Application of Self-Curing Concrete Method Using Polyethylene Glycol

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APPLICATION OF SELF-CURING CONCRETE METHOD USING POLYETHYLENE GLYCOL

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ABSTRACT

In this investigation the method of self-curing of the concrete is applied using polyethylene glycol (PEG 400), with the aim of proposing a novel alternative of curing in the concrete that suppresses the traditional external curing of the concrete indicated in ASTM C31, in order to obtain expected compression resistance results, observing the development of concrete hydration processes. The experimental campaign included the production of 159 cylindrical specimens of dimensions 10x20 cm and 18 beams of dimensions 15x15x50 cm. Relationships a / c = 0.70, 0.60 and 0.45 and resistance tests at ages 7, 14 and 28 days were considered. Dosages of PEG 400 were used in 0.5%, 1% and 1.5% of the cement weight for the determination of the dosage that provides the best compression resistance results. Concrete properties were characterized such as tensile strength by diametral compression, rupture modulus, and its microscopic composition was observed using SEM scanning microscopy. Finally, it was obtained that for the age of 28 days of concrete, the dosage of 1% of the cement weight for the additive PEG 400 provides the most satisfactory results of compressive strength, diametral compression traction and rupture modulus, both for a / c = 0.70, 0.60 and 0.45.

Keywords: Self Curing Concrete, Maturity Method, Concrete Strength

INTRODUCCION

According to the critical scenario that manifests itself based on the deficiencies observed in the practice of concrete curing, which generate unsatisfactory characteristics of concrete, it is necessary to propose the use of products that can solve this problem from the design so that create an alternative for suppress the external curing process of the concrete which generates multiple uncertainties in the final strength of the concrete, which vary according to the efficiency with which this procedure is developed.

ACI 308R-01 (2001) [1] and ASTM C 31 (2015) [2], propose the guide for the curing of concrete describing curing methods and the materials used for these purposes. In addition, it exposes the different types of curing according to the type of construction that is executed and the controls that are taken to guarantee the proper curing of the concrete: The internal curing of concrete and the importance of this technique to reduce the autogenous contraction and the formation of cracks in the concrete, Junaid (2015) [3] and Henkensiefken (2009) [4], Amaro (2002) [5] the compressive strength of concrete according to The various methods of external curing exist, Baradan and Un (2011) [6] show the importance of temperature and humidity on the development of the mechanical properties of Portland cement under different curing regimes.

Jagannadha and Srikanth (2012) [7], Azhagarsamy and Sundararaman (2016) [8] investigate materials that self-cure agents in concrete and show the advantages of internal curing or self-curing. In This publication a study of the resistance of the self-curing concrete for different water-cement ratios is elaborated for the case in which polyethylene glycol of molecular weight 400g / mol is used as self-curing agent.

Mousa, Mahdy, Abdel-Reheem, Yehia (2015) [9] investigate the characteristics of self-cured concrete using pre-saturated light aggregates, as well as the use of micro silica and polyethylene glycol of molecular weight 200g/mol to compare the results offered by these products in Regarding water retention and durability.

This research seeks to propose the use of an additive that promotes the self-curing of concrete, as is the case of polyethylene glycol (PEG400), material that acts as a potential self-healing agent, which leads to great benefits such as cost reduction dedicated to the curing process, greater retention of water to improve the hydration of the cement making it more uniform and efficient.

1.1 CONCRETE CURING

The term "curing" is often used to describe the process by which concrete based on hydraulic cement matures and develops properties in a hardened state over time as a result of continuous hydration in the presence of sufficient water and adequate temperature. (ACI 308R, 2001) [1].

The curing of the concrete avoids self-drying, which is the internal drying of the concrete due to the water consumption resulting from the hydration of the cement. In relation to this, in mixtures of low a / c ratio, sealed against water loss or water entry, there is a greater risk that these mixtures can be dried internally. Thus, curing measures are required as soon as the concrete is at risk of drying and when such action damages the concrete or inhibits the development of the required properties (ACI 308R, 2001) [1].

1.2 SELF-CURING OR INTERNAL CURING OF CONCRETE

Self-cured concrete means that no labor is required to provide water in the concrete, or even no external curing is required after placement. The properties of this concrete are at least comparable and even better than those of concrete with traditional curing. Self-curing is an "internal curing" system in which a water-soluble polymer is added to the concrete mix. This method overcomes the difficulty of ensuring that construction personnel employ effective curing procedures since the internal curing composition is a component of the blend (Krishna & Jaipal, 2017) [10]. Some materials that can provide internal water deposits are: Light aggregate (natural and synthetic, expanded slate), superabsorbent polymers (SAP) (size of 60-300 nm), shrinkage reducing admixture (SRA), such as polyethylene glycol.

Currently, there are two main methods available for self-curing concrete. The first method uses lightweight saturated porous aggregate (LWA) to supply an internal source of water, which can replace the water consumed by the chemical contraction during the hydration of the cement. The second method uses polyethylene glycol (PEG) that reduces the evaporation of water from the surface of the concrete and also helps in water retention (Abishek, 2016) [11].

Due to the difference in the chemical potential between the vapor and liquid phases, continuous evaporation of moisture takes place from the external surface of the concrete. The polymers added to the concrete mix mainly form hydrogen bonds with the water molecules and reduce the chemical potential of their molecules, which manifests itself in the reduction of vapor pressure, thus reducing the rate of evaporation of the surface (Daliya, 2016) [12].

