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Physical-Mechanical Properties Of Concrete Mixtures Incorporating Sugar Cane Molasses

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Abstract:

The rapid industrial growth has led to the need to create new construction materials from organic wastes and agroindustrial, by-products in order to reduce environmental impacts and raw materials, generating an ecological material. The objective of this article is to determine the physical-mechanical properties of concrete mixtures incorporating sugar cane molasses as an alternative material to retarding and plasticizing agents in dosages of 0% to 1%, in order to determine the optimum dosage of this material to be used as a retarding and plasticizing additive in concrete. The results of mixing the material indicated that at dosages of 0.4% and 1% molasses, results similar to those of a comercial, plasticizer are achieved, In addition, it was identified that the incorporation of molasses causes a substantial improvement in the strength of the concrete. From the results obtained, it is evident that the use of molasses as a plasticizing and retarding agent is a viable alternative considering the physical and mechanical properties of the material.

Keywords: Molasses, sugar cane, concrete, dosages, workability, compressive strength.

1. INTRODUCTION

Concrete has been used in civil engineering projects including road surfaces, housing, buildings and bridges, despite having disadvantages such as low tensile strength, imperfect flexibility and low resistance to early crack propagation (Ahmad & Zhou, 2022). Thus, rapid industrial growth has led to the need for improved materials in terms of strength, stiffness and density (Rajak et al., 2019), along with the production of greener concrete to preserve the environment, using waste materials or industrial bioproducts (Patnaik et al., 2022).

To promote the sustainable development of concrete, the replacement of components such as aggregates with mineral or natural admixtures is included in order to obtain socio-environmental benefits (Wu et al., 2022). Organic wastes and agro-industrial by-products are of great importance to replace traditional materials, providing ecological and cost-effective materials for the population (Pappu et al., 2007). Natural fibers are composed of lignocellulosic materials obtained from natural plants and agro-industrial waste (Karade, 2010); these fibers as reinforcement in concrete enable thermal recycling, ease of use, lightweight structures and specific strength properties so their use in construction offers an alternative for their elimination and raw material reduction (Rohan et al., 2018).

In a construction exists is the need to reduce the percentage of water/cement ratio in order to increase the strength of concrete without affecting the flowability of the mixture (Mansor et al., 2018). Molasses is the by-product of the sugar industry and can be considered as a possible water-reducing mix for concrete (Rashid et al., 2019), being a sustainable alternative as an admixture, which allows modifying the behavior and structure of concrete, enhancing or reducing its characteristics. The objective of this article is to determine the physical-mechanical properties of concrete mixes incorporating sugar cane molasses as an alternative material to retarding and plasticizing agents in dosages from 0% to 1%.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Cement and Aggregates

The cement used during the laboratory tests was Portland cement for general use (UGC) from the Argos company, to which laboratory tests were carried out to determine the specific gravity and bulk loose density, which for the material used corresponds to 3.08 g/cm3 and 1150 kg/m3 respectively. The fine and coarse aggregates used were washed natural aggregates obtained from the A&G E.U. crushing plant located in Curumani - Cesar.

2.1.2. Molasses

Sugarcane molasses is a dark brown syrupy liquid, a by-product of the sugar industry, its composition is influenced by factors such as crop characteristics, soil type, ambient temperature, humidity, production season, production practices and storage variables (Table 1), due to this, variation in nutrient content, flavor, color, viscosity and total sugar content can be found (Behar, 2017). Molasses was obtained from agricultural deposits in the municipality of Ocaña, Norte Santander, with an incorporation of molasses in dosages from

0% to 1%, measuring its influence on the behavior of the concrete, both in fluidity, setting time and resistance in different curing periods.

Table 1. Components and properties of molasses

Color	Marrón oscuro
Status	Liquido
Specific Gravity	1.4 g/cm^3
pH	5.0
Humidity	26% (a 110ºC)
Ash	12.30% (por calcinación 550ºC)
Organic Matter	61.7% (por calcinación 550ºC)
Total Humic Extract	56.5%
Total Nitrogen	1.3%
Total Phosphorus	0.5%
Total Potassium	4.0%

Source: (Otunyo & Koate, 2015).

2.2. Experimental design

The experimental design consisted of dosages of 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% of commercial sugar cane molasses, where the physical and mechanical components of the concrete were evaluated, in order to determine the optimum dosage of this material to be used as a retarding and plasticizing additive in concrete. For the slump test, the number of tests were carried out for the 6 dosages, plus 1 with conventional additives, performing two tests at 0 Min, 30 Min and 60 Min, for a total of 21 tests. In the case of mechanical resistance, a total of 97 tests were carried out, an average of 5 specimens for the ages of 7, 14 and 28 days, for the 6 dosages and 1 with conventional additive.

