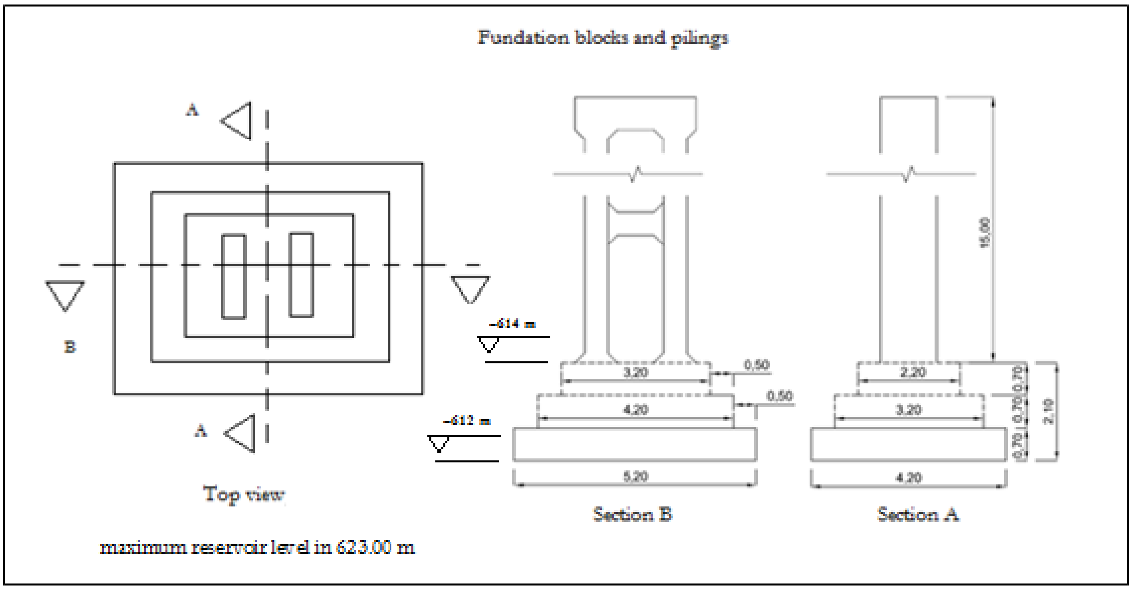

FIGURE 10: Dimensions of Foundation blocks and concrete columns.

FIGURE 11: View from the footbridge, supported on concrete columns and foundation blocks.

In the technical visit, performed by the technicians of CESP, appeared the necessity to repair the blocks and concrete columns, which were heavily cracked with openings above 10.0 mm, which compromised the concrete strength, elasticity and durability. Figures 12 to 15 show the Foundation blocks and concrete columns of the steel catwalk, water intake access and highlighting the more pronounced cracks, with gaps between 1.0 mm to 4.0 mm. There were also points of aggregate segregation on the basis of the concrete columns surface, and on the surface of the Foundation block.

FIGURE 12

FIGURE 13

FIGURES 12 and 13: View of foundation blocks and concrete columns of steel catwalk, and highlighting the sharp cracks, with top opening up to 1.0 mm.

FIGURE 14: View from the block of the concrete columns, highlighting the cracks, with top opening up to 1.0 mm. Presence of leaching and segregation on the concrete surface.

FIGURE 15: Detailed view of the Foundation blocks, measuring the opening of cracks on the order of 2.0 mm Observe the resulting gel of the AAR.

The cracks were mapped and after that the methodology to waterproof the block and also schedule the activities to perform the jobs were defined.

It was decided to inject a structural epoxy based adhesive because, despite blocks and concrete columns presented cracks due to AAR, they required repairs in order to restore structural integrity and monolithicity. The structural epoxy has high compressive and tensile strength, and was used to bond the structure. To make the injections with resin, it was necessary to caulk the cracks with structural epoxy - adhesive - bi-component.

The repair of the block and concrete columns began in the first half of 2015, according to CESP reports [1, 3], with water jetting for cleaning the surface. This cleaning left the structure free of any particle that might prevent the correct repair of structure. After the water jetting, began the process of caulking the cracks with epoxy – base adhesive to waterproof and fill the concrete cracks.

To insert the injection nozzles, holes were made on the diagonal of the crack (45°), each one with 15 cm maximum, in such a way that there was longitudinal cut between cracks at a depth of 12.00 to 30.00 cm. After drilling, nozzles were inserted, Figure 16. After cleaning and drying, injections were initiated with epoxy resin, Figure 17. After applying the resin injection nozzles were removed.

FIGURE 16

FIGURE 17

FIGURES 16 and 17: Holes for the insertion of nozzles and implementation of the injection process.

Finally, as the presence of water is the factor that triggers the alkali-aggregate reactions, texture coating (highly flexible liquid-pure acrylate dispersion) was used as waterproofing agent on the blocks and part of the concrete columns, avoiding the contact of the concrete structure retrieved with the reservoir water and rainfall. This waterproof process was chosen because the possibility of remaining AAR activity, see Figure 18. In this period the quantities of materials indicated in table 2 were applied.

FIGURE 18: View from the set blocks and concrete columns, texture coating, after the injection job.

TABLE 2: Applied Quantities of products used in the services.

PRODUCT	QUANTITY
Structural epoxy based adhesive	8.00 kg
Structural epoxy-adhesive-bi-component	23.43 kg
Texture coating - highly flexible	72.00 kg
Injection nozzles	120.00 unit

3 RESULTS

The repair services on the joints and cracks in the walls of the concrete structures ventilation tunnel of water intake couldn't get a complete sealing of the infiltrations, caused by the reservoir, but the reduction was significant. Thus, the results could be considered satisfactory.

The completion of repair on concrete columns/beams and foundation blocks of the steel catwalk structure to access the water intake were possible because in that moment, the reservoir was about 14.5m below maximum level, exposing the entire concrete structure.

4 CONCLUSIONS

Despite the presence of the AAR in the concrete structures of water intake, we can say that the materials, equipment and the technique adopted in the repairs process, contributed to decrease the infiltrations and to maintain their durability.

In addition to the maintenance, the monitoring equipment, like extensometer, triorthogonal meter, inverted pendulum, tensotast base and remote acquisition of relative displacements between the walls of the storage compartment of the stop-logs were installed on top of the water intake on previous occasions to this maintenance, for monitoring the effects of the AAR in the structure [7, 8].

Although the structure lives together with the phenomenon of the reaction, it is not currently interfering in the operation and maintenance of the hydropower plant.

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