1.3 POLYETHYLENE GLYCOL

Polyethylene glycol, also known as polyethylene glycol (PEG), polyethylene oxide (PEO), polyoxyethylene (POE) or macrogol, is a polyether produced by the condensation of ethylene oxide and water. The general formula of PEG is $H(OCH_2CH_2)_nOH$, where n is the average number of repeating oxyethylene groups, typically from about 4 to about 180. The low molecular weight members from n = 2 to n = 4 are diethylene glycol, triethylene glycol and tetraethylene glycol respectively, are produced as pure compounds. The abbreviation (PEG) is called in combination with a numerical suffix that indicates the average molecular weight (Krishna & Jaipal, 2017) [10].

2.1 EXPERIMENTAL DESCRIPTION

Concrete mixtures were designed for each of the following water cement ratios: a / c = 0.70, 0.60 and 0.45, selected for the most frequent use in the construction field for compliance with the usual resistance requirements (a / c = 0.70, 0.60), and durability requirements (a / c = 0.45).

Test pieces of 10 x 20 cm were manufactured according to the ASTM C192 (2016) [13] standard to be subsequently tested by compression at the ages of 7, 14 and 28 days following the procedure of ASTM C39 (2015) [14] for each of the water ratios. cement in studio.

The prepared specimens were placed in a room with homogeneous and uniform temperature conditions of 23 ± 2 ° C and relative humidity of 70%, this to maintain homogeneous conditions in the prepared samples and to avoid uncertainties in the results product of humidity and temperature variations.

From the analysis of the results, the optimal dosage was determined by comparing the compression resistance results using a PEG 400 dosage of 0.5%, 1% or 1.5% of the cement weight, with the concrete standard.

With the defined optimum dosage of PEG 400, specimens were manufactured to determine other characteristics of the concrete at 28 days, such as diametral compression traction, rupture modulus and microscopic scanning SEM analysis.

2.2 MATERIALS

In the present investigation, crushed stone from the UNI quarry is used, whose granulometric distribution resembles spindle 6 of the ASTM; coarse sand from the JICAMARCA quarry, SOL Type I cement, potable water and as an additive the polyethylene glycol with molecular weight 400 g / mol (PEG 400).

Characteristics of the aggregates

The main characteristics of the aggregates used in the design of the mixture are described below in Table 1, where: PE: Specific weight, PUS: Unit weight loose, PUC: Unit weight compacted, A: Absorption, H: Humidity, TNM: Maximum nominal size, MF: Fineness module.

TABLA 1
Physical characteristics of the aggregates

Material	P.E. g/ml	P.U.S g/ml	P.U.C. g/ml	*A %*	*H %*	*TMN*	*MF*
Sand	2,67	1,632	1,886	0,6	2,8	-	3,06
Stone	2,69	1,388	1,569	1,0	0,54	¾”	7,02

2.3 MIX DISIGN

The Walker methodology is used to obtain the best combination of aggregates for the relation a / c = 0.70. Then, for all the relationships (a / c = 0.70, 0.60 and 0.45), it was decided to maintain the distribution of aggregates in 50% of sand and 50% of stone with respect to the total volume of aggregates prepared for the mixture, with the In order to consider a homogeneous distribution of aggregates in the 3 cases of study and by workability conditions.

The identification of the samples elaborated in the investigation are detailed in Table 2.

TABLA 2
Sample types for each of the water-cement ratios (a/c)

IDENT.	CURED	% PEG 400
SC +0.0%wc	Without curing	+0.0% cement weight
SC +0.5%wc	Without curing	+0.5% cement weight
SC +1.0%wc	Without curing	+1% cement weight
SC +1.5%wc	Without curing	+1.5% cement weight
C +0.0%wc	Cured in water all the time	+0.0% cement weight

Table 3, Table 4 and Table 5 show the dosing of materials per m3 corrected for humidity and absorption of the aggregates for the ratio a / c = 0.70, 0.60 and 0.45, respectively in each of the identified scenarios.

TABLA 3
Dosing of materials in wet state for concrete mixtures a / c = 0.70

	Cement (kg)	Sand (kg)	Stone (kg)	Water (lt)	Additive (kg)
SC +0.0%wc	311.4	904.9	895.5	209	-
SC +0.5%wc	311.4	904.9	895.5	209	1.56
SC +1.0%wc	311.4	904.9	895.5	209	3.11
SC +1.5%wc	311.4	904.9	895.5	209	4.67
C +0.0%wc	311.4	904.9	895.5	209	-

TABLA 4
Dosing of materials in wet state for concrete mixtures a / c = 0.60

	Cement (kg)	Sand (kg)	Stone (kg)	Water (lt)	Additive (kg)
SC +0.0%wc	363.3	880.3	875.5	209	-
SC +0.5%wc	363.3	880.3	875.5	209	1.82
SC +1.0%wc	363.3	880.3	875.5	209	3.63
SC +1.5%wc	363.3	880.3	875.5	209	5.45
C +0.0%wc	363.3	880.3	875.5	209	-

TABLA 5
Dosing of materials in the wet state for concrete mixtures a / c = 0.45

	Cement (kg)	Sand (kg)	Stone (kg)	Water (lt)	Additive (kg)
SC +0.0%wc	484.4	828.6	822.7	210	-
SC +0.5%wc	484.4	828.6	822.7	210	2.42
SC +1.0%wc	484.4	828.6	822.7	210	4.84
SC +1.5%wc	484.4	828.6	822.7	210	7.26
C +0.0%wc	484.4	828.6	822.7	210	-

2.4 PREPARATION OF THE SAMPLES

A total of 135 cylindrical concrete specimens of 10x20 cm were manufactured according to ASTM C192 [13], which were tested in compression at 7, 14 and 28 according to ASTM C39 [14] for each of the 5 initial scenarios identified for each of the 3 a / c ratios. initially indicated.

