CSHEE

CIGB ICOLD

PROCEEDINGS

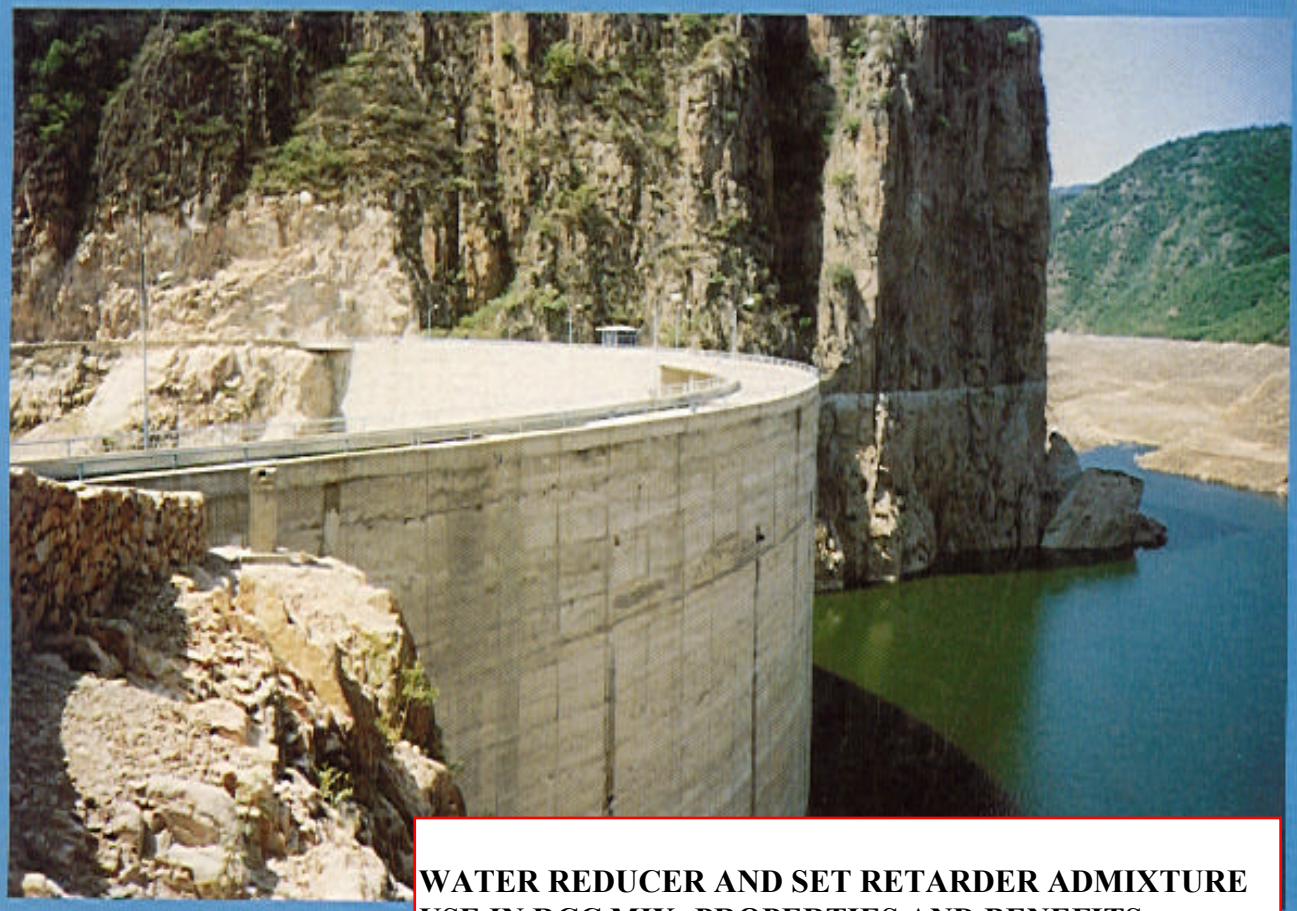
International Symposium on Roller Compacted Concrete Dam

April 21～25 1999

Chengdu, Sichuan Prov.

