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Ultrasonic Energy, an effective method to determine the setting times on RCC and the maximun time to obtain a hot joint. Miel-I dam (Colombia)

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ABSTRACT

A new methodology to identify the setting times on RCC based on the analysis of an ultrasound wave is introduced. The ultrasonic energy parameter allows to detect the progressive growth of hydrates inside RCC. Using the ultrasonic energy measurements the setting times on a plain RCC were studied and one that included a 1% of plasticizing-retarding admixture. The measurements were done under the different atmospheric conditions that exist in situ at dam Miel-I.
The study also establishes how in time the direct tensile strength decreases between a base layer (n) and a layer (n+1) as the material in the layer (n) begins its setting. It was determined that after the RCC on the base layer (n) reaches its initial setting, the direct tensile strength decreases between 50% and 60% to its initial value. A hot joint, meaning this that one where superficial treatments and mortars are not necessary to reach the adherence of design between layers, therefore it is possible to obtain it before the initial setting.

INTRODUCTION

RCC's characteristics and properties on the fresh stage as well as in the hardened one, have been studied in general, copying the procedures that were design for the conventional ones. This way the compressive strength, tension, elastic module, etc, estimation it is done on the same specimens used for conventional concrete, taking into account significant variations in the consolidation mode and the initial sieving of the material. The results of these procedures approximate in an acceptable way to values obtained from the nucleus extracted from the material of the dams. However the setting times on RCC, which become the most important properties on the fresh stage, can not successfully be evaluated using the conventional procedures for conventional concrete[1].
The difficulties of using a similar method of penetration resistance similar to the one described on the standard ASTM C403, are related with the necessity of evaluating a material which all the fractions above 4.76 mm have been eliminated. Also using the needle method over a non sieved material, leads to problems with coarse aggregates that on RCC become an essential fraction. Anyway the needle methods have been used[2] with

limited results to represent the setting that really occurs on the field, due to the lack of alternatives.

The importance of identifying the setting times on the RCC which has just been compacted and stills fresh, is based on assuring an adequate adherence between layers. The horizontal joints between layers, where the bond is required, becomes from the impermeability point of view, one of the most vulnerable parts of the dam. The correct identification of the setting times, for different atmospheric conditions, allows to establish the limits in time, for which a superficial treatment on the joint should or should not be done, or the use of mortars of bond, in order to guarantee the level of adherence of design between layers.

For the RCC that has been compacted in situ forming a layer (n), previous studies have identified the initial time of setting the limit[3] up to when is possible to extend and compact a new layer (n+1), obtaining an appropriate adherence in the joint, without any superficial treatment on the base layer (n).

This modality, where a treatment between the joint of two subsequent layers is not needed (n, n+1) it has been named as *hot joint*[4]. This system which is very economical in comparison to the alternative of surface preparation or use of mortar of bond, is the one who permits to reach high placing rates.

Therefore, while the base layer (n) has not set it is possible to get, an adequate adherence between layers directly placing the next layer (n+1) without investing time or money treating the joint or placing a mortar. However, if the recent methods do not provide representative results to determine the time of setting of the material, How can one correctly establish the instant up to when a hot joint can be done successfully?. How to identify the initial setting?. In order to answer to these matters, several methodologies[5,6,7,8] have been proposed but in general a consensus hasn't been reached.

This article introduces a new methodology that permits to identify the moment when the initial setting begins on RCC, using the ultrasonic energy parameter. It also describes the obtained results with this technology, on RCC in MIEL-I under different atmospheric conditions and using different doses of a plasticizing-retarding admixture. Also, the direct tension strength between layers and the time of setting are correlated and appear on the results. The obtained results allowed to optimize the placing times on the MIEL-I dam (Colombia) and to determine the limits to obtain a hot joint.

ULTRASONIC ENERGY

The use of sound for the study of concrete goes back to the thirties and the idea since its origin, consists of taking advantage of the close relation that exists between the velocity of sound and the composition of the material where the waves travel through. This way, measuring the velocity of a high frequency wave pulse through the material, it is possible to characterize the internal structure of it. The velocity parameter has been used to detect voids, cracks and to approximate to the elastic module and density of a hardened concrete. Furthermore, the measuring and calculation instruments of wave analysis which are currently in the market, have allowed to extract much more information from a wave than its transit time.