Subsequently, 24 additional cylindrical concrete specimens of 10x20 cm were manufactured according to ASTM C192 [13], for the performance of tensile tests by diametric compression and microscopic tests by SEM scanning for standard concrete samples and samples with PEG 400 additive with 1% of the weight of the cement for each of the 3 a / c ratios initially indicated.

Likewise, 18 prismatic beams of 15x15x50 cm were made for the execution of tests of modulus of rupture for samples of standard concrete and samples with additive PEG 400 with 1% of the weight of the cement for each of the 3 relations a / c indicated initially.

3. RESULTS AND ANALYSIS

3.1 RESULTS OF COMPRESSION TESTS

The concrete specimens were tested by compression according to ASTM C39 [14] for a / c = 0.70, 0.60 and 0.45. Figure 1 shows test pieces compressed.

Fig. 1. Test specimens of concrete tested in compression

Results of compression tests

Table 6, Table 7 and Table 8 summarize the averages of the resistances obtained at 7.14 and 28 days for the relation a / c = 0.70, 0.60 and 0.45, respectively in each of the identified scenarios.

TABLA 6
Averages of compression resistance (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.70

	7 days	14 days	28 days
SC +0.0%wc	174	187	208
SC +0.5%wc	187	210	231
SC +1.0%wc	211	220	247
SC +1.5%wc	205	219	238
C +0.0%wc	206	216	256

TABLA 7
Averages of compression resistance (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.60

	7 days	14 days	28 days
SC +0.0%wc	227	252	276
SC +0.5%wc	242	276	315
SC +1.0%wc	269	299	335
SC +1.5%wc	246	272	312
C +0.0%wc	265	296	343

TABLA 8
Averages of compression resistances (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.45

	7 days	14 days	28 days
SC +0.0%wc	318	336	366
SC +0.5%wc	353	410	441
SC +1.0%wc	392	449	480
SC +1.5%wc	350	406	434
C +0.0%wc	348	386	455

3.2 RESULTS OF TENSILE TESTS BY DIAMETRICAL COMPRESSION

The concrete specimens were tested by diametral compression according to ASTM C496 [15] for a / c = 0.70, 0.60 and 0.45. Figures 2 and 3 show part of the test pieces tested.

Fig. 2. Visualization of the failure in cylindrical concrete specimens by tensile test.

Fig. 3. Specimens of concrete tested to traction

Results of tensile tests by diametric compression for a / c = 0.70, a / c = 0.60 and a / c = 0.45

TABLA 9
Averages of tensile strengths (kg / cm2) obtained at 28 days for a / c = 0.70, a / c = 0.60 and a / c = 0.45

a/c	0.70	0.60	0.45
SC 1.0% - 28D	23.1	28	37.4
C 0.0% - 28D	23.9	26.8	35.6

3.3 RESULTS OF BENDING TESTS ON BEAMS

Concrete beams were tested for the determination of their breakage modules according to ASTM C78 [16] for a / c = 0.70, 0.60 and 0.45. Figures 4 and 5 show some of the beams tested.

Fig. 4. Test specimens of concrete tested in compression

Fig. 5. Test specimens of concrete tested in compression

Breaking modulus test results for a / c = 0.70, a / c = 0.60 and a / c = 0.45

Table 10 is shown below, which summarizes the average values of the 15 cm x 15 cm x 50 cm beam breaking modules obtained at 28 days, for a / c = 0.70, a / c = 0.60 and / c = 0.45.

TABLA 10
Average modulus of rupture (kg / cm2) obtained at 28 days for a / c = 0.70, a / c = 0.60 and a / c = 0.45

a/c	0.70	0.60	0.45
SC 1.0% - 28D	32	37.8	47.1
C 0.0% - 28D	34.3	39.6	46.1

3.4 RESULTS OF SEM SCANNING ELECTRON MICROSCOPY

The images corresponding to the microscopic characteristics of concrete specimens for a / c = 0.45 are shown below. Figures 6 and 7 show the German scanning electron microscope ZEISS model EVO 10 and the placement of the concrete sample in it.

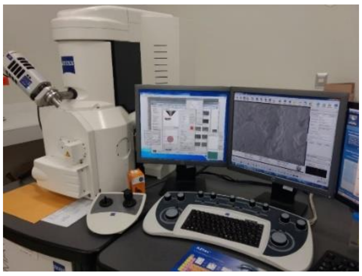

Fig. 6. SEM scanning electron microscope

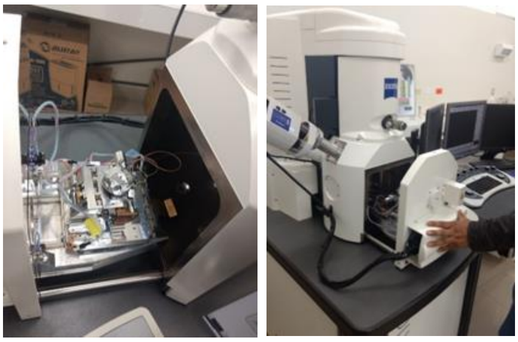

Fig. 7. Sample placement in the SEM scanning electron microscope

Results for a / c = 0.45 at 7 days of age

Figures 8 and 9 show the microscopic characteristics of a 1.5cm x1.5cm x1cm concrete sample coded as SC + 1.0% wc for a / c = 0.45 at 7 days of age, observed in the scanning electron microscope with a 10 000x and 50 000x amplification respectively.