CHINA

Volume I



WATER REDUCER AND SET RETARDER ADMIXTURE USE IN RCC MIX- PROPERTIES AND BENEFITS

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WATER REDUCER AND SET RETARDER ADMIXTURE USE IN RCC MIX- PROPERTIES AND BENEFITS

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ABSTRACT

RCC must be vibrated and liquefied to obtain maximum density in compaction and, consequently, the watertightness and strength required by each project. In this process, a crucial factor is consistency control (VeBe time) at the moment of RCC compaction, and not only at its production.

This paper exposes the benefits of using water reducer (plasticizer) and set retarder admixtures in RCC. During the construction of the hydroelectric plant of Salto Caxias, in the state of Paraná- Brazil, laboratory experiments were done at the concrete plant and at the placement front in search of RCC quality and uniformity improvements. Reports are presented on VeBe consistency (time), density, compaction ratio, homogeneity, compressive strength, and cost comparisons based on statistical data. The main direct and indirect benefits are identified and discussed.

1- INTRODUCTION

The use of water reducer and/or setting retarder admixtures in roller compacted concrete (RCC) seemed unimportant until the mid 90s. With a better understanding of the concepts of consistence-workability, fresh mix cohesiveness, and of set, of the interrelation between these concepts and of the compaction transmission in the RCC layers, and specially with the need for more operational time in the compaction and transportation of the concrete, the convenience of employing multifunctional admixtures grew.

Since then, various jobs [1 through 5] in several countries have adopted this technique, being the use of water reducer and air entraining admixtures very common in Japan.

2- THE STUDY OF RCC WITH A PLASTICIZER RETARDER ADMIXTURE IN THE SALTO CAXIAS DAM

During the construction of the Salto Caxias Hydroelectric Power Plant (built by COPEL, Paraná State - Energy Company), studies were done focussed on reaching a greater homogeneity of the RCC layer. The aim was to evaluate the effects of the plasticizer retarder admixture on the consistency, consistency endurance, strength and uniformity of the RCC.

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Two types of study were done, laboratory experiments in February of 1997, and test section experiments (on the body of the dam, right margin) in May and June of the same year.

Evidence was found of benefits brought to RCC by the use of the plasticizer retarder admixture.

2.1- VeBe Consistency and Workability Time

VeBe consistency was determined with no additional weight over the mix. A transparent container was used to aid visualization of the effects of the admixture and of vibration (VeBe), as in Figu re 01.

Figure 01- Acrylic Container for VeBe Consistency Experiment.

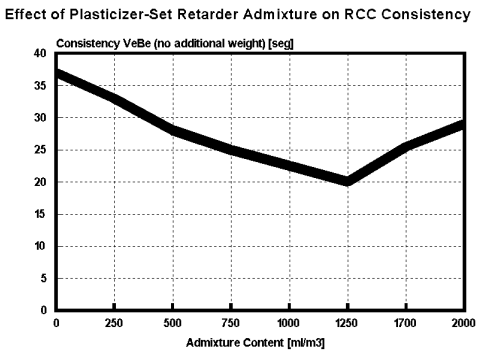

Figure 02- The Effect of the Admixture on Consistency

The experiment suggests that the admixture increases workability such as to allow a reduction of VeBe time (consistency) in up to 40%, (with no weight over the mix sample in the container) at the moment of production (at the Concrete plant), as shown by Figure 02. For the case studied, the optimal admixture content was observed to be around 1.25% of the cement weight.

The time VeBe reduction, for the optimal content, was verified in the test section, as illustrated by Figure 03. Even with a 10kg/m3 water reduction, and subsequent cement reduction (fixing the W/C ratio), the ***"T6"*** mix kept its consistency with the addition of the admixture, in addition to some reduction in the VeBe time when compared to the standard mix ***"J2e6".***

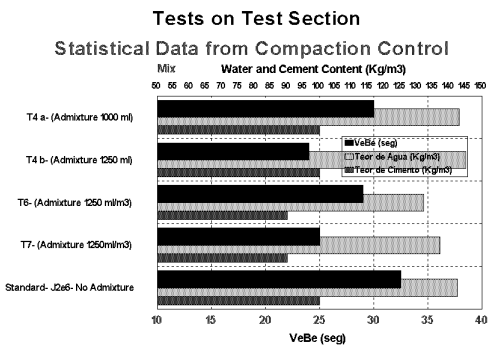

Figure 03- VeBe Consistency (Time) comparison of the mixes used in the Test Section.