The ultrasonic energy concept becomes one of these new advantages and permits to detect the progressive growth of the solid phase (crystals) in a composite material. The energy parameter takes into account the amplitude, frequency and intensity variations of the wave[9,10] that goes through the material. The material on its fresh stage composed by a set of initial phases proportions, gaseous, liquid and solid changes these proportions when becomes rigid and sets. With an emitting transducer of 24 kHz, that makes a train of ultrasound waves go through the RCC on its fresh stage, then after going through the material (Fig.1) the signal is picked up by a receiving transducer. Then the mentioned signal is decomposed by an oscilloscope to calculate, based on this, an energy value. Therefore, a shot is made every minute, to pick up a signal and from it obtain an energy value. The energy values which represent the state of the solid phase inside the material, are plotted in time.

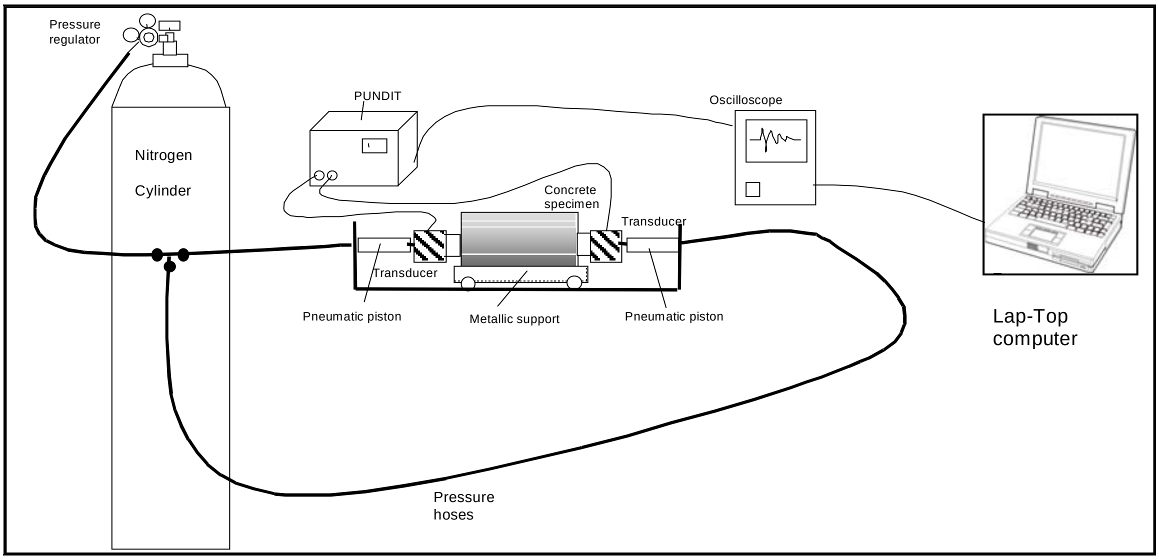

Fig.1-Ultrasonic energy device measuring over a RCC specimen

The ultrasonic energy values plotted in time, reflect the apparition of the crystalline net and put into evidence the moment of massive apparition of C-S-H hydrates that it is defined as the initial setting time. Figure 2 shows the evolution of the energy values on a 70 kg of cement per each cubical meter of RCC, used in the Zanja Honda dam (Colombia).

As we can see the curve that initially begins in a horizontal way, changes drastically when the material is near to reach the 5 hours showing the massive appearance of solids. This “taking off” of the curve that indicates that the material has become rigid, corresponds to the initial setting of the concrete[11,12].
On the other hand the final setting, corresponds to a concavity that appears a time later and that is determined tracing two tangents to it. However, for the recent investigation, the measurements were focused on the initial RCC time of setting and its relation with its capacity of adherence of this RCC set or not, with a new fresh concrete that it extends and compacts over the material.

