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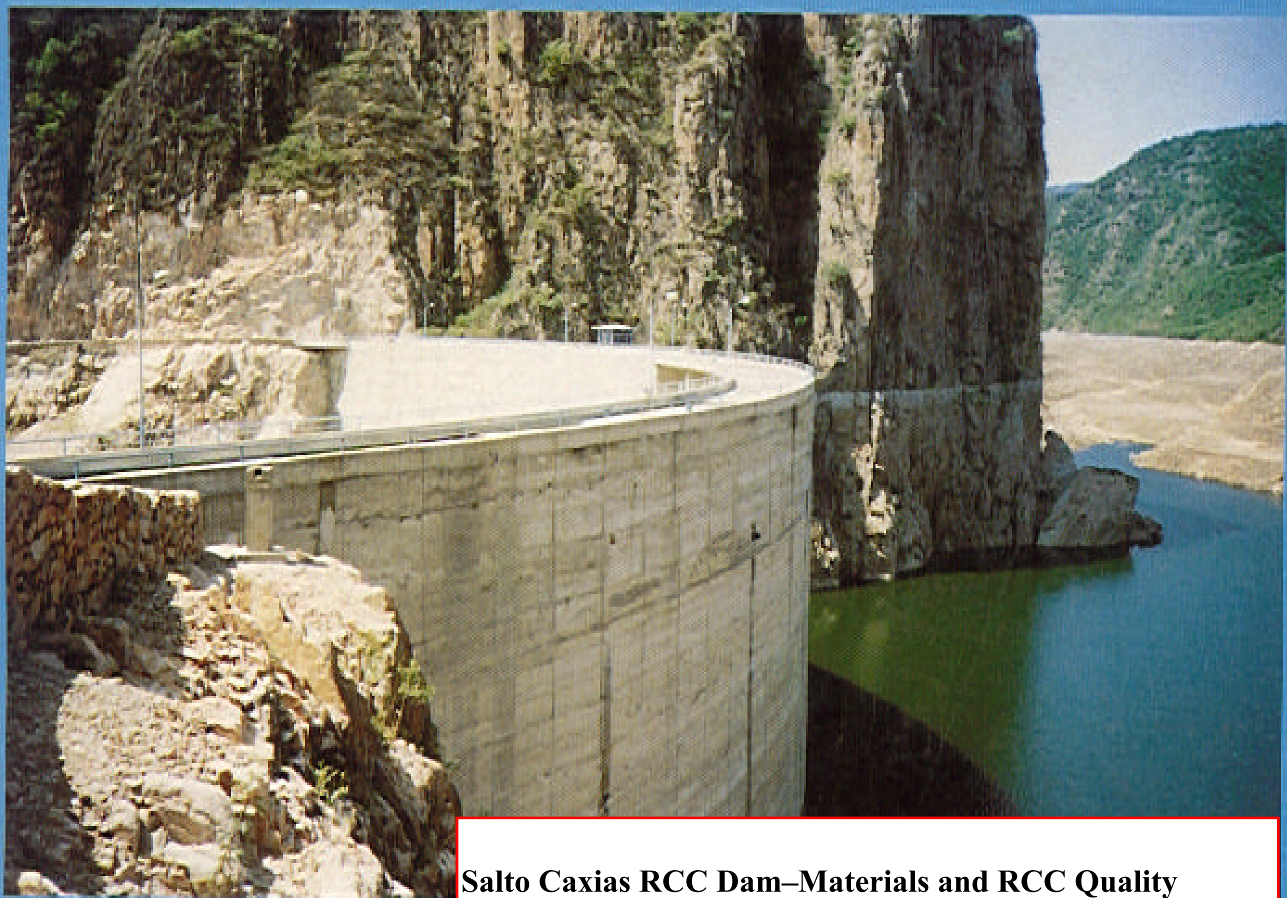

Salto Caxias RCC Dam–Materials and RCC Quality Control

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Salto Caxias RCC Dam–Materials and RCC Quality Control

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ABSTRACT

This paper presents data on the Quality Control of materials and the RCC used for the RCC dam at Salto Caxias Hydroelectric Power Plant, Paraná State- Brazil.