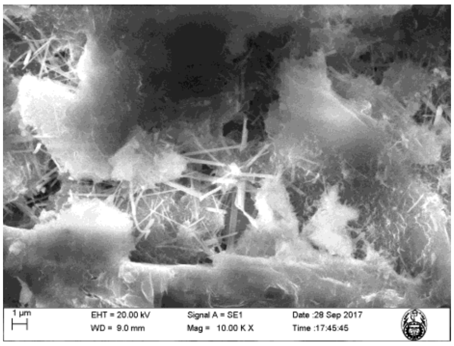

Fig. 8. Observation in scanning electron microscope SEM of sample SC + 1.0% wc at age 7 days for a / c = 0.45, with an amplification of 10 000x

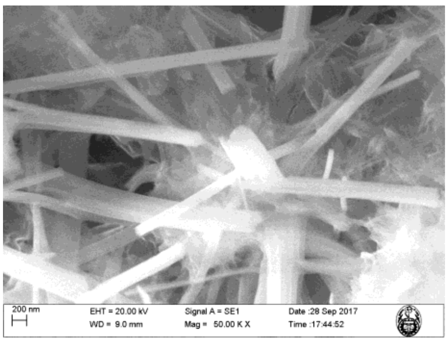

Fig. 9. Observation in scanning electron microscope SEM of sample SC + 1.0% wc at age 7 days for a / c = 0.45, with an amplification of 50 000x

Figures 10 and 11 show the microscopic characteristics of a 1.5cm x1.5cm x1cm concrete sample coded as C + 0.0% wc for a / c = 0.45 at 7 days of age, observed in the scanning electron microscope with a 10 000x and 50 000x amplification respectively.

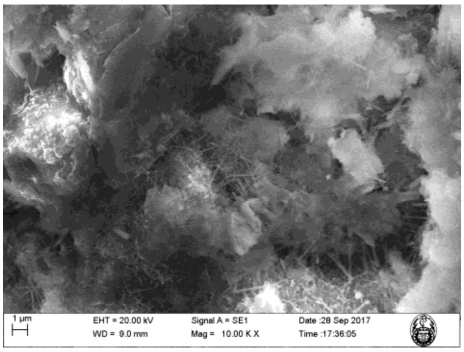

Fig. 10. SEM scanning electron microscope observation of sample C + 0.0% wc at age 7 days for a / c = 0.45, with an amplification of 10,000

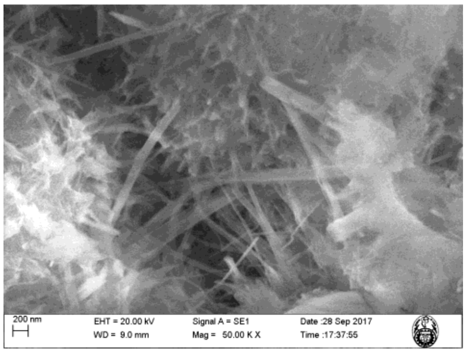

Fig. 11. Observation in scanning electron microscope SEM of sample C + 0.0% wc at age 7 days for a / c = 0.45, with an amplification of 50 000x

Results for a / c = 0.45 at 28 days of age

Figures 12 and 13 show the microscopic characteristics of a 1.5cm x1.5cm x1cm concrete sample coded as SC + 1.0% wc for a / c = 0.45 at 28 days of age, observed in the scanning electron microscope with a 10 000x and 50 000x amplification respectively.

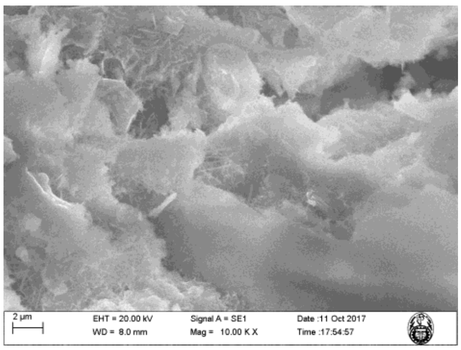

Fig. 12. Observation in scanning electron microscope SEM of sample SC + 1.0% wc at age 28 days for a / c = 0.45, with an amplification of 10 000x

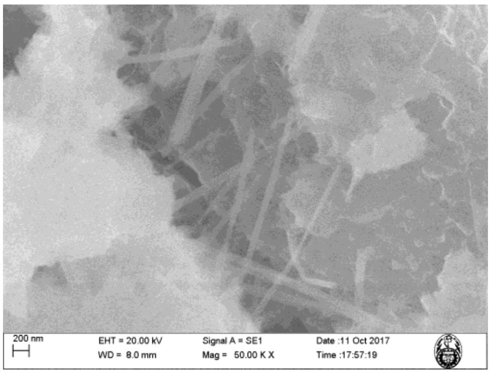

Fig. 13. Observation in scanning electron microscope SEM of sample SC + 1.0% wc at age 28 days for a / c = 0.45, with an amplification of 50 000x

Figures 14 and 15 show the microscopic characteristics of a 1.5cm x1.5cm x1cm concrete sample coded as C + 0.0% wc for a / c = 0.45 at 28 days of age, observed in the scanning electron microscope with a 10 000x and 50 000x amplification respectively.