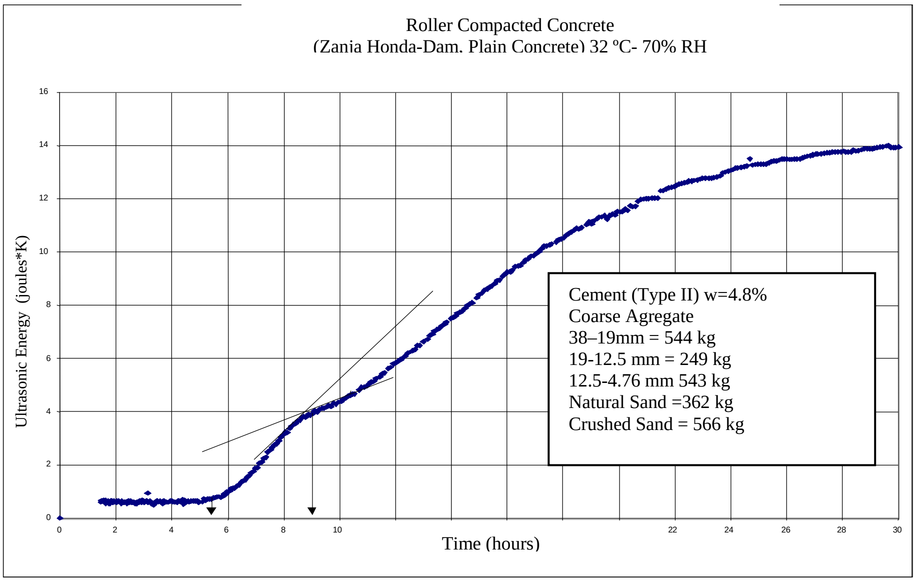

Fig. 2-Ultrasonic energy values evolution and RCC´s setting times- Zanja Honda dam (Colombia)

DETERMINATION OF THE TIMES OF SETTING ON THE RCC IN MIEL I DAM

On trying to determine the initial setting time or the limit up to when is possible to obtain a hot joint between layers, mixtures under controlled temperature conditions and relative humidity in the laboratory were done. The tested mixtures had the following designs:

Table 1 - Type of Mixtures

	Mixture # 1	Mixture # 2	Mixture # 3
Cement	150	150	150
Sand (Barmac)	997	1005	1005
Crushed Sand	787	793	793
Coarse Aggregate 63.5 mm	112	112	112
Coarse Aggregate 38.1 mm	312	314	314
Coarse Aggregate 9.5 mm	630	635	635
Humidity (%)	5.1	4.5	4.5
Admixture (Plastiment RCC-M)	0%	0.7%	1.0%

Indoor conditions at a controlled temperature and a constant humidity of (26±2°C, 85±5% HR), of different specimens were used in the fresh stage based on the designs, and as the ultrasonic wave went through, the different energy values were calculated for every minute, the results appear on the Figure 3.

As it appears on the Figure 3, the initial setting time of the RCC without admixture was registered after 6 hours of being mixed, for the RCC that included 0.7% of admixture, the initial time of setting went up to 11 hours and 20 minutes, and for the RCC that was mixed with 1.0% of admixture, the initial setting time took place after 19 hours and 50 minutes.

The admixture dose is defined based on the placing needs for the construction. These results obtained under controlled atmospheric conditions, demonstrate the admixture's performance. The dam constructor was interested in having a material or layer (n) that would kept fresh (without reaching its initial setting) for more than 15 hours, so in this time lapse the other layer could be placed (n +1) without any especial surface treatment (hot joint) obtaining sufficient adherence on the joints. This way the 1% admixture dose was chosen and outfield tests were done.

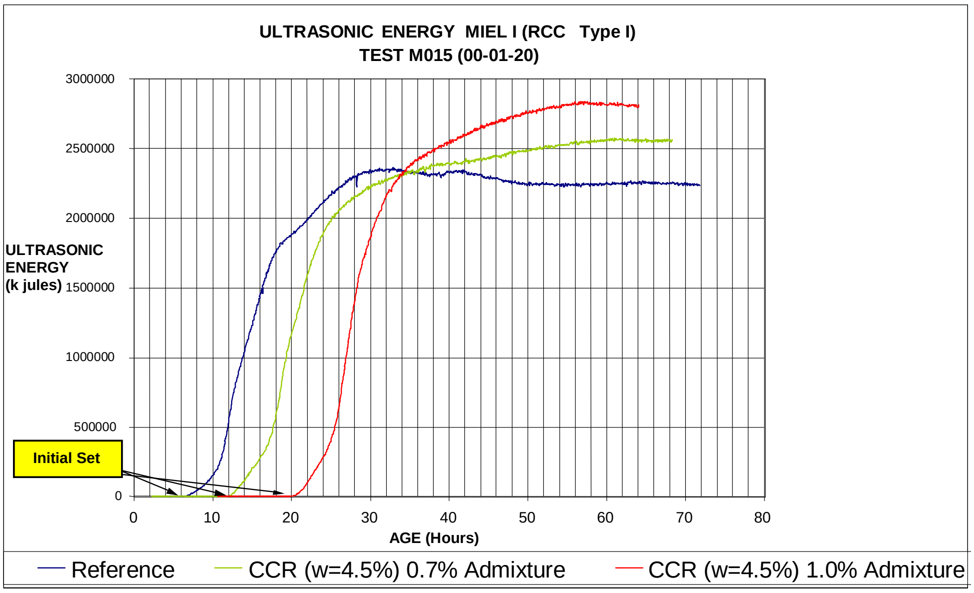

Fig.3-Ultrasonic energy values evolution and initial times of setting for different admixture doses under controlled temperature and relative humidity

Field tests (Variable Temperature and Relative humidity)

To approximate to the hydration or setting process on field, tests were done over specimens exposed to the temperature, under wind conditions, and the solar radiation found in situ.