During construction, COPEL- Government Energy Agency at Parana State-Brazil, was responsible for the supervision and implementation of a Quality Control Plan. The results shown here indicate that great uniformity and quality were obtained, this can be further illustrated by a low cement content content as well as small coefficient of variation.

1-INTRODUCTION

During construction of approximately 950,000m3 of RCC for the dam and spillway massive portion of Salto Caxias Power Plant, materials and concrete Quality Control System experienced adjustments and fine-tuning.

The Quality Control System, in use from late 95 to mid 98, can be divided in two very different periods, with many procedures having been modified or improved.

Forty-two Operational Standard Procedures - "OSP" were developed in order to guide and control actions.

The two basic periods that can be noticed are:

Period	Term	RCC volume placed
Initial	II/96 to V/96	111,200
Final	VI/96 to VI/98	834,400
Global	II/96 to VI/98	945,600

During the initial period, the different teams were adjusted and operational difficulties evaluated and overcome.

During the final period, much longer and responsible for a bigger RCC volume, procedures and actions resulted in the improvement of results and control.

These adjustments and implementations occurred in three different basic groups as described further on.

2- TESTS FOR RCC QUALITY CONTROL

1 -COPEL- Companhia Paranaense de Energia- Rua Coronel Dulcídio 800- 80420-170- Curitiba-PR.-Brazil- Tel: 55-41-322 1212

2 - AiE-Andriolo Ito Engenharia SC Ltda-São Paulo-SP-Brazil-Tel: 55-11-260 5613; Fax: 55-11-260 7069- e:mail fandrio@ibm.net; site:www.andriolo.com.br

"OSPs"- Operational Standard Procedures - were established for innumerous tests in order to discipline, guide and organize actions and routines.

The following tests were considered:

- VeBe Consistency (without Weight);
- RCC Moisture - Hotplate Drying Test;
- RCC Moisture - "WMD" (DMA in Portuguese);
- Density through compaction on VeBe apparatus;
- Grain Curve and Modulus of Fineness of RCC mix;
- Cement content of RCC by the neutralization heat method;
- Grain Size Curve, Modulus of Fineness, Powdered Material, Absorption, and Aggregate Density at individual ranges;
- Density Tests on specimens of hardened RCC;
- Density, moisture and compaction ratio of RCC at the placement front, by use of a Nuclear Densimeter;
- CVC (conventional) concrete temperature (Pre-cooled) at upstream face
- Simple axial compressive strength test and diametral compression tensile strength tests on cylinder specimens;
- Characteristics of the specimens from cores drilled from the dam - Density, Compressive Strength, Absortion, Modulus of Elasticity, Direct Tensile Strengtth and Indirect Tensile by Diametral Compression (Brazilian Test).

3- PROCEDURES RELATED AND HELPFUL TO CONTROL

"OSPs"- Operational Standard Procedures, were also established for complementary and auxiliary routines, considering:

- Calibration of batching and mixing (tilting for CVC and Continuous for RCC) plants and control of anomalies that cause variations;
- Content correction of RCC components, by controlling the moisture content of aggregates;
- Control of cement content and lost in calibration of the plant that causes variation;
- Control of water content and irregularities that cause variation;
- Control of segregation blocking elements;
- Control of the software and hardware operating at the batching and mixing plants;
- Control of roller speed and number of passes;
- Control of compaction transmission to lower lifts;
- Control of water loss of RCC mix between production and compaction;
- Statistical control of RCC cylinder test results regarding resistance, evolution with age, and coefficient of variation;
- Statistical control of test results regarding fresh concrete uniformity control;
- Statistical control of test results at placement front with a nuclear densimeter;
- Control of mortar application on joint construction surface;
- Control of interval between mixing (at Concrete Plant) and compaction;
- Control of lift height
- Control of construction joint surface treatment;
- Checking of RCC mass temperature, through installed thermometers;
- Checking of sliding of contraction joints through installed extensometers in RCC;
- Checking of water pressures at RCC mass through installed piezometers in RCC.

