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Abstract

In the present work the incidence of C. odorata L. aggregate extract in the mixing water was evaluated as an alternative to improve the compressive strength of concrete and the workability of the mix, following NTC 673 and NTC 396 standards. For the analysis of compressive strength and workability of concrete mixes two variables were involved which were water/cement ratios of 0.55 and 0.60 and dosages of cedar extract by weight of cement added in the mixing water of 0.0, 0.3, 0. 5, 0.7 and 0.9 %, resulting in a total of 30 cylindrical specimens of 4 inches in diameter and 8 inches in height manufactured under a 1:2:2 ratio, with coarse aggregate of maximum size of ¾ inches and type I cement for general use, in accordance with NTC 550. Describe the main results and indicate the exact level of statistical significance. Highlight those results achieved that are novel. The use of cedar exudate is recommended to improve the workability and compressive strength of concrete.

Key Words: Rubbery exudate, concrete workability, cedar tree.

Evaluación del extracto de *Cedrela odorata* Linnaeus en la manejabilidad del concreto y su resistencia a la compresión

Resumen

En el presente trabajo se evaluó la incidencia del extracto de C. Odorata L. agregado en el agua de mezclado como alternativa para mejorar la resistencia a la compresión del concreto y la manejabilidad de la mezcla, siguiendo las Normas NTC 673 y NTC 396. Para el análisis de la resistencia a la compresión y la manejabilidad de las mezclas de concreto se involucraron dos variables que fueron relaciones agua/cemento de 0.55 y 0.60 y dosificaciones de extracto de cedro por peso de cemento adicionado en el agua de mezclado de 0.0, 0.3, 0.5, 0.7 y 0.9 %, resultando un total de 30 especímenes cilíndricos de 4 pulgadas de diámetro y 8 pulgadas de altura fabricados bajo relación 1:2:2, con agregado grueso de tamaño máximo de ¾ de pulgadas y cemento tipo I de uso general, de conformidad con la Norma NTC 550. Se evidenció una favorabilidad en la resistencia del concreto con la implementación de la relación a/c de 0.55 bajo todas las dosificaciones del extracto con respecto a la muestra blanco, siendo 33.48 % la mayor eficiencia obtenida bajo la adición del 0.7%. Por su parte se obtuvo un aumento de la manejabilidad de la mezcla bajo la adición del 0.7 y 0.9 % del extracto en ambas relaciones a/c con respecto a las mezclas blanco. Se recomienda el uso del exudado gomoso de cedro para mejorar la trabajabilidad y la resistencia a la compresión del hormigón.

Palabras Claves: Exudado gomoso, trabajabilidad del concreto, árbol de cedro.

Introduction

Hydraulic concrete is a material widely used in the construction industry, due to its good behavior under compressive stresses, being this, one of the most important indicators of the quality of concrete as reported by Garin, Santilli, & Pedoja (2012); Different factors cause a decrease in compressive strength such as weather, high temperatures, low relative humidity and wind, which can result in concrete placement problems as reported by Pérez & González (2015), and causing financial losses pursuant to Abdulsada & Török (2019).

Improving concrete properties is important in the field of civil engineering. It is well known that compressive strength is considered one of the most critical and useful concrete properties in accordance with Rebouh et al., (2017). Thus, because in construction reinforced concrete is widely used engineering material, and its durability is a most important problem disturbing the service life of the engineering structures due to the corrosion of steel structures inside the reinforced concrete according to Rajendran (2015). Therefore, the use of gummy substances, mucilages or green plant extracts such as aloe, cactus, nopal, and mangrove tree leaves and tea have been evaluated in reinforced concrete mixtures; obtaining that the pathological problems of concrete decrease as previously reported by Okeniyi et al. (2014), Babilonia Escallon & Urango Rojas (2015) and Hernández et al. (2016).

García Díaz & Méndez Medina (2016), reported that C. Odorata L., usually known in Colombia as Cedar, it is a tree of troopophile forests widely distributed along all the low regions and Andean foothills below 2000 m of altitude. Taking into account that

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cedar is part of the same gum arabic family, which has similar properties to the plants studied above, the present work aimed to evaluate the incidence that its extract has on the compressive strength and manageability of concrete.