The measurements were done over RCC specimens fabricated in the early morning, meaning this that they evolved under the lowest possible temperatures on field and over RCC specimens fabricated just hours before the highest temperatures (2:00 pm). During the set of tests done at different temperatures, the mixture 1 without admixture and the design 3 (Table 1) that had a 1% of plasticizing-retarding admixture especially design for RCC, were compared.

Under the most extreme conditions of temperature in situ (41±2°C) two different specimens correspondent to the designs were fabricated, design 1 or pattern and design 3 with a 1% admixture and with a least 10% less of humidity than the plain one.

In the Figure 4, appeared the two ultrasonic energy waves in time, correspondent to both designs under the most critical temperature conditions. As we can see for the material exposed to the atmospheric conditions, the plain concrete reached its initial setting time 3 hours after being mixed, while the concrete with a plasticizing-retarding admixture reached this state only at 12 hours, meaning this that the time of setting was quadruple.

In the Figure 4, it also appears overexposed the outdoor temperature.

In the same way series under the lowest ambient temperature were done, meaning this at night. This way in the Figure 5 appears the curve of the temperature outdoor, that in the early morning time goes down to 20°C.

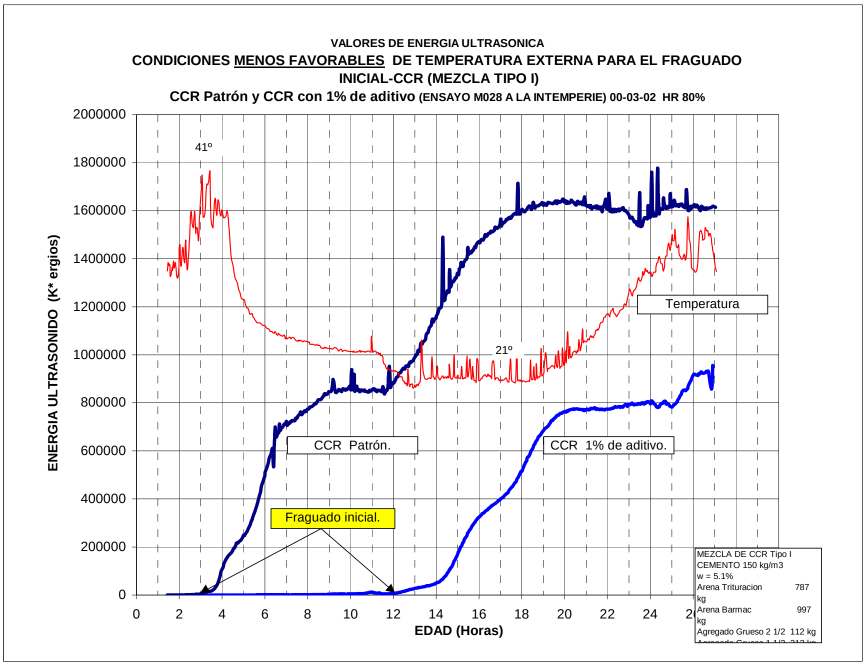

Fig. 4-Pattern RCC´s times of setting and RCC with 1% admixture under outdoor atmospheric conditions where the initial exposure of the compacted material matches with the highest temperature of the day.

The setting times of the designs (with and without admixture) for these conditions were of 4 hours for the plain RCC and 16 hours for the design that included the plasticizing-retarding admixture.