4- ACTIONS ON EQUIPMENTS AND MATERIALS- ADAPTATIONS

"OSPs"- Operational Standard Procedures were established for actions and equipment, considering:

- Discharge chute adaptation to avoid segregation at the exit of mixers;
- Use of reverse direction conveyor belts in order to avoid segregation;
- Control of powdered material grading and crushed sand absorption by observing proportioning between different basalt types;
- Use and calibration of different types of "WMD" apparatus;
- Use of tractor with agricultural fogging sprinklers for the RCC dam cure;
- Compaction control focused on uniformity of lift base;
- Use of crushed sand with 18% of powdered material, for the RCC, as well as the CVC for upstream face.

Figure 01- Discharge nozzle adaptation to minimize segregation at the exit of mixers

Figure 02- Tractor with agricultural sprinkler, adapted for cure.

5- DATA ON MATERIAL CONTROL

The following statistical parameters on material control were established based on procedures adopted:

Period/ Evaluation	Initial	Final	Global
Granulometry- Modulus of Fineness Coefficient of Variation	Sand = 6.6% Gravel 25= 3.4% Gravel 50= 2.7%	Sand = 5.1% Gravel 25= 2.5% Gravel 50= 0.9%	Sand = 5.6% Gravel 25= 3.2% Gravel 50= 1.7%
Absorption Coefficient of Variation	Sand = 28.9%	Sand = 23.1% Gravel 25= 27.3% Gravel 50= 36.5%	Sand = 27.3% Gravel 25= 27.3% Gravel 50= 36.5%
Fines Content (< 0.075mmm) Coefficient of Variation	Sand = 13.7% Gravel 25=45.3% Gravel 50=53.3%	Sand = 7.4% Gravel 25= 28.1% Gravel 50= 33.5%	Sand = 9.5% Gravel 25= 37.5% Gravel 50= 48.2%
Aggregate Density Coefficient of Variation	Sand = 1.5%	Sand = 1.1% Gravel 25= 2.5% Gravel 50= 1.9%	Sand = 1.4% Gravel 25= 2.5% Gravel 50= 1.9%

Figure 03- Statistical data on materials control

6- DATA ON FRESH RCC MIX CONTROL

Tests on fresh mixes show the following parameters:

Period/ Evaluation	Initial	Final	Global
Consistency- Coefficient of variation (%)	13	21.1	20.3
Cement content- Coefficient of Variation (%)	12.4	4.8	5.8
RCC Humidity at Plant- Coefficient of variation (%) Hot-plate	9.2	5.4	5.9
RCC Humidity at Plant- Coefficient of Variation (%) WMD	N/A	1.9	1.9
Density at VeBe apparatusVariation Coefficient	3.5	2.1	2.3
Field Density Variation Coefficient	2.13	1.53	1.68

Figure 04- Statistical data on Fresh mix RCC

Period / Evaluation	Initial	Final	Global
Drilled Cores Density- Coefficient of Variation (%)	189	1.77	1.78

Figure 05- Density data on RCC drilled cores test specimens

Factors that contribute to the reduction of RCC resistance variation coefficient are a decrease in cement content variation and water content during production.

The cement content variation was reduced mainly by controlling calibration of cement scales, not only by performing tests on the cement content, but also by implementing a routine of anomaly-reducing actions. Examples are : *cleaning of belt conveyors and scales whenever there is material accumulation, at least three times every period; monitoring and regulating the support rollers*; monitoring and regulating the belt return cleaner; regular scales alignment (without interrupting the production) and corrective action and production interruption whenever a higher cement grading variation is detected by the cement grading test (Australian method).

Water content variation was reduced essentially by a rigorous control of the moisture of the aggregates (sand, gravel 25 and gravel 50mm). An average of one test (Hot-plate) every 15 to 20 minutes was performed (by a full-time collaborator) and corrective action or even production stop occurred whenever water grading, obtained by WMD testing, exceeded the variation limit desired.