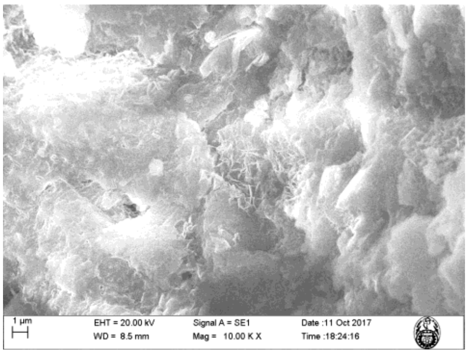

Fig. 14. SEM scanning electron microscope observation of sample C + 0.0% wc at age 28 days for a / c = 0.45, with an amplification of 10,000

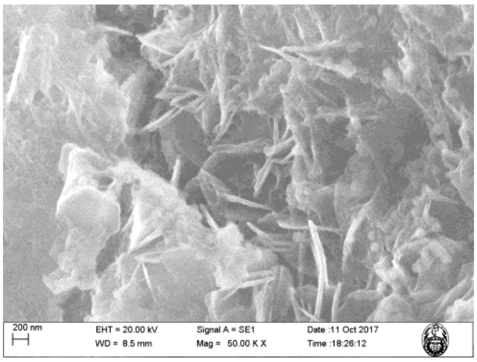

Fig. 15. Observation in scanning electron microscope SEM of sample C + 0.0% wc at age 28 days for a / c = 0.45, with an amplification of 50 000x

3.5 ANALYSIS OF RESULTS

Many equations have been published to characterize the compressive strength versus cure time relationship, among these, the exponential and hyperbolic equations have been recommended in ASTM C 1074 [17]. The exponential dependence of concrete strength with cure time (S (t)) is expressed by the equation:

$$S(t) = S_u . exp\left[-\left(\frac{\tau}{t}\right)^{\beta}\right] \qquad (1)$$

and allows to estimate the maximum compression resistance value of a type of concrete.

Where,

Su: is the maximum compressive strength to reach
t: time in hours
τ: time constant
β: constant form

Compression result analysis for a / c = 0.70

From table 6, figures 16, 17, 18, 19, 20 and table 11 are constructed, where it is observed that for a / c = 0.70 the best compression characteristics are found for specimens containing 1% of PEG400 additive with average compressive strength 2.4% higher than the average compressive strength of the standard concrete at the age of 7 days (See Figure 16).

At 14 days, 1.9% higher than the average compressive strength of the standard concrete (See figure 17). At 28 days, 3.5% lower than the average compressive strength of the standard concrete (See figure 18).

Figure 19 shows the compressive strength achieved by this concrete over the curing time. The results of the resistance data adjustment achieved versus the cure time with equation [1] are shown in Table 11 and one of the adjustment curves is shown in Figure 20.

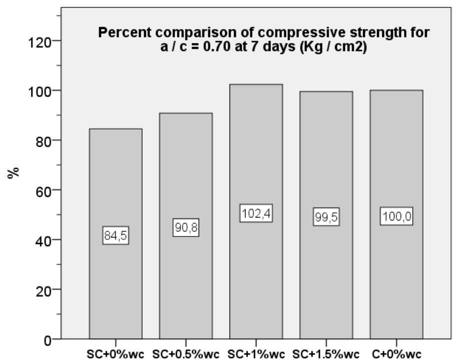

Fig. 16. Percent comparison of compressive strength obtained at 7 days for a / c = 0.70

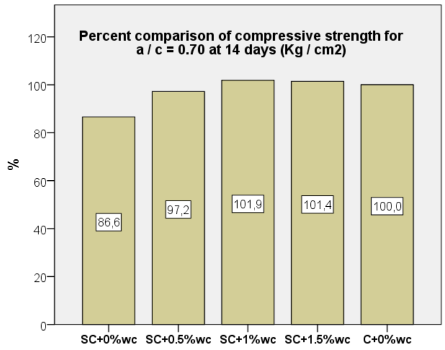

Fig. 17. Percent comparison of compressive strength obtained at 14 days for a / c = 0.70

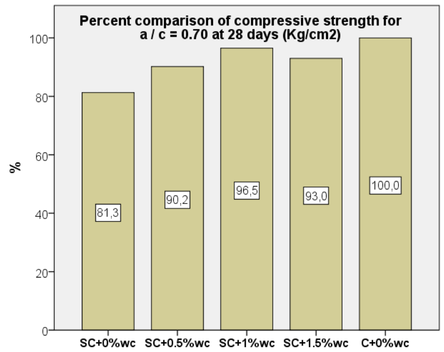

Fig. 18. Percent comparison of compressive strength obtained at 28 days for a / c = 0.70

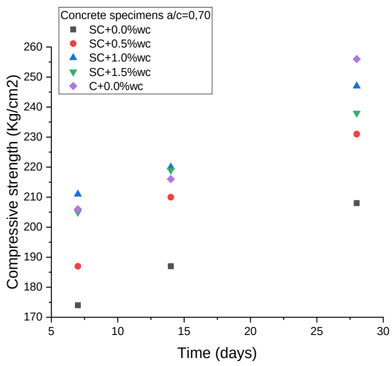

Fig. 19. Compressive strength values obtained at 7, 14 and 28 days for a / c = 0.70

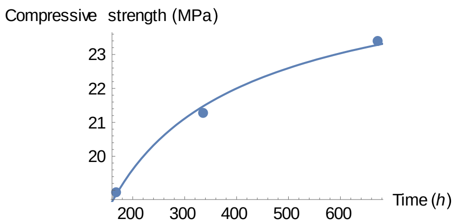

Fig. 20. Compressive strength obtained at 28 days for SC + 0.5% wc; a / c = 0.70 and adjustment curve with exponential function.

TABLA XI

Results of the non-linear adjustment of the compressive strength averages (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.70, using the exponential function resistance-cure time

	Su (MPa)	τ (h)	β
SC +0.0%wc	23.37	30.99	0.71
SC +0.5%wc	26.62	34.98	0.68
SC +1.0%wc	26.79	30.0	0.80
SC +1.5%wc	26.06	24.99	0.75
C +0.0%wc	29.89	41.01	0.65

Compression result analysis for a / c = 0.60

From table 7, figures 21, 22, 23 are constructed, where it is observed that for a / c = 0.60 the best compression characteristic corresponds to specimens containing 1% PEG400 additive with average compressive strength 1.5% higher than the average compressive strength of the standard concrete at the age of 7 days (See Figure 21). At 14 days, 1% higher than the average compressive strength of the standard concrete (See figure 22). At 28 days, 2.3% lower than the average compressive strength of the standard concrete (See figure 23).