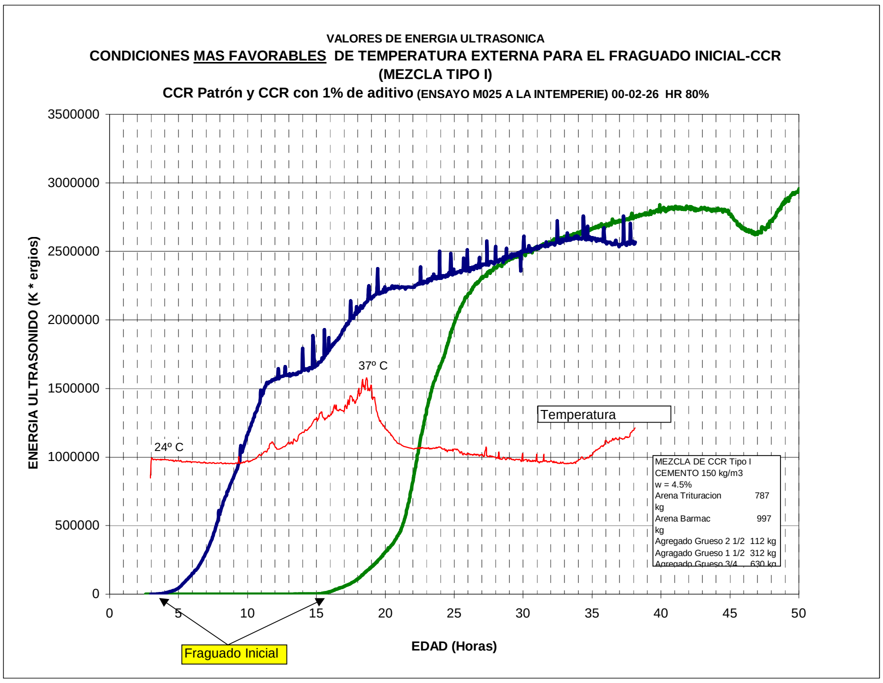

Fig. 5 Pattern RCC´s times of setting and RCC with 1% admixture under outdoor atmospheric conditions where the initial exposure of the compacted material matches with the lowest temperature of the day

According to the existing literature[13], these times would be the advisable one where a special treatment of the surface of the material should be implemented and use a mortar of bond to guarantee the adherence with the next layer. After the base layer (n) has had its initial setting, it will not be possible to obtain a hot joint, meaning this that after the material has reach the initial setting, the capacity of adherence with the fresh material of the next layer (n+1) decreases.

With the aim of determining the relation between the RCC's initial setting time (take off of the curve) and its capacity of adherence with a new material in the fresh stage, joints were built in laboratory and at the same time the evolution of the setting of the base layer (n) was measured.

RELATION BETWEEN THE INITIAL TIME OF SETTING AND THE CAPACITY OF ADHERENCE

In order to reproduce in lab the horizontal joints between layers, cylindrical molds (15*30 cm) whose borders end in trunk like sections to facilitate the latter measurement of direct tensile strength. The fabricated specimens appear in the Fig.6 and the photos1-3

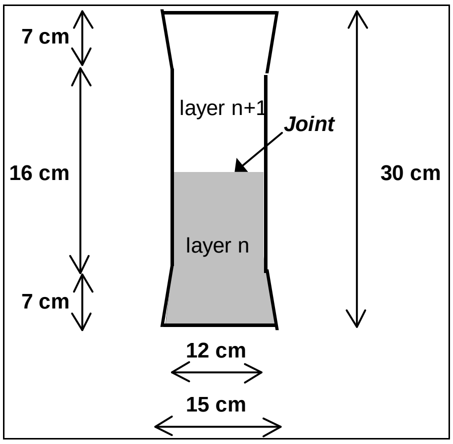

Fig.6


Photo 1


Photo 2


Photo 3

In its first phase the mold is filled up and the cylinder is compacted up to the half of the height, this way the base layer (n) is obtained, whose face is left exposed to the atmospheric conditions. The setting of this material that fills half of the mold and that it is the base layer (n) is measured with ultrasonic energy. This way for the different times of setting for the base layer (n) the cylinder is completed with fresh RCC (layer n+1) obtaining a joint in the half of the specimen (Fig. 6). These joints were fabricated for different ages of the layer (n); defining four instants for the RCC of the base layer (n) in which a new layer was compacted (n +1) on top of it forming a joint.

Type of Joint	Placement time layer n + 1
A	1 hour after RCC has been mixed
B	Before the initial setting
C	After the initial setting
D	After the final setting

Table 2 - Times when the joints were fabricated

Figure 7 shows the times when the joints were fabricated (placement of the layer n+1) for different times of setting of the base layer (n). The curves of ultrasonic energy that reflect the point of setting of each RCC, were obtained based on the model RCC and on the RCC with 1 % admixture and correspond to designs under different atmospheric conditions.