By controlling water content and aggregates, a reduction in the consistency variation was expected and can be observed along the final period. The study however, was spoiled by the fact that together with control actions VeBe was implemented without weight instead of with weight, attempting to improve method accuracy. The greater subjectivity of the VeBe method with weight (smaller variation amplitude) indicates that the value obtained is closer related to the subjectivity of the observer, reducing its significance.

The reduction of the density variation of the RCC compacted at the VeBe apparatus, is also a product of the reduction of the variation of aggregates and water content.

By comparing results from tests performed at the plant and in field and from experience gained during testing and production control, it is possible to notice:

- ❖ VeBe consistency tests performed during production, though very useful and efficient in determining the consistency, do not allow for adequate so that rapid measures can be taken in relation to individual water content control. Specially if the aim is to reduce the compressive strtength variation coefficient to levels similar to those of CVC;

- The same may be determined for the hotplate test where the variation if the test itself does not allow greater precision.

The WMD method presents adequate precision considering that one result is enough for detecting variations and taking actions.

By comparing water content results from hotplate test to those resulting from the WMD method, the first evidently varies less in the same period.

It is important, though to keep performing both Hotplate and VeBe tests, as complementary tests for water content control. Since the WMD test is based on calibration, if poorly calibrated, it may alter results, but this error can be easily detected by comparing the three results. In fact, when analyzing a greater number of results, all three methods to a same result; the first two, vary a bit more, though.

The same is valid for the density test on the VeBe apparatus. This test presents a greater variation than results from densimeter tests in field, which is not truthful since the same material is being tested, and VeBe density does not suffer during placement and compaction with environment temperature or exposition time, etc...

A reduction in density variation measured in field by the nuclear densimeter was caused mainly by a greater lift homogeneity and RCC workability control at the concrete plant. The improvement of the lift homogeneity was caused by the change in the concept of control.

During the initial period, control wanted a 97% average compaction ratio. During the second period, on the other hand, the aim was to achieve a 97% compaction at the lower sublayer. This became possible and the average compaction ratio throughout the lift 98,5%.

Reduction of the workability variation at the concrete mixing plant was caused by factors already described with emphasis on the water content variation control at the plant.

7- CONTROL OF HARDENED RCC TESTS DATA

The same way, tests on molded RCC specimens have revealed the following parameters:

Period/ Evaluation	Initial	Final	Global
Density determined on cylinders- Coefficient of Variation (%	N/a	1.15	1.15
Compressive Strength at 7 days- Coefficient of Variation (%)	25.4	19.3	20.0
Compressive Strength at 28 days- Coefficient of Variation (%)	27.2	17.4	18.6
Compressive Strength at 90 days- Coefficient of Variation (%)	18.8	16.0	16.3
Compressive Strength at 180 days- Coefficient of Variation (%)	21.1	14.5	15.3
Compressive Strength at 360 days- Coefficient of Variation (%)	23.3	13.7	14.8

Figure 06- Statistical data on tests performed on hardened RCC cylinders specimens

Compressive strength variation was reduced on account of control actions implemented before, as already described. The average variation obtained still relates to the transition period and contains an added variation generated by resistance variation in all ages with environment temperature

Evaluation	Initial	Final	Global
Compressive Strength at 480 days-Coefficient of Variation (%)	31.0	21.6	22.7

Figure 07- Statistical data on tests performed on drilled cores specimens

Figure 08 shows that at times, the monthly variation coefficient was below 10%. The most common values are between 11 and 13%.

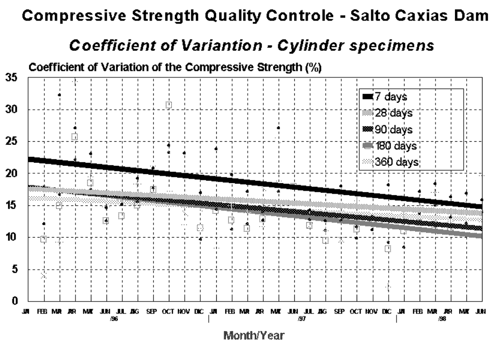

Figure 08a- Monthly evolution of the Coefficient of Variation at different control ages