Materials and methods

Two independent variables were used for the analysis of compressive strength and workability of the concrete mixes: water/cement ratio (0.55 and 0.60) and dosage of cedar extract by weight of cement added in the mixing water (0.0, 0.3, 0.5, 0.7 and 0.9 %). Everything was done in triplicate according to the NSR-10 standard, resulting in a total of 30 cylindrical specimens with 4 in diameter and 8 in height made under a 1:2:2 ratio, with coarse aggregate of maximum size of ¾ and type I cement for general use, according to the NTC 550 standard.

Preliminary test

The initial setting of the cement paste was previously monitored for additions greater than 1% of the cedar extract, in order to find favorable conditions for the construction of the cylindrical specimens, through the tests of normal consistency of the cement and setting time of the hydraulic cement method of the Vicat apparatus, following the standards INV E-310-07 and INV E-305-07.

Concrete Mixture Settling

During the manufacture of the concrete mixes, a record of the workability was made through the slump test with the Abraham's cone according to NTC 396 by ICONTEC (1992), to estimate the possible incidence of the extract with respect to a standard sample without the substance. For this purpose, the experimental values of settlement vs. percentage of exudate, for the two a/c ratio series, were plotted, and in this way trends and behaviors of manageability with increasing amounts of the added extract were looked at. Similarly, the values of settlement under the addition of each amount of extract were compared with the control mixtures.

Concrete compressive strength

This test was done in accordance with the requirements and procedures laid down in the test standard I.N.V. E - 410 - 07 by INVIAS (2007) and NTC 673 by ICONTEC (2010). For this, after 28 days of curing, the diameters of the concrete cylinders previously submerged in water were measured. Then, less than two hours later, destructive compressive strength tests were performed. To evaluate the incidence of the Cedar tree extract on the compressive strength of the concrete at 28 days of age, the values obtained in the tests carried out on the specimens with different contents of the extract and water were compared with the resistance values of the control or white samples, through the following expression.

$$I\% = \left(\frac{C_{RE} - C_{RB}}{C_{RB}}\right) x100 \quad (1)$$

Where I is the efficiency in percent, C is the compressive strength in psi, R is the water/cement ratio of the sample, B denotes blank samples and E is the percentage exudate of the sample.

Results and discussion

Effect of the exudate on mixture setting

In Table 1 the setting times of the cement paste are presented as a previous result, test under which it was allowed to discard the implementation of the exudate of the cedar in quantities equal or greater than 1% in the concrete mix.

Table 1. Results of preliminary test, cement paste setting test.
Source: Own elaboration.

Ratio w/c	Exudate by weight of cement	Exudate concentration in water (g/L)	Initial setting time (minutes)
	Control sample	0.00	130.4
0.55	1.0 %	18.18	135.0
	1.5 %	27.27	300.0
	2.5 %	45.45	311.3
0.60	1.0 %	16.67	187.5
	1.5 %	25.00	337.5
	2.5 %	41.67	410.0

From the initial setting times in minutes (Table 1), it can be seen how a delay in the setting of the paste occurs when implementing exudate concentrations equal to or greater than 1 %, with respect to the control sample (130.4 min), the most adverse results being achieved from 1.5 % of the exudate, which means twice the time with respect to the control sample. On the other hand, the most unfavorable time was 410 min under the addition of 2.5 % of exudate and under a w/c ratio of 0.6. Due to all this, in the present investigation exudate ratios equal to or less than 0.9 % of the weight of the cement were implemented; also, 48 h will be considered as the hardening time of the concrete cylinders before water curing.

Settling of concrete mixtures

The results of the slump test carried out on each type of mixture are shown in Table 2, which shows the consistency according to the average slump value of the two tests.