To the group of specimens that contained the joints, after 28 days, the direct tensile strength was measured (Photos 1, 2, 3). The way in which the base RCC layer (n) begins to lose its capacity to adhere a new layer (n+1) and the relation of the capacity of lost of bond in comparison to the initial setting appears in the Figure 8.

The curing of the specimens was done at a temperature of 23°C±2°C and with a relative humidity greater than 95%. The borders of the specimens were adapted and bonded to metallic sheets with an epoxy resin, 24 hours before the failed. The specimen device had a rotation system that helped to correct the alignment and avoid a momentum or concentration of strengths (Photos 1, 2, 3). It is important to take into account that during the fabrication of the joints, the surface of the joint was cleaned up in order to avoid loose particles and was always kept moistened.

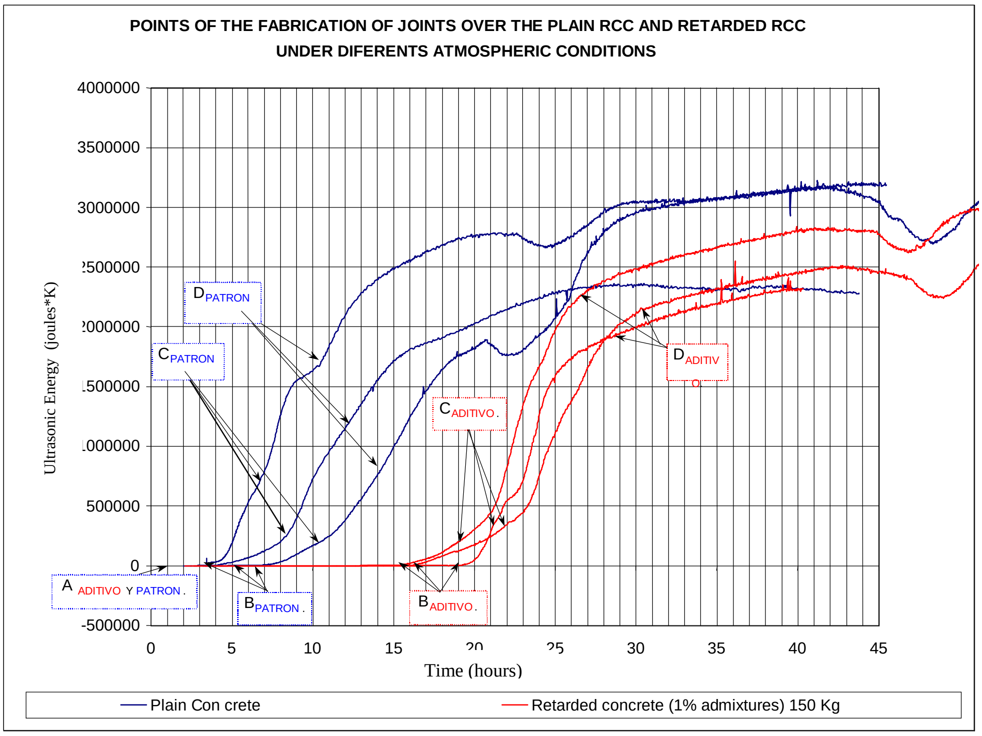

Fig.7-Instants of the fabrication of joints over the pattern RCC and RCC with a 1% plasticizing-retarding admixture

For the case of the plain concrete, it can be seen in the Figure 8 that if a new layer is placed and compacted (n+1) over the material (n) just minutes after being compacted, the direct tensile strength reaches the 18 kg/cm^2 (instant A). Just moments before the initial setting occurs, when a fresh RCC (n+1) is placed and compacted over the material, this one has decreased its adherence capacity to 14 kg/cm^2 (moment B). Once the initial setting time has occurred, that in this case took 3.5 hours, the adherence capacity merely reaches the 10 kg/cm^2 (moment C). In addition, when the layer (n+1) is

placed and compacted over the plain concrete after this one has already gone through its initial and final setting (moment D) the adherence between layers barely reaches a value near to 4 kg/cm^2.
For the setting retarded RCC, the initial value of adherence for a joint fabricated just minutes after being compacted the base material (layer n), it reaches a similar value to the adherence of the joint in the plain concrete under the same conditions, being this 18 kg/cm^2. One hour before the initial setting took place in this mixture, for this case being a 14 hours average, the capacity of adherence had decrease to 16 kg/cm^2 at 18 hours. For moment D (after its final setting) the direct tensile strength in the joint was of 6 kg/cm^2 at 28 hours.

