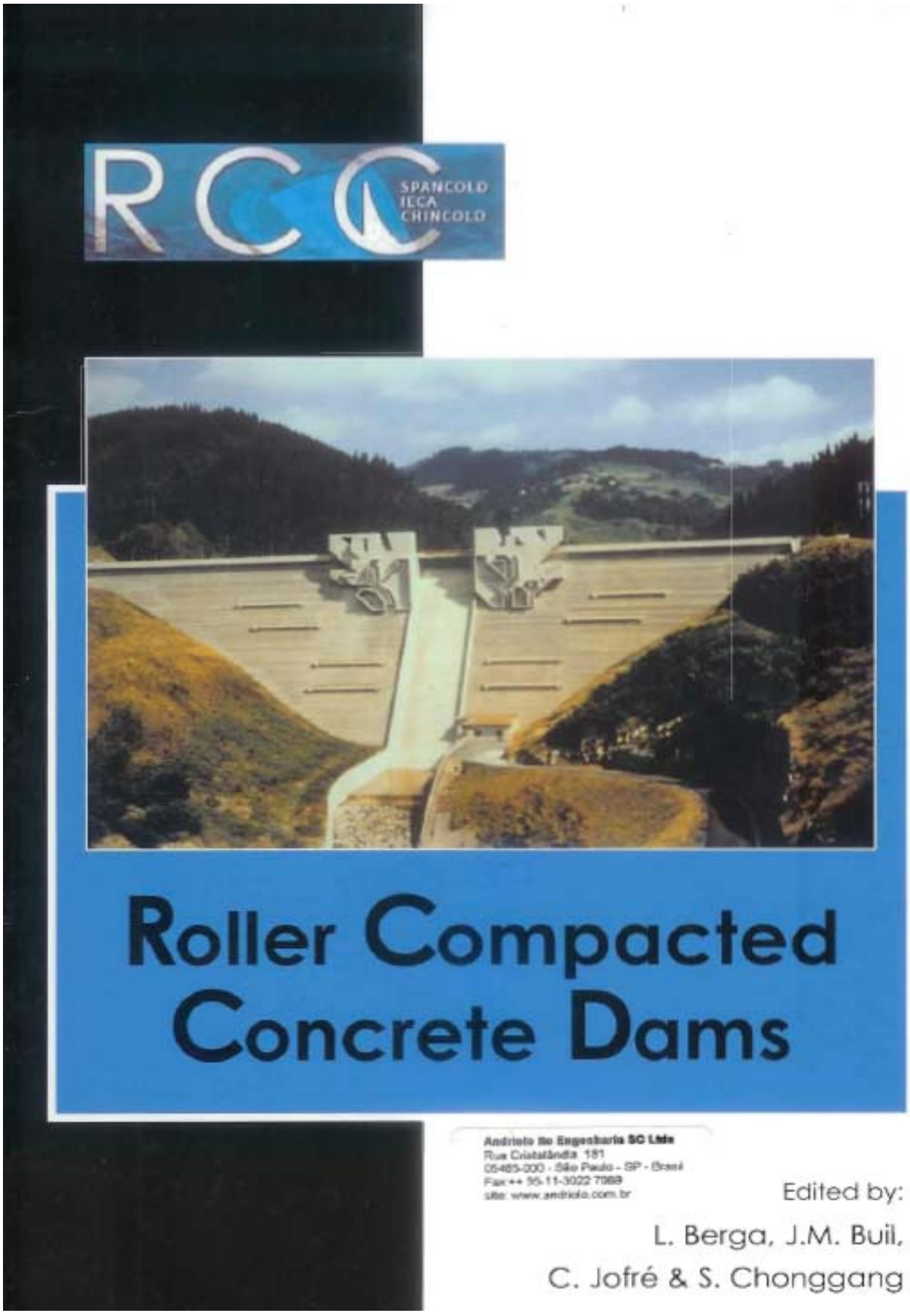

Additives in RCC – Research and a Real Case

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ABSTRACT: The use of additives in RCC is a relatively new approach. In the Brazilian RCC dams the researches and uses started around 1996. Several tests were made in the period of 1996-1999 including the test in laboratory and field at Salto Caxias Dam(Moser et al.1999), and the test in laboratory and field at Dona Francisca Dam, around 1999-2001. This approach was adopted during the construction of Dona Francisca RCC Dam, as the first real case were the plasticizer-retarder admixtures were used in the RCC in a large scale and a continuous production. This paper discusses the economical benefits and quality and uniformity improvements obtained.