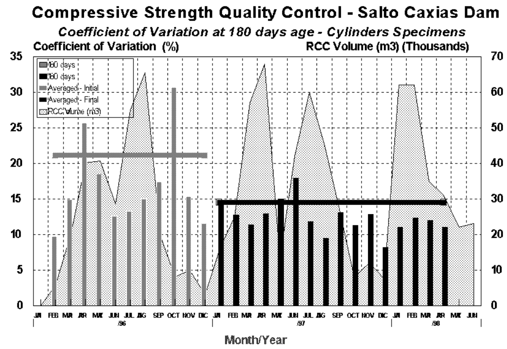

Figure 08b- Compressive strength- Coefficient of VariatioResistance (accumulated) at 180 days age for the two periods - initial and final.

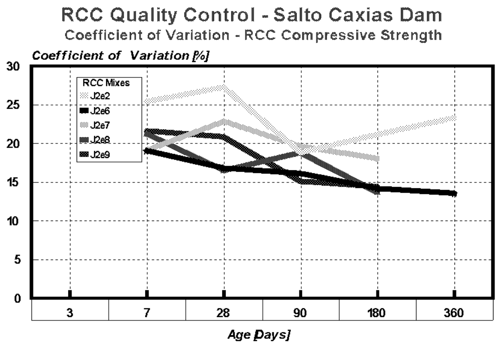

Figure 09a- Reduction of Coefficient of Variation for mixes used in many periods

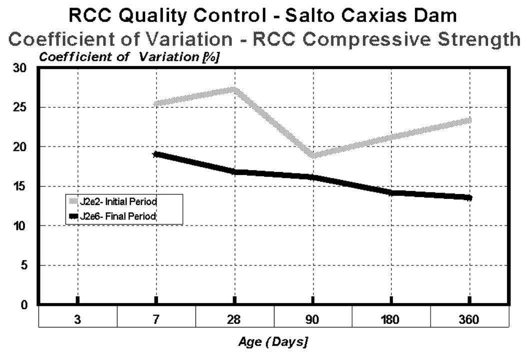

Figure 09b- Coefficient variation characteristics for most common mixes in each period

These values are very similar to those found for the CVC upstream faces, with a coefficient of variation at control age, pondered for all controled mixes, after control actions has been taken was reduced to 11.9% for tests performed till then.

8- DATA ANALYSIS OF CONTROL IN COMPARISON WITH OTHER JOBS

Control performed at Salto Caxias dam can be evaluated by comparing it to other RCC jobs [1 e 2], considering global variation coefficient parameters that appear in Figure 10 as well as the resistance evolution (percentage of the 28 days age darta) comparison showed in Figure 11.

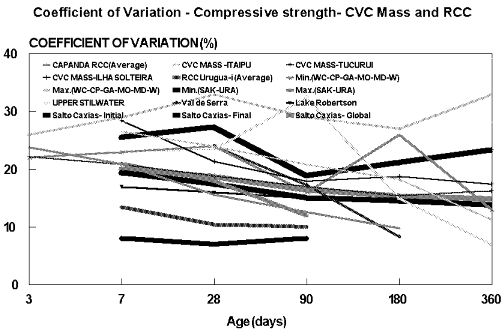

Figure 10-Compressive Strength Coefficients of Variation – comparison of many RCC jobs, and three great CVC Mass dams

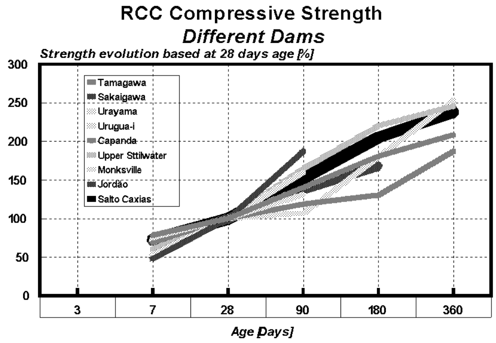

Figure 11- Compressive Strength Evolution – comparison of many RCC jobs

10- REFERENCES

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