2.3. Mix design

Two mix designs were proposed, one by the (ACI) method and the other by the graphical method; however, it was observed that the graphical method had better results (Table 2), by analyzing the accuracy of each design, taking the selected slump as an evaluation criterion and therefore, the dosages were calculated using this method.

Table 2. Design by graphical method

Descripción	**Value**
Volume without aggregates (lt)	**320,1**
Volume of fine aggregate (lt)	**326,3**
Coarse aggregate volume (lt)	**353,5**
Volume of cement (lt)	**121,11**
Volume of aggregates (lt)	**679,9**

Weighted density (aggregate)	**2,70**
Total weight of aggregates (kg)	**1833**
Check weight of aggregates (kg)	**1833**
Absorbed water sand	**17,8**
Absorbed water gravel (1 1/2")	**14,4**
total weight of cementitious mass (kg)	**369**
loose unit mass of sand	**863**
loose unit mass of 3/4" crushed material	**969**
quantity of water	**199**

3. RESULTS

3.1. Physical properties

The analysis of the physical properties for concrete is influenced by the incorporation of molasses, which corresponds to the workability obtained through the slump of the material, being a property that directly affects the strength, quality, appearance and even the cost of labor for the operations. From the data obtained, the following graphs are obtained to identify, as a function of the dosage, those mixtures that present a higher slump, here is also included the design of a mixture with the incorporation of a commercial plasticizer, in this case PLASTOL HR DM (figures 1 and 2).

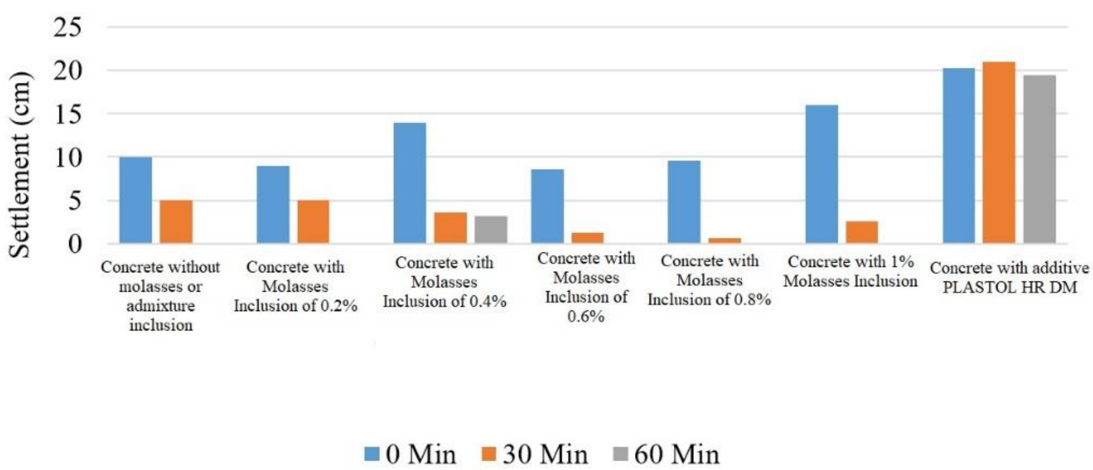


Figure 1. Orange cone settling results.

It is evident that the use of the commercial plasticizer provides a higher workability on the concrete mix that is maintained after 30 and 60 min. However, in the dosages of 0.4% and 1% molasses, similar results are achieved after the mixing process, although they are not retained beyond 30 min.

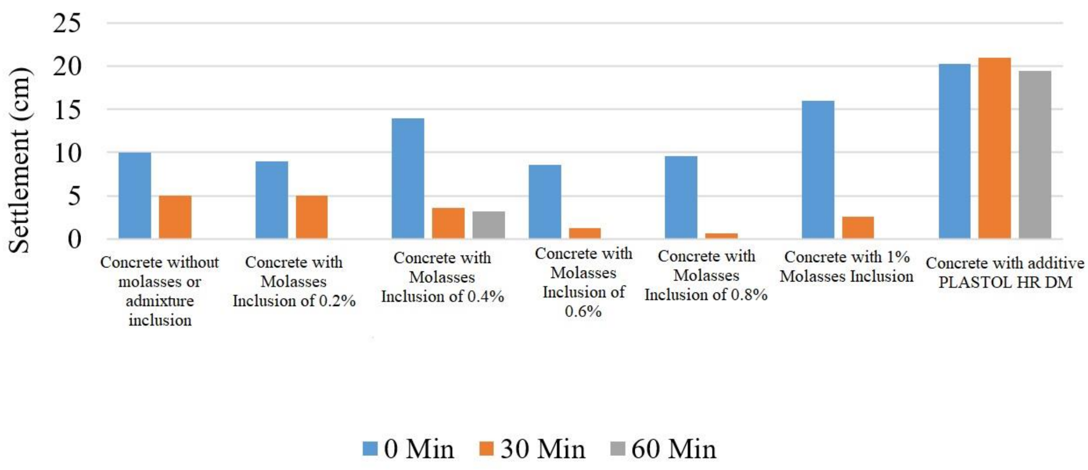


Figure 2. Gray cone settling results.