1 INTRODUCTION

The development of research using water reducer and/or setting retarder admixtures in Roller Compacted Concrete (RCC) in Brazil began in 1996 in the construction of Salto Caxias Dam. Several conclusions were attained from the tests in laboratory and in the test section experiments(Moser et al. 1999). After that, new research was developed for Dona Francisca RCC Dam. The positive results achieved in these laboratory tests confirmed the advantages obtained in the researches done at Salto Caxias Dam. For this reason, for the first time in Brazil, an RCC with admixtures was proportioned in a Dam Structures. The use started up without cement reduction and after the 90-day-age results the expected ratio in cement reduction, in comparison with the laboratory test, actually took place and the cementitious content was reduced. In this paper is demonstrated the result of the use of more than 260 samples representing 250.000m3 of RCC with admixtures, produced in a continuous mixer plant.

2 DATA COMPARISON OF DONA FRANCISCA AND SALTO CAXIAS RCC DAMS

2.1 *Mix Proportion – Salto Caxias Tests*

The RCC mixes used in the additives studies at Salto Caxias are quoted in Figure 01.

Mix Proportion Salto Caxias		Cement	Water	Art. Sand	Coarse 25 mm	Coarse 50 mm	Retard Plast.	Cannon Time
		Kg/m³	Kg/m³	Kg/m³	Kg/m³	Kg/m³	Kg/m³	s
With Admixture	T6	90	133	1160	757	505	1,12	30 ± 5
	T7	90	143	1146	748	499	1,12	25 ± 5
Without Admixture	J.2.e.6	100	143	1142	745	497	-	30 ± 5
	T5	100	153	1127	736	491	-	25 ± 5

Figure 1- Mix proportion RCC Salto Caxias

2.2 *Mix Proportion – Dona Francisca Dam*

The RCC mixes used in the additives studies at Dona Francisca are quoted in Figure 02.

Mix Proportion Dona Francisca		Cement	Water	Art. Sand	Coarse 25 mm	Coarse 50 mm	Retard Plast.	Cannon Time
		Kg/m³	Kg/m³	Kg/m³	Kg/m³	Kg/m³	Kg/m³	s
With Admixture	B.2.25.7	85	140	1123	678	553	1,02	25 ± 5
	B.2.30.8	85	135	1108	693	567	1,02	30 ± 5
	B.2.25.6	90	140	1085	695	569	1,08	25 ± 5
	B.2.30.7	90	135	1094	698	571	1,08	30 ± 5
	B.2.30.5	100	136	1083	697	570	1,20	30 ± 5
Without Admixture	B.2.25.4	90	148	1070	691	565	-	25 ± 5
	B.2.25.2	95	149	1066	751	501	-	25 ± 5
	B.2.25.3	95	149	1066	688	563	-	25 ± 5
	B.2.30.3	95	144	1073	693	567	-	30 ± 5
	B.2.30.1	100	145	1069	690	565	-	30 ± 5

Figure 2- Mix proportion RCC Dona Francisca

2.2 *VeBe Consistency and Workability Time*

The reduction of VeBe time obtained with the use of admixtures at Dona Francisca was the same as at Salto Caxias Dam tests(Moser et al. 1999) . There was a reduction of VeBe time (consistency) in up to 40% at the same water content level or a water content reduction of circa 10kg/m3, for the same VeBe time level.

Three different brands of admixtures were tested and they kept the same performance as at Salto Caxias. It may be induced from it that in the case of Dona Francisca the admixtures raw material variations (from different suppliers) did not affect the relation with the water/VeBe reduction.

The Effect in Workability using admixtures in the RCC of Dona Francisca Dam are quoted in Figure 03.