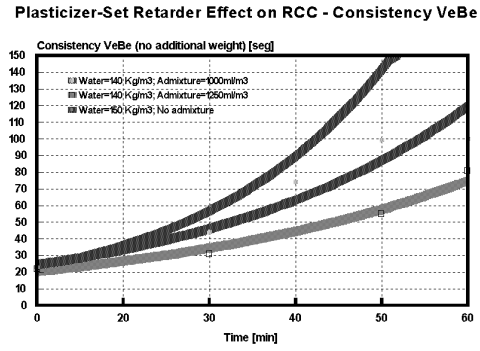

Figure 04- Increase in Workability Time (Consistency) for mixes of same initial VeBe.

In the case of the ***"T4(a and b)"*** mixes, that keeps all characteristics of the standard mix, only adding the admixture, consistency (VeBe time) was reduced, being this reduction proportional to the admixture grading used, 1.0-l/m3 or 1.25-l/m3. The same can be said about ***"T7"*** mix, where the same water content as in the standard mix was maintained, the cement content was reduced by 10kg/m3, admixture was added, and the reduction in VeBe time was noticeable.

The lab experiments also show that the admixture keeps workability the longest (Figure 04). In the studied case, a reduction of 60% in the VeBe time can be observed 40 minutes after the initial mixture, when compared with the mix without admixture and of same initial VeBe. This reduction is greater for longer intervals.

This effect can be visually observed at field tests that, comparing mixes of same VeBe during production at batching plant, reveal a higher plasticity of those mixes with admixture at the moment of compaction. In some cases it was necessary to wait before initiating compaction due to roller sinking.

Analyzing both effects of the plasticizer-retarder admixture, reduction of VeBe time in production and reduction of VeBe time loss between production and compaction, it is possible to conclude that, for the weather conditions of the study and a 40 minute interval between mixture and compaction, up to an 80% VeBe time reduction (with no weight) may be obtained at the moment of compaction, relative to the no admixture situation. This value may even be larger depending on the weather conditions and the interval between placement and compaction.

2.2- Increase in The Compaction Ratio

The reduction of VeBe time at the moment of compaction, derived from the use of the admixture, provides RCC with a greater compaction transmission among its layers. Respected the limits of overcompaction, high values of compaction ratio (around 99%) can be obtained, both on top and on the bottom of layers, consequently raising their average compaction ratio.

This effect is linked with VeBe consistency once, the higher the VeBe value, that is, the "dryer" the RCC, the more difficult is the compaction-vibration transmission. The lower the VeBe value, the more "moist" is the RCC, and the easier is the vibration-compaction transmission. This is what Figure 05 shows in the lab experiments and Figures 06 and 07 in the job test section.

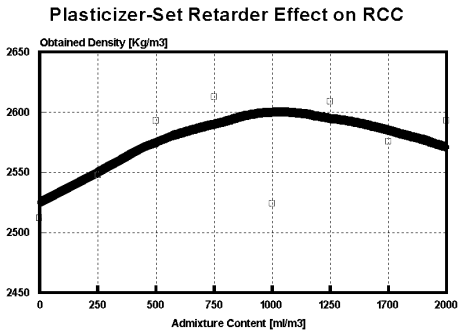

Figure 05- The effect of the Plasticizer Admixture on compaction ratios and Density

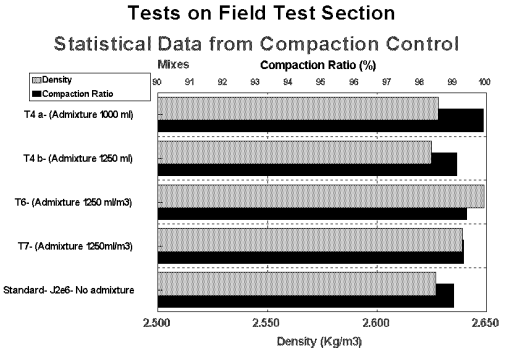

Figure 06- Comparison of compaction ratios of evaluated mixes at the Test Section