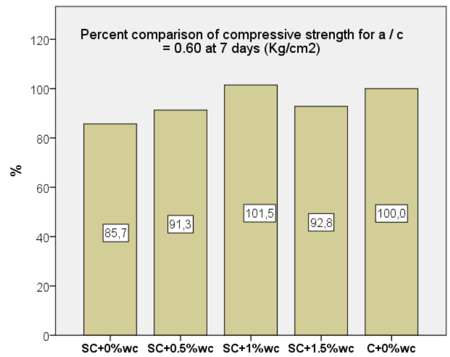

Fig. 21. Percent comparison of compressive strength obtained at 7 days for a / c = 0.60

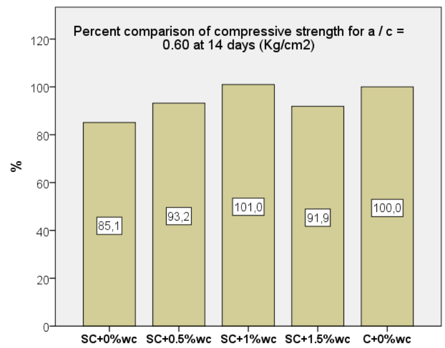

Fig. 22. Percent comparison of compressive strength obtained at 14 days for a / c = 0.60

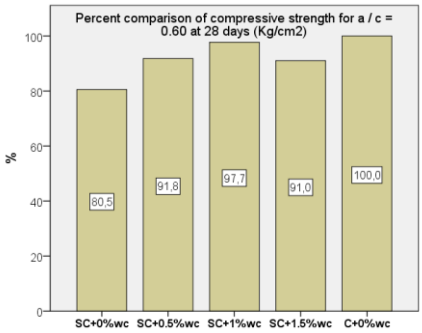

Fig. 23. Percent comparison of compressive strength obtained at 28 days for a / c = 0.60

The increase in compressive strength versus cure time for this concrete is shown in figure 24, of the adjustment of these experimental data with equation [1], figure 25, the data shown in table 12 are obtained. A maximum compressive strength value of 41.61 MPa is determined from this setting.

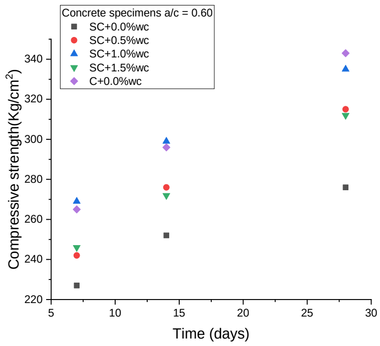

Fig. 24. Compressive strength values obtained at 7, 14 and 28 days for a / c = 0.60

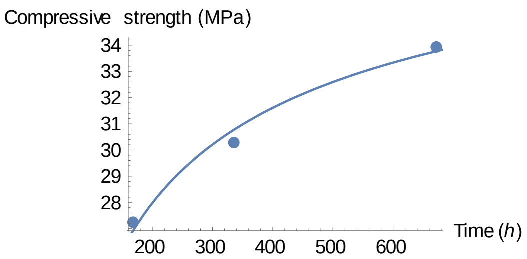

Fig. 25. Compressive strength obtained at 28 days for SC + 10% wc; a / c = 0.60 and adjustment curve with exponential function.

TABLA XII
Results of the non-linear adjustment of the compressive strength averages (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.60, using the exponential function resistance-cure time.

	Su (MPa)	τ (h)	β
SC +0.0%wc	31.89	30.99	0.65
SC +0.5%wc	38.87	51.01	0.62
SC +1.0%wc	41.61	34.98	0.53
SC +1.5%wc	36.62	45.97	0.69
C +0.0%wc	38.39	61.01	0.92

Compression result analysis for a / c = 0.45

From Table 8, Figures 26, 27 and 28 are constructed where it is observed that for a / c = 0.45 the best compression characteristics are found for specimens containing 1% PEG400 additive with average compression resistance 12.6% higher than the average compressive strength of the standard concrete at the age of 7 days (See Figure 26). At 14 days, 16.3% higher than the average compressive strength of the standard concrete (See figure 27). At 28 days, 5.5% higher than the average compressive strength of the standard concrete (See figure 28).

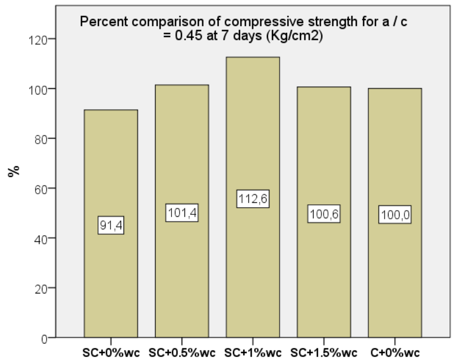

Fig. 26. Percent comparison of compressive strength obtained at 7 days for a / c = 0.45

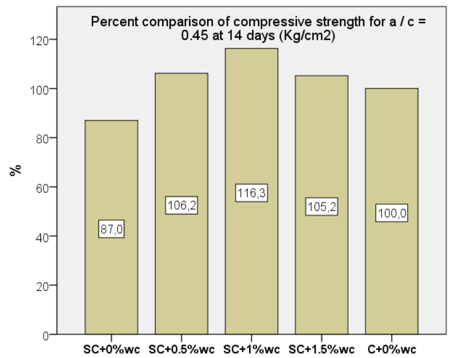

Fig. 27. Percent comparison of compressive strength obtained at 14 days for a / c = 0.45

The increase in compressive strength versus cure time for this concrete is shown in figure 29, of the adjustment of these experimental data with equation [1], shown in figure 30, the data recorded in table 13 are obtained. A maximum compressive strength value of 53.97 MPa is determined from this setting.