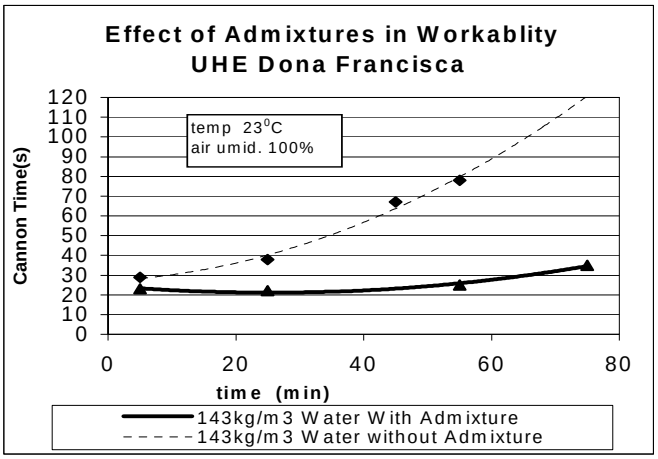

Figure 3- Effect of Admixtures in the workability of RCC

2.3 *Density*

At both projects, Salto Caxias and Dona Francisca, were used aggregates (Coarse and Fine), crushed from basaltic rocks. The density of basalt of Dona Francisca was around 2.85t/m3 and Salto Caxia 2,90t/m3.

RCC density was measured by using different methodologies such as:

- Theoretical: by summing-up the masses considered in the dosing;
- DMA: this test is to obtain the water volume displaced when a concrete sample, with known weight, is placed in a cylindrical vessel provided with a siphon. The vessel has a known water volume. The displaced water volume is the same as the concrete volume. Thus, the concrete unit weight can be calculated.
- VeBe: by means of the mass and volume of RCC used in the VeBe Consistency test;
- Densiometer: by measuring with Nuclear Densimeter, during compaction at the placement front;
- Test cores: by measuring volume and mass of the test samples obtained from the test cores extracted from the structure.

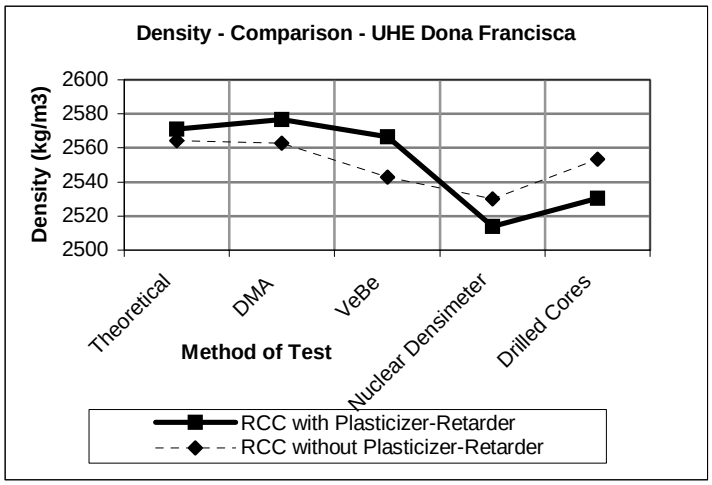

Figure 4- Comparison of Density Different Method of Test

2.4 *Compaction Ratio*

The degree of compaction is used as control limit. Taking into account that the theoretical density was altered due to modification of the water content consequential to additive use, the basis of comparison was modified, which implicates in the variation of the density but not of the degree of compaction.

2.5 *Layer Uniformity*

The admixture effect allows for preserving compaction transmission by preserving VeBe time at the moment of compaction, even under adverse situations during structure execution, as high local temperatures or difficulties in placement (areas of difficult access). Thus, a greater homogeneity is obtained in the structure which can be subject to varying weather and operational conditions whose effects can be inhibited by adjustments in the admixture content used, with no harm to other parameters such as strength etc.

2.6 *Compressive Strenght*

To highlight the comparison of the additive performance as to compressive strength, the data of compressive tests were transformed into “Mix Efficiency” which is the quotient of resistance by cementitious consumption (MPa/ (kg/m3)). Figures 05 and 06 highlight these comparisons and the efficiency of the additive in the RCC.