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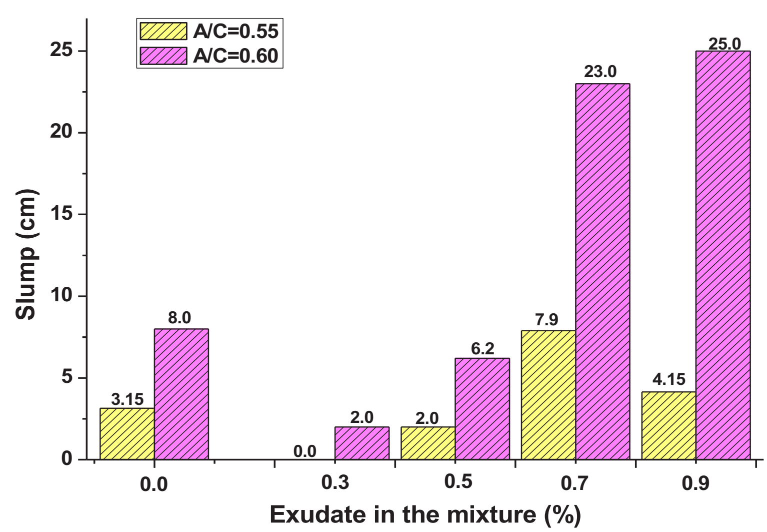
Table 2. Fresh concrete slump, consistencies according to
Source: (Sánchez de Guzmán, 2011)

Ratio a/c	% exudate	Slump in cm			Consistency
		Slump1	Slump2	Media	
0.55	0.0	3.30	3.00	3.15	Dry
	0.3	0.00	0.00	0.00	Very dry
	0.5	2.00	2.00	2.00	Very dry
	0.7	8.00	7.80	7.90	Plastic
	0.9	4.30	4.00	4.15	Semi- plastic
0.60	0.0	8.00	8.00	8.00	Plastic
	0.3	2.00	2.00	2.00	Very dry
	0.5	6.40	6.00	6.20	Plastic
	0.7	23.0	23.0	23.0	Super fluid
	0.9	25.0	25.0	25.0	Super fluida

Figure 1 shows the dispersion of the slump (cm) versus the percentage of exudate added to the mix, for both water-cement ratios:

Figure 1. Mixture settling vs. % exudate added. Source: Own elaboration.



In Figure 1, it can be seen how as the quantity increased, the workability of the mixture decreased below the control mixture when using the w/c ratios of 0.55 and 0.60 and 0.3 and 0.5 % exudate; on the other hand when adding 0.7 % exudate, plastic consistencies of 7.9 cm of slump and 23 cm of fluid were obtained for the a/c ratios of 0.55 and 0.60 respectively. With the addition of 0.9 %, the slump increased to 25 cm with the w/c ratio of 0.60, while for w/c of 0.55 the slump decreased compared to the addition of 0.7 %. Thus it can be seen that there is a variable behavior of the consistency of the concrete mix as the amount of extract increases, being favorable to add extract to the mix to improve workability; which could mean an improvement in the quality of pozzolans, as well as other qualities of concrete such as reduction of heat of hydration and thermal contraction, resistance to compression, bending, and corrosion by sulfates, salinity, and the reaction of alkalis-aggregates according to Pradipta et al. (2019).

Compressive strength analysis

Table 3 shows the experimental data of failure loads and the diameter of the cylinders. Of the three failure load data for each type of sample (R55-00 to R60-09), the outliers were discarded (the asterisked data in Table 3) and then an average of the remaining data was obtained.

Table 3. Failure load data and cylinder diameters in the endurance test.
Source: Own elaboration

Ratio w/c	% exudate	Failure load (KN)				Diemeter (cm)
		Test tube 1	Test tube 2	Test tube 3	Average	
0.55	0.0	135.8*	153.2	152.1	152.65	10.16
	0.3	154.6	159.3	157.2	157.03	10.16
	0.5	166.9	143.4*	164.0	165.45	10.16
	0.7	206.8	203.4	153.8*	205.10	10.16
	0.9	193.5	168.6*	194.7	194.10	10.16
0.60	0.0	128.1*	148.8	151.9	150.35	10.16
	0.3	102.6	106.6	103.2	104.13	10.16
	0.5	127.1	148.5*	128.8	127.95	10.16
	0.7	115.3	117.6	115.9	116.27	10.16
	0.9	112.8*	133.3	136.1	134.70	10.16

Table 4 shows the average failure load divided by the area of the cylinder section, thus obtaining the resistance.