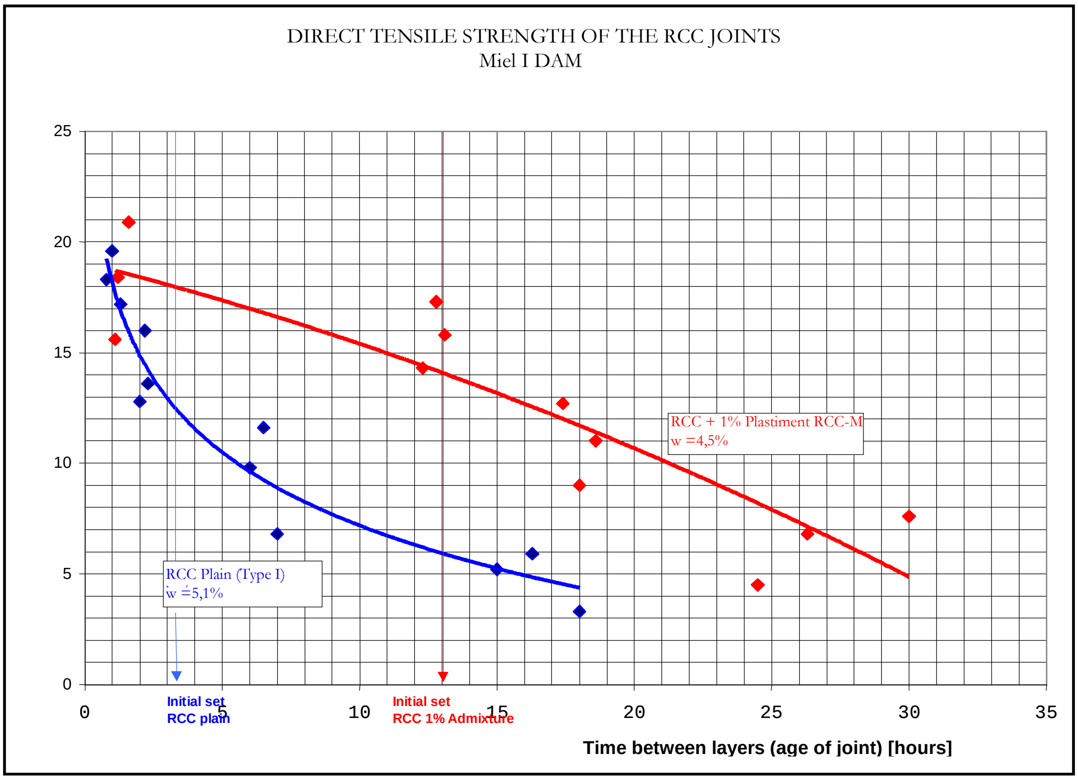

Fig.8 - Direct tensile strength on the RCC joints for the pattern design and for the design with a 1% plasticizing-retarding admixture.

The capacity of adherence in the time of a joint between layer n and layer n+1, can be expressed in a percentual manner (Fig. 9) taking 100% as the direct tensile strength obtained by a joint made just minutes after the base layer (n) was compacted.

As the obtained values demonstrated, after the initial setting has taken place (moment C) the capacity of adherence reduces to a 50-60% of the one possible to obtain, if the joint is fabricated after compacting the base layer. Meaning this that there is a need for additional surface treatments to recover the level of adherence on the bond. It becomes convenient to fabricate a joint the quickest possible, since the results show that even though the RCC have not reached to the initial setting, it had already decreased to 77% - 86% its capacity of bond.