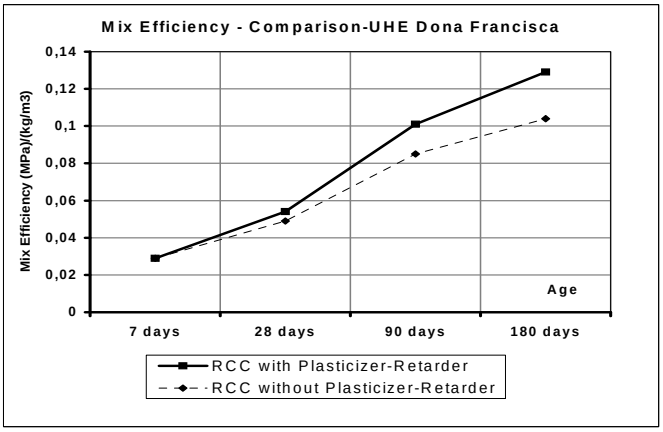

Figure 5- Effect of Admixtures in Mix Efficiency of RCC Dona Francisca

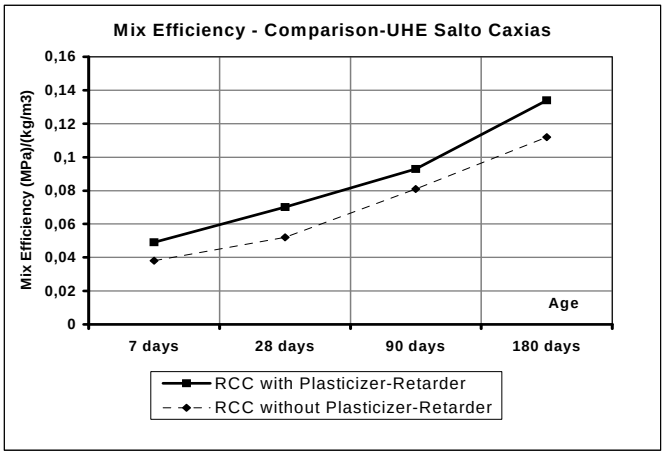

Figure 6- Effect of Admixtures in Mix Efficiency of RCC Salto Caxias

As showed in the figure 5 and 6, in both cases the Mix Efficient was significatively improved by use of admixtures. For the RCC of Dona Francisca this improvement was more notable after the age of 90days. These effect may be explained for the difference of the Fly ash content in the Pozolanic Cement used. The Pozolanic Cement of Salto Caxias had circa 20-25% fly ash and the used in Dona Francisca had 33-38% of fly ash.

Otherweise in the comparison of the data it can be observed that the RCC with plasticizer-retarder admixtures, have at 90-day age for Dona Francisca, practically the same strength values as the RCC without admixtures, at 180-day age. These performance at the old ages for the mixes with admixtures in comparison with without admixtures are greater in Dona Francisca than the Salto Caxias.

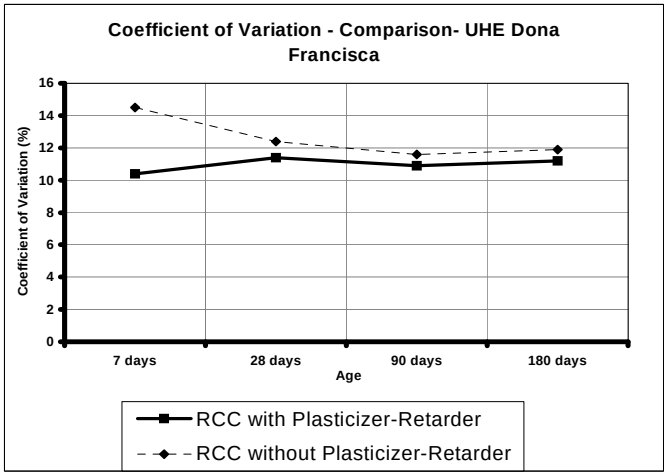

Figure 7- Effect of Admixtures in Mix Efficiency of RCC Dona Francisca

The uniformity during the control is also improved, as can be seen in Figure 07, due to the use of the plasticizer-retarder admixture.

2.7 *Reduction Of Cementitious Content*

To be also noticed that evidences showed that the RCC with additives present about 20% more resistance than the RCC without additives, which means a potential binder consumption reduction of equivalent magnitude, in order that the same level of resistance be kept.