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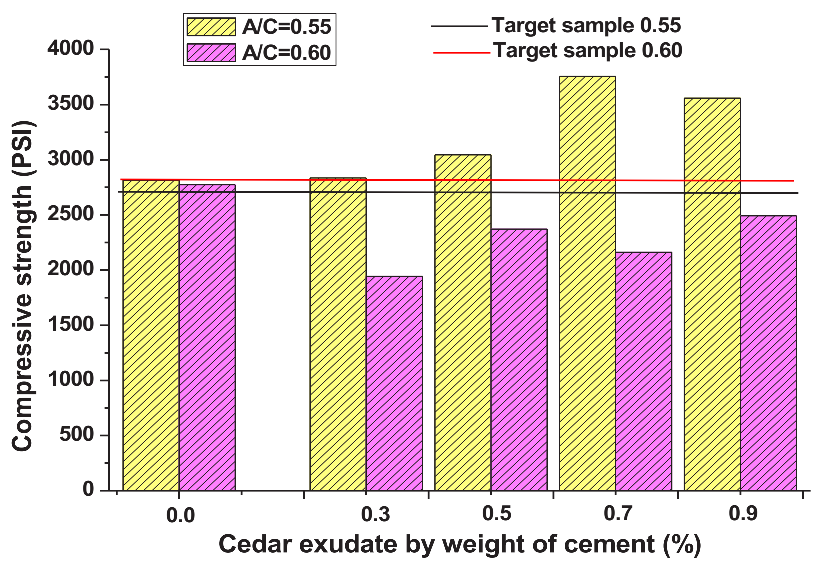
Table 4. Concrete compressive strength results.
Source: Own elaboration

Relation w/c	% exudate	Failure load (Kg)	Area (cm^2)	Resistance (Kg/cm^2)	Resistance (psi)	Efficiency with respect to the white sample (%)
0.55	0.0	15565.96	81.07	192.00	2742.84	-
	0.3	16012.94	81.07	197.51	2821.60	2.80%
	0.5	16871.20	81.07	208.10	2972.83	8.17%
	0.7	20914.38	81.07	257.97	3685.27	33.48%
	0.9	19792.69	81.07	244.13	3487.62	26.46%
0.60	0.0	15331.43	81.07	189.11	2701.51	-
	0.3	10618.64	81.07	130.98	1871.09	-29.94%
	0.5	13047.27	81.07	160.93	2299.03	-14.51%
	0.7	11855.90	81.07	146.24	2089.10	-22.08%
	0.9	13735.57	81.07	169.42	2420.31	-10.14%

It was found the increase of the compression strength increase in the concrete; this may be due to the addition of extract attracts the excess chloride ions and bound to them since they have positively charged in the hydrated form. By this way, has been reported by Valdez et al. (2018) that the corrosion of reinforcing steel due to the presence of chloride ions might be reduced or controlled. The results found in this study coincide which the ones reported by Palanisamy (2018) for *Ricinus communis* extract made by.

Figure 2 shows the compressive strength of the cylinders when adding the different amounts of extract, and the efficiency with respect to the target samples.

Figure 2. Concrete strength in psi by addition of exudate. Source: Own elaboration.



From Figure 2, it was established that by using the w/c ratio of 0.6, the compressive strength was reduced by 1.47% with respect to the target samples when the different amounts of extract tested were added. When the extract is added, the resistance results were favorable for the w/c ratio of 0.55. Also, it can be noticed that the resistance under the w/c ratio of 0.60; analyzing individually each percentage of addition of the extract, presented a more pronounced decrease with respect to the resistance obtained with the w/c ratio of 0.55, having the biggest decrease of 42.48% when adding 0.7% of the extract, which can be caused because the rubbery cedar extract acts as a retardant and delays the action or effect of the tricalcium silicate or tricalcium aluminate of the cement, modifying the resistance to compression in the first ages of the concrete as informed by Abdulsada & Török (2019). However, in other studies it has been found that the compressive strength of concrete decreases with the addition of inhibitors over short periods of time, but with the increase in the curing period, the difference in compressive strength of the inhibited concrete and the blank sample (without inhibitor) is reduced according to Pradipta et al. (2019) and Quraishi et al (2017). It was reported by Okeniyi et al. (2017), the compressive strength improvement on the studied steel-reinforced concretes at the compressive strength change effect; thus implied that the inhibition efficiency, $\eta = 93.97 \pm 4.53\%$, exhibited by the use of 4 g *P. muellerianus* leaf extract.