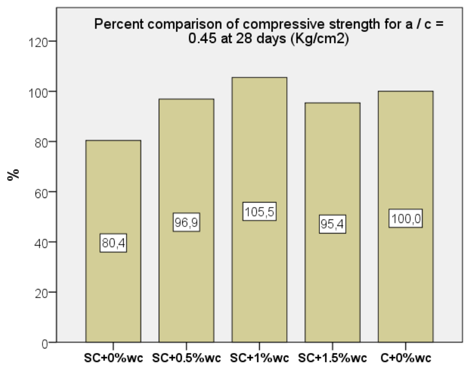

Fig. 28. Percent comparison of compressive strength obtained at 28 days for a / c = 0.45

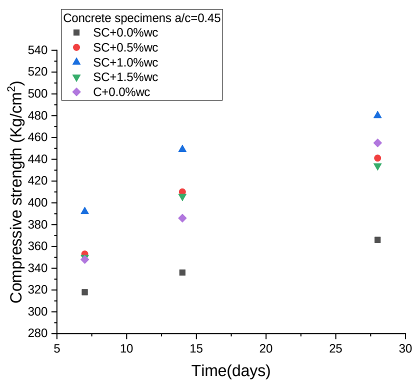

Figure 29. Compressive strength values obtained at 7, 14 and 28 days for a / c = 0.45

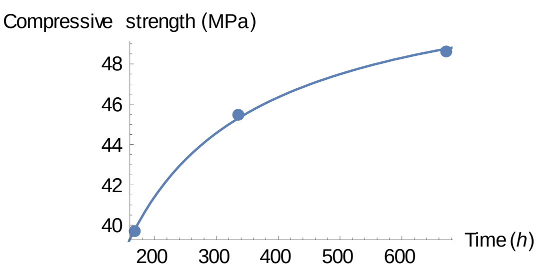

Figure 30. Compressive strength obtained at 28 days for SC + 10% wc; a / c = 0.45 and adjustment curve with exponential function.

TABLA XIII
Results of the non-linear adjustment of the compressive strength averages (kg / cm2) obtained at 7.14 and 28 days for a / c = 0.45, using the exponential function of resistance-curing time.

	Su (MPa)	τ (h)	β
SC +0.0%wc	40.47	20.99	0.68
SC +0.5%wc	48.25	47.99	0.97
SC +1.0%wc	53.57	38.99	0.83
SC +1.5%wc	47.53	46.99	0.97
C +0.0%wc	53.97	51.98	0.68

Analysis of tensile results for a / c = 0.70

From Table 9, Figure 31 is constructed, where it is observed that, for a / c = 0.70 at the age of 28 days, the best traction characteristics by diametral compression are found for specimens containing 1% PEG400 additive with an average tensile strength of 23.9 kg / cm2, 3.4% lower than the average compressive strength of the standard concrete, which has 23.1 kg / cm2.

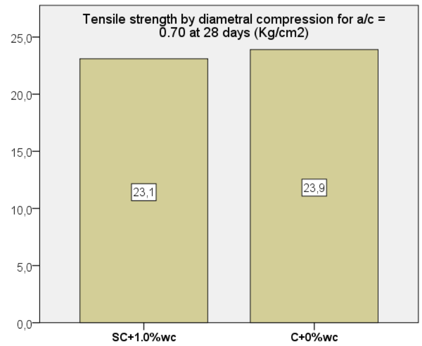

Figure 31. Results of tensile strength at 28 days for a / c = 0.70

Analysis of tensile results for a / c = 0.60

From Table 9, Figure 32 is constructed, where it is observed that, for a / c = 0.60 at the age of 28 days, the best traction characteristics for diametral compression are found for specimens containing 1% PEG400 additive With an average tensile strength of 28 kg / cm2, 4.5% higher than the average compressive strength of the standard concrete, which has 26.8 kg / cm2.

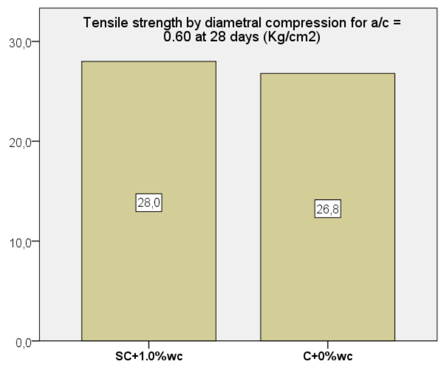

Figure 32. Results of tensile strength at 28 days for a / c = 0.60

Analysis of tensile results for a / c = 0.45

From Table 9, Figure 33 is constructed where it is observed that, for a / c = 0.45 at the age of 28 days, the best traction characteristics by diametral compression are found for specimens containing 1% PEG400 additive with an average tensile strength of 37.4 kg / cm2, 5.1% lower than the average compressive strength of the standard concrete, which has 35.6 kg / cm2.