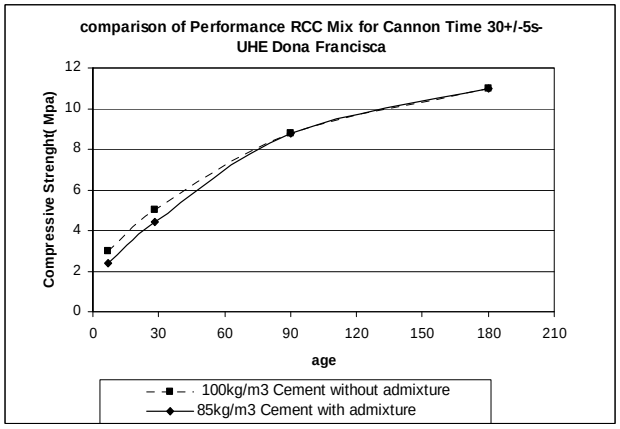

Figure 8- Reduction of Cement for the same compressive Strenght and Cannon Time using admixture

2.8 *Heat of Hydratation Reduction*

The possible reduction of binder content for the same level of resistance consequential to the use of plasticiser-retarder additive enables the reduction of heat generated from hydration.

It wasn't measure the reduction of Hydratation Heat caused by the Set Retard effect of the Admixture, but it can be also expected (Herrera,2000)

2.9 *Operational Advantages*

The are many advantage obtained of using Admixture in RCC:

Use admixtures for reduction in VeBe time at the moment of compaction and consequent increase in easiness of compaction, the number of compaction roller passes can be reduced while preserving the compaction ratio and specified density.

With the same number of passes can also be obtained the reduction in water content using admixture, preserving the specified density, and noting the need to keep a minimum compaction ratio.

With the reduction in the number of passes and consequent increase in roller productivity it is possible to reduce the number of rollers for a given production, or increase production with a given number of rollers .

Due to the better compaction transmission generated by the reduction in VeBe time at the moment of compaction, another benefit that can be obtained with the use of the admixture is the increase in layer height. The increase in layer height generates a productivity increase and reduction of executing time.

There is also a greater flexibility to halt the effects of weather and operational characteristics. In the Use of admixture in RCC of Dona Francisca Real Case the Operational Advantages observed was more workability time for the same Cannon Time at the production, reduction of Water and Cement content and reduction of the Hydratation Heat, keeping the compaction ratio in the specified limits.

The uniformity of the RCC was also improved, the Coefficient of Deviation was reduced with the Use of admixtures and the visual aspects of the cores shown uniformity for all the Climate Seasons.

2.10 *Cost Saving*

The economy obtained with the Use of admixtures in the RCC observed in the Real Case Dona Francisca(see also section 2.7), was around 15kg/m3 of cement and the cost of the admixture was equivalent to 5kg/m3, showing a cost reduction equivalent to 10kg/m3. Considering that in Brazil the cost of cement (delivered at the work) is of approximately US$100/t, this results, for a quantity of approximately 300,000m3, in an economy of around US$300,000

3- COMMENTS

The characteristics observed in the Real Case Dona Francisca in comparison with the Tests of Salto Caxias are the same in Water and Cement Content Reduction , Heat of Hydratation Reduction, workability increasing,Operational Advantages, Cost Saving. The only difference observed was a little reduction in the Average Compaction Ratio in comparison with the RCC Mixes with admixtures and Reducted Water and Cement Content, for the fields test, keeping in all cases the minimum required . The Salto Caxias Test made in the same Season for the both, showed the same Average Compaction Ratio.

Because the comparison was made in different situation of the Construction and the more part of the Mixes without admixtures was applied in the Season of lower temperatures and the more part of the mixes using admixtures was applied in the Season of greater temperature, is difficult the conclusion.

It was also comproved in the real case that the use of the admixture as an effective VeBe consistence control instrument at the moment of compaction adds a useful tool to RCC quality control, because it’s possible to keep the same workability in that moment, and a required Compaction Ratio independent of the weather conditions and the situations of difficult access of placement, increasing the uniformity, besides generating direct and indirect cost savings.

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