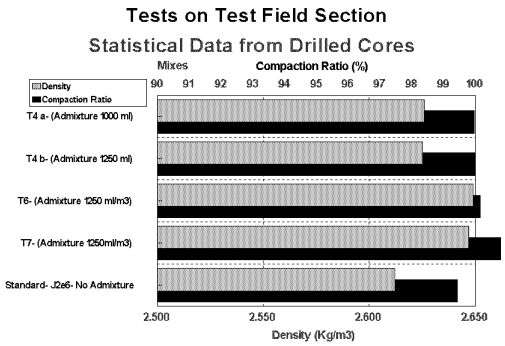

Figure 07 – Density data obtained from cores drilled at the Test Section.

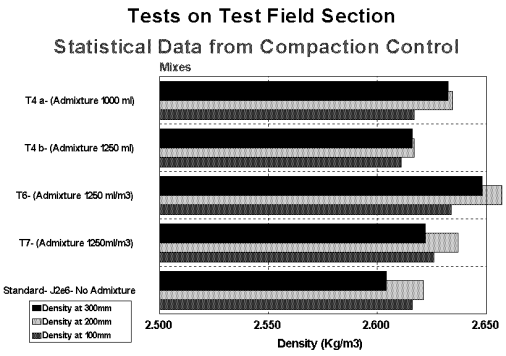

Figure 08- Homogeneity comparison of the evaluated Test Section mixes.

Both in the field experiments and in the drilled cores experiments of the test section, the average compaction ratio was higher than in the reference mix. Even the ***"T6"***mix, with same initial VeBe as the standard mix, presented a higher compaction ratio, proving the benefits of maintaining a smaller VeBe time at the moment of compaction.

2.3- Increase in Density

The use of the admixture, as seen in the previous items, allows reducing the water content, while preserving the VeBe. This water reduction raises the theoretical density of the mix. As preservation of VeBe consistency also preserves compaction ratio, the resulting effect is an increase in layer density proportional to the increase in theoretical density. This can be illustrated with the ***"T6"*** mix studied in the test section. The water content reduction, resulting from the admixture addition, while preserving consistency, was one of the causes of the greater layer density when compared with the standard mix (Figures 06 and 07).

Alternatively, layer density can also be increased by reducing VeBe time, with the use of the admixture, while preserving the water content. The compaction ratio then increases. When preserving water content, theoretical density is also preserved. The layer density then increases through an increase in the compaction ratio. This can be illustrated by mixes ***"T4"*** and ***"T7"***, and even ***"T6"*** (in addition to the water reduction effect) that showed an increase in layer density relative to the standard layer due to the reduction in VeBe time, both in RCC production and at the moment of placement, and consequent increase in compaction ratio and density (item 2.2; Figures 06 and 07).

3- LAYER HOMOGENEITY

With the improved vibration-compaction transmission to the lower zones in the layers of the RCC, brought by the reduction and preservation of VeBe at the moment of compaction, a greater RCC uniformity can be obtained, once similar and high values of compaction ratio are reached in all sublayers. This effect is noticeable in the test section experiments where all mixes using admixture presented a greater homogeneity than the standard mix (Figures 08 and 09).

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, that can be subject to varying weather and operational

conditions, the effects of which can be inhibited by adjustments in the admixture content used, with no harm to other parameters such as strength, etc.

4- INCREASE IN STRENGTH

With the reduction of the water content, caused by the use of the admixture, and preserving consistency, a reducing in the W/C factor is obtained, leading to an increase in resistance.

This is demonstrated by the improved "mix efficiency" (strength/cementitious content ratio) with the use of the admixture, meaning a reduction in cement even greater than the water reduction, preserving the W/C factor (Figure 13).