On the other hand, the compressive strength of concrete at 28 days increases when an amount of the extract is added from 0.3 to 0.9 % of the weight of the cement to the mixing water corresponding to a w/c ratio of 0. 55, which could be due to the fact that, when the rubbery cedar extract is added, the amount of cement decreases, since it is added to the concrete in % with respect to the weight of the cement, so when the inhibitor concentration is increased, the cement is reduced, thus decreasing the hydration components because it depends on water and cement, which translates into an increase in compressive strength according to Abdulsada & Török (2019). Figure 3 shows the strength increase efficiencies of concrete manufactured under varying amounts of extract, relative to the target samples of each w/c ratio. It was reported the growing of the compressive strength of the normal-strength and highstrength specimens fluctuates with increasing steel slag content, adding more than 80% of steel slag pursuant to Guo et al. (2019).

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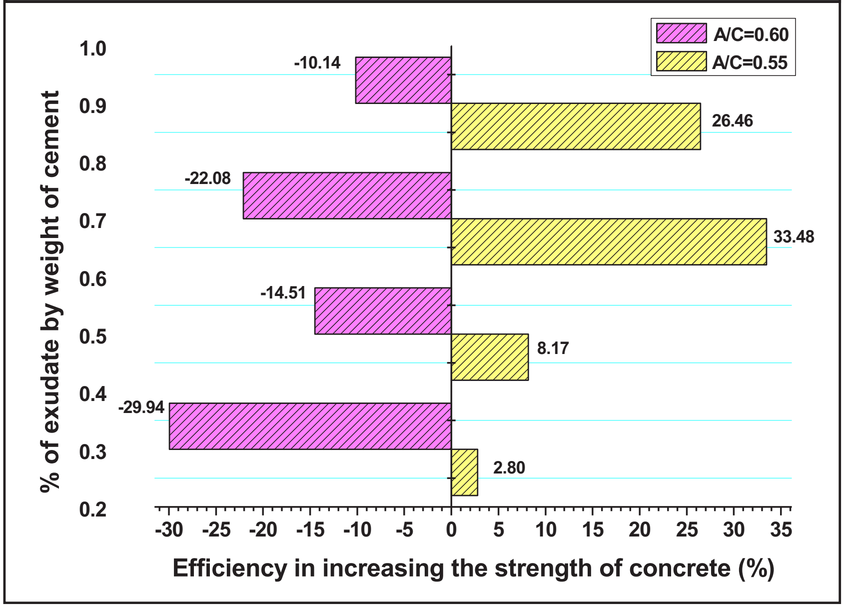
Figure 3. Efficiency of Cedar exudate on compressive strength of concrete with respect to white sample. Source: Own elaboration.



As shown in Figure 3, the highest efficiency obtained was 33.48 % under a concentration of 0.7 % of the extract and with the a/c ratio of 0.55, conditions under which an increase in the workability of the fresh mixture was obtained with respect to the white mixture. On the other hand, it should be noted that under this same amount of water the efficiencies increased with the addition of the extract from 0.3 % to 0.7 %. However, it decreased to 26.46 % when implementing 0.9% of the substance. On the other hand, the efficiencies under the w/c ratio of 0.6 were negative, which evidences the decrease in strength with respect to the target sample, when using any of the amounts involved of the extract in the concrete mix. In relation to the above, the most negative efficiency was presented under the addition of 0.3 %, and the least negative under 0.9 %.

Conclusions

The manageability of the mixture was substantially improved with respect to the target using: 0.7% exudate for w/c ratio of 0.55, and 0.7% and 0.9% exudate for a w/c ratio of 0.6. The use of exudate at any ratio evaluated increased the resistance to compression with a w/c ratio of 0.55, obtaining efficiencies of more than 3% in all cases evaluated. The addition of 0.7% exudate showed better performance in increasing the resistance and manageability of the mixture with respect to the standard sample.

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