3.2. Mechanical Properties

In the mechanical properties of the material, the mechanical strength of the concrete was measured in the specimens, following the NTC 673 standard, where the compressive strength was determined by applying an axial compressive load until failure occurs. In this sense and following the specifications of the standard, the test specimens were tested with dosages of 0.0% 0.2% 0.4% 0.6% 0.8% 1.0% and admixture with admixture. These specimens were tested at 7, 14 and 28 days, the results obtained are described in Table 5 of concrete strength averages.

Table 3. Concrete Strength Averages

Type of concrete	**Average strength f'c at 7 days.**	**Average strength f'c at 14 days.**	**Average strength f'c at 28 days.**
Concrete without inclusion of molasses or admixture	2294,50 psi	2474,71 psi	2906,27 psi
Concrete with molasses inclusion of 0.2%.	3674,90 psi	4270,28 psi	4662,97 psi
Concrete with 0.4% molasses inclusion	2954,79 psi	3619,79 psi	4106,03 psi
0.6% molasses-inclusive concrete	3545,45 psi	4380,87 psi	4575,22 psi
0.8% molasses-inclusive concrete	987,71 psi	3442,48 psi	4167,43 psi
1.0% molasses-inclusive concrete	105,88 psi	1075,82 psi	3981,87 psi
Concrete with PLASTOL HR DM admixture at 0.65%.	1652,71 psi	2446,79 psi	2688,71 psi

Figure 3 shows the average results of the strengths achieved, where it is shown that most of the designs reached minimum design values, such as 2100, 2400 and 3000 psi at 7, 14 and 28 days. The incorporation of molasses seems to indicate a substantial increase in the strength of the concrete, showing better results with dosages between 0.2% and 0.6%, contrary to what occurs with the use of admixture for which the strength is reduced in the first 7 days, increasing later for 14 and 28 days, without exceeding the values of the reference mix.

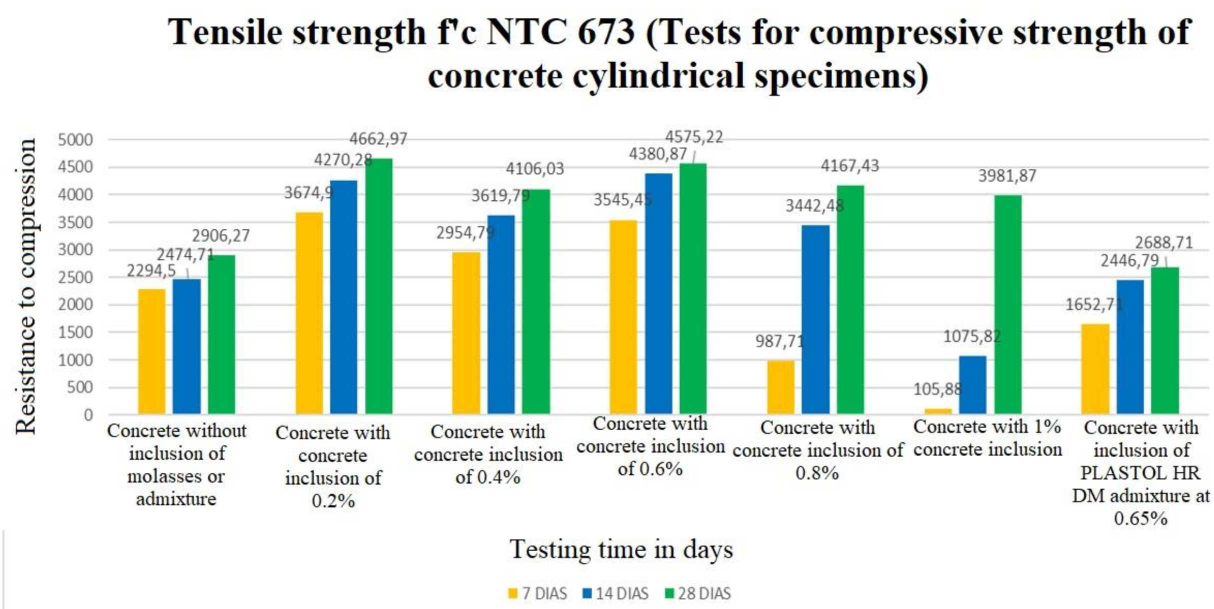