Lab studies showed possible an increase in resistance equivalent to a 10% rise in cement content with the addition of admixture in the amount of 1.25% of the cement weight. This observation results from the possibility of reducing about 8% of the water content (Figure 10), with a consequent equivalent reduction in the W/C factor, preserving the VeBe consistency.

Alternatively, it is also known that RCC resistance is closely linked to its compaction. An increase in the compaction ratio and of layer homogeneity can then create an increase in RCC strength.

Ultimately, even an increase in the dam body (item 3) homogeneity will contribute to an increase in resistance, due to the reduction of the Coefficient of Variation of the strength of the drilled core samples.

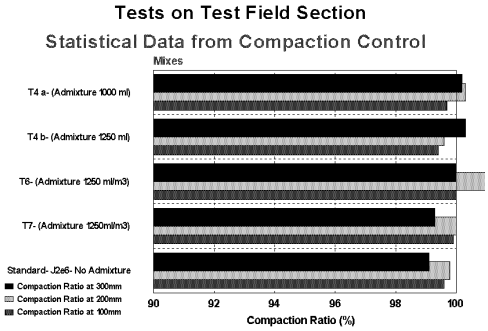

Figure 09- Homogeneity comparison of the tested mixes in the Test Section

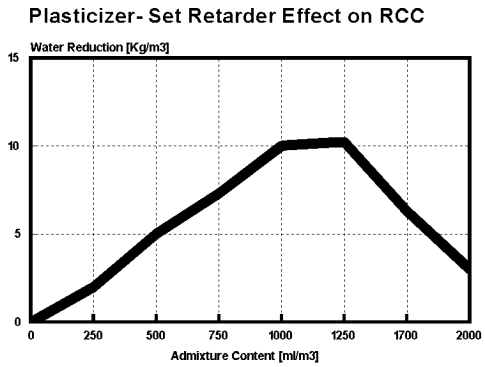

Figure 10- Water content variation due to the use of Admixture for the same Consistency level.

In the test section studies, the water reduction was verified, and the ***"T6"*** mix, with 10Kg/m3 less water (7% less than the standard mix), resulted in consistency slightly below that of the standard mix (Figure 03).

5- REDUCTION OF CEMENT CONTENT

The water reduction brought by the use of the admixture, in addition to the benefit of increases in the compaction ratio, layer homogeneity and RCC dam body homogeneity, allows for the reduction of the cement content, for each given required strength.

This could be demonstrated in the field tests. For the ***"T6"*** mix, a greater strength than that of the standard mix was obtained using 10Kg/m3 less of cement. Alternatively, admixture addition

and the consequent VeBe time reduction did not reduce the resistance of the ***"T4"*** mix relative to the standard mix (Figures 11 and 12), but rather increased its resistance and "mix efficiwency".

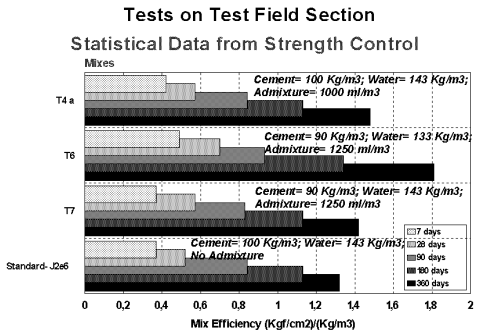

Figure 11- "Mix Efficiency" of Test Section mixes, evaluated through cast specimens.

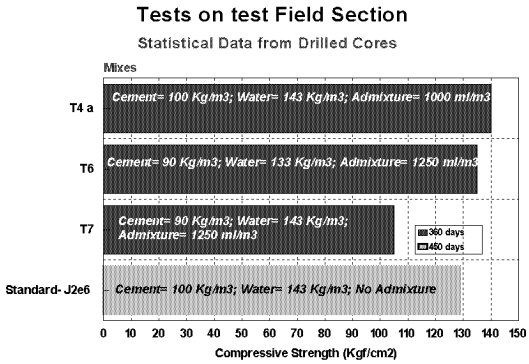

Figure 12 – Compressive Strength of Test Section mixes, evaluated through drilled core samples.