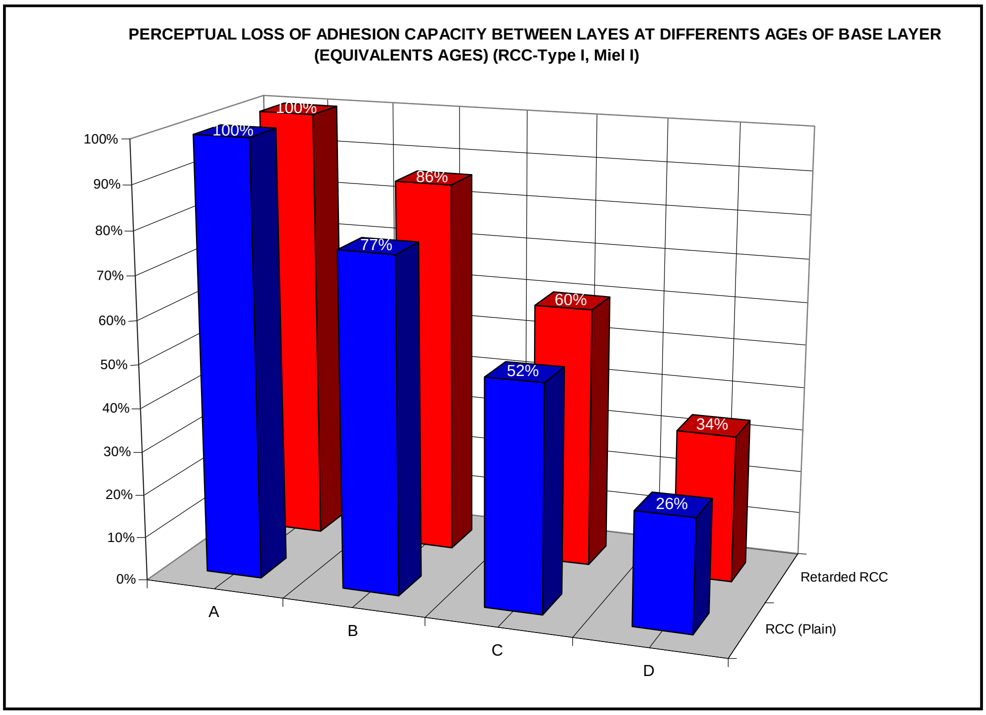

Fig.9-*Direct tensile strength of the joints with different compaction times between layers*

The use of a plasticizing-retarding admixture prolongs the initial setting times, in this case quadruple the time, from 3 to 12 hours under the most critical temperature conditions and from 4 to 16 in the early morning. This makes possible to make a hot joint in RCC retarded up to 12 and 16 hours after the base layer is mixed and compacted, avoiding the use of special surface treatments and mortars of bond.
In addition, in Figure 8 if the adherence of the design is of 13 kg/cm^2, the upper layer (n+1) must be placed and compacted on the plain RCC before the base layer (n) is 3 hours old. While in order to reach the same adherence on the retarded RCC is possible to wait up to 15 hours without placing the layer n+1 and the mentioned level of adherence will be reached.

CONCLUSIONS

1. The study of RCC on the fresh stage with ultrasonic energy permitted to identify the time of settings of the material under different atmospheric conditions.

2. The evolution of the values of ultrasonic energy showed the effect of the use of different doses of a plasticizing-retarding admixture on the times of setting of RCC. According to this the appropriate dose should be selected according to the construction needs.

3. The 1% admixture in comparison to weight of the cement for different atmospheric conditions quadruple the initial setting time in comparison to the plain RCC without admixture.

4. The direct tensile strength on the horizontal joints decreases after the initial setting of the base layer, between 50 to 60% of the initial obtained value when the joint is fabricated just after the base layer was compacted.

5. The direct tensile strength on the horizontal joint decreases progressively with the time of exposure of the base layer, even before the initial setting takes place. The definition of the limit of hot joint as the instant of initial setting, takes into account a drop in the capacity of bond to 77% - 86% to the direct tensile strength, obtained in joints fabricated immediately after base layer was compacted.

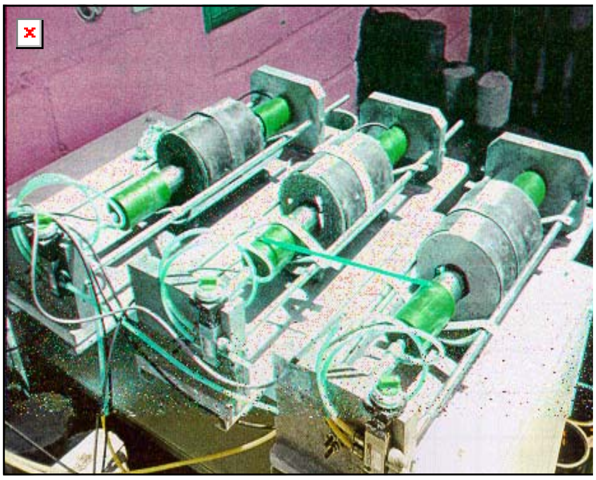

Photo 4. Miel I (Colombia) Ultrasonic energy measurement units

Photo 5. Horizontal joints specimens used to measure direct tensile strength.

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