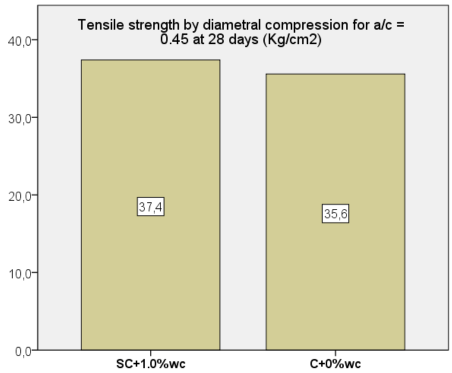

Figure 33. Results of tensile strength at 28 days for a / c = 0.45

Analysis of rupture module results for a / c = 0.70

From Table 10, Figure 34 is constructed where it is observed that, for a / c = 0.70 at the age of 28 days, the best break modulus characteristics are found for specimens containing 1% PEG400 additive with an average tensile strength of 32 kg / cm2, 6.7% lower than the average compressive strength of the standard concrete, which has 34.3 kg / cm2.

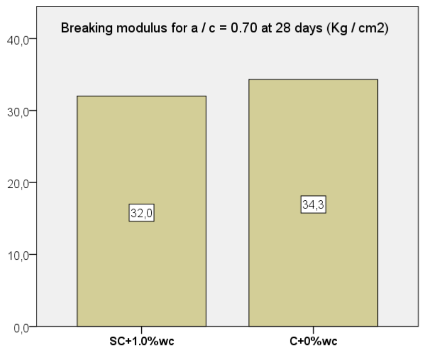

Figure 34. Breaking modulus results at 28 days for a / c = 0.70

Analysis of rupture module results for a / c = 0.60

From Table 10, Figure 35 is constructed where it is observed that, for a / c = 0.60 at the age of 28 days, the best breakage modulus characteristics are found for specimens containing 1% PEG400 additive with an average tensile strength of 37.8 kg / cm2, 4.5% lower than the average compressive strength of the standard concrete, which has 39.6 kg / cm2.

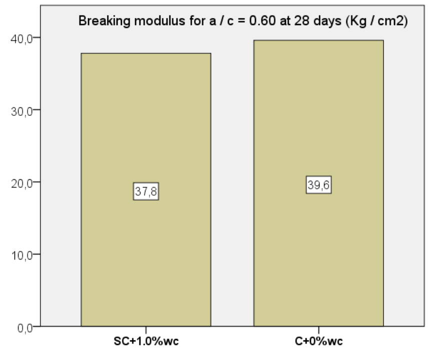

Figure 35. Results of tensile strength at 28 days for a / c = 0.60

Analysis of rupture module results for a / c = 0.45

From Table 10, Figure 36 is constructed where it is observed that, for a / c = 0.45 at the age of 28 days, the best break modulus characteristics are found for specimens containing 1% PEG400 additive with an average tensile strength of 47.1 kg / cm2, 2.2% higher than the average compressive strength of the standard concrete, which has 46.1 kg / cm2.

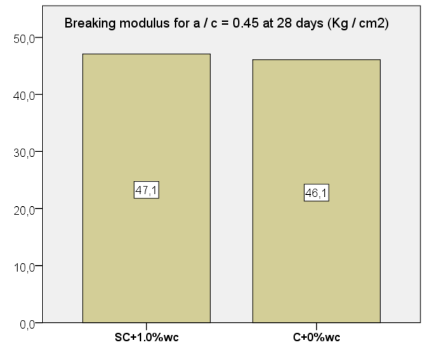

Figure 36. Results of tensile strength at 28 v days for a / c = 0.45

Analysis of results of the microscopic test for a / c = 0.45 at 7 days

The analysis encompasses the qualitative comparison of the images recorded with the scanning electron microscope SEM, based on figures 8, 9, 10 and 11. Thus, it is observed that, by 7 days of age, the characteristics of the formation of the crystals, (concrete hydration products) are similar both for samples containing 1% additive without curing and for samples that do not contain additive and that were cured in water. Likewise, in both cases the multidirectional bonds between cement particles that begin to become denser in the first days are observed more clearly, which confers the increase in resistance as these hydration products become denser with the passing of weather.

Analysis of results of the microscopic test for a / c = 0.45 at 28 days

The analysis covers the qualitative comparison of the images recorded with the scanning electron microscope SEM, from figures 12, 13, 14 and 15. At 28 days of age, the characteristics of the formation of the crystals, (concrete hydration products) are similar both for samples containing 1% additive without curing and for samples that do not contain additive and that were cured in Water. Likewise, in both cases the multidirectional bonds between cement particles are observed in less quantity and clarity compared to 7 days, since for this age almost all of the reactions that confer resistance to concrete have already occurred, as Consequently, the formation of new hydration products has a very low rate and finally consolidated crystals are observed.

CONCLUSIONS

- The additive used PEG 400 fulfills the function of self-curing at the ages evaluated of 7.14 and 28 days in concrete with ratios a / c = 0.45, 0.60 and 0.70, since it provides favorable and acceptable characteristics in the mechanical properties of the concrete.
- The results show that, for ages 7, 14 and 28 days, concrete with ratios a / c = 0.45, 0.60 and 0.70, and dosage 1% of the cement weight of additive cement PEG 400, provides the best results of resistance to compression, tensile strength and rupture modulus, compared to the results obtained with their respective concrete pattern.
- A better performance of the PEG 400 additive is observed, in terms of the compressive strength of the concrete for the early ages (7 days) for the ratio a / c = 0.45, a / c = 0.60 and / c = 0.70, higher than the results achieved by the concrete pattern at that certain age, this because the additive promotes better cement hydration in the first days due to its moisture retention capacity.
- The PEG additive works best for low a / c ratios, which is evident in our particular case of a / c = 0.45, in which we obtained a 5.5% increase in the compressive strength of concrete, 5.1% in strength to tensile of concrete and 2.2% in the modulus of breakage of concrete, compared to the results achieved by the concrete pattern in each case.

ACKNOWLEDGMENT

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