6- HEAT OF HYDRATION REDUCTION

With the reduction of the cement content, enabled by the water content reduction and increase in "mix efficiency", the RCC heat of hydration is reduced proportionally to the reduction in cement content. In the case studied, this reduction was equivalent to a 10% cement reduction.

7- OPERATIONAL ADVANTAGES

The authors believe, alert and recommend that operational modifications and optimizations not be done at the expense of uniformity and quality.

With the 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.

This reduction in the number of passes can also be obtained through the reduction in water content obtained with the use of the admixture, preserving the specified density, and noting the need to keep a minimum compaction ratio.

With the reduction of 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.

Because of 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. In the test section, layers of 40 cm were made using admixture (T4 mix with 1,25l/m3 of admixture). The placement was done in two layers of 20 cm and the compaction was then done of the 40 cm.

The data in Figures 06, 08 and 09 (T4 mix with 1.25l/m3) show that, even changing this parameter, the density, compaction ratio and layer homogeneity of a 300mm deep layer with admixture, were greater than those of a 300mm deep standard compacted mix.

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.

The control on the uniformity of RCC in the field is greatly simplified by the addition of the admixture, once the loss of workability with the start of set, whether because of acceleration of

set due to weather conditions, whether because of an increase in exposure time due to difficult placement circumstances, can be adjusted with the use of the plasticizer-retarder admixture, with no harm to strength and Coefficient of Variation, fact that would be impossible with the addition of water.

As an example, an increase in local temperature, accelerating the start of set, can be compensated by an increase in the plasticizer-retarder content as to keep the VeBe consistency unaltered at the moment of compaction. In face of a fall in temperature, the plasticizer-retarder content is reduced to preserve VeBe Consistency without affecting RCC strength, as the water content remains unaltered.

The same procedures can be followed in hard to reach areas where the time lag between mix and compaction is greater than normal. The admixture content should be raised to maintain the VeBe until the moment of compaction. When circumstances return to normal the admixture content may be reduced.

8- ADVANTAGES FOR DESIGN

With the increase in density of the RCC layer, and of the dam body, a greater density can be admitted in the design. Preserving safety coefficients, this allows for reducing dam sections while keeping total weight, thus reducing volume.

Alternatively, the uniformity thus obtained allows the project to modify impermeable barrier at upstream face, usually made of CVC, by using RCC with a modified proportioning.

9- COST SAVING

In the studies done, and based on the cost of construction materials used at the Salto Caxias Hydroelectric Plant, a cost reduction was observed, in addition to all the benefits obtained, when comparing the cost of plasticizer- retarder admixture use and that of adding water (and cement). For the ***"T6"*** mix, with a 10kg/m3 reduction in cement content, a saving of US$0,12/m3 was observed. If compared the strength of this mix with that of the standard mix, an even greater reduction in cement content could be done, possibly reaching 13kg/m3.

These numbers are based on the VeBe reduction at the moment of production. If the possible water reduction were included, preserving VeBe at the moment of compaction, an even greater saving would be obtained. In the case studied, the implied time lag between placement and compaction is greater than 20 minutes (Figure 04).

Other factors not included in this economic analysis are the expected rise in the drilled core strength, generated by the rise in compaction ratio and the layer homogeneity in the field; and the rise in the obtained minnimum strength of the core samples, in face of the expected reduction in the Coefficient of Variation of the drilled cores, generated by the greater homogeneity of both the layer and the dam body.

10- COMMENTS

The partial fluidizing and greater workability time of RCC obtained by use of the plasticizer-retarder admixture offers technical and economic advantages that can not be a priori and arbitrarily ignored, and should be evaluated in the mix-proportioning programs.

The use of the admixture as an effective VeBe consistence control instrument at the moment of compaction, adds to RCC quality control a useful tool, specially in regions of adverse weather conditions, at situations of difficult access of placement, or when a greater homogeneity guarantee is desired, besides generating direct and indirect cost savings.

Improvement of uniformity and other properties are valid parameters for the evolution of RCC dams towards maximization of the use of RCC and minimization of that of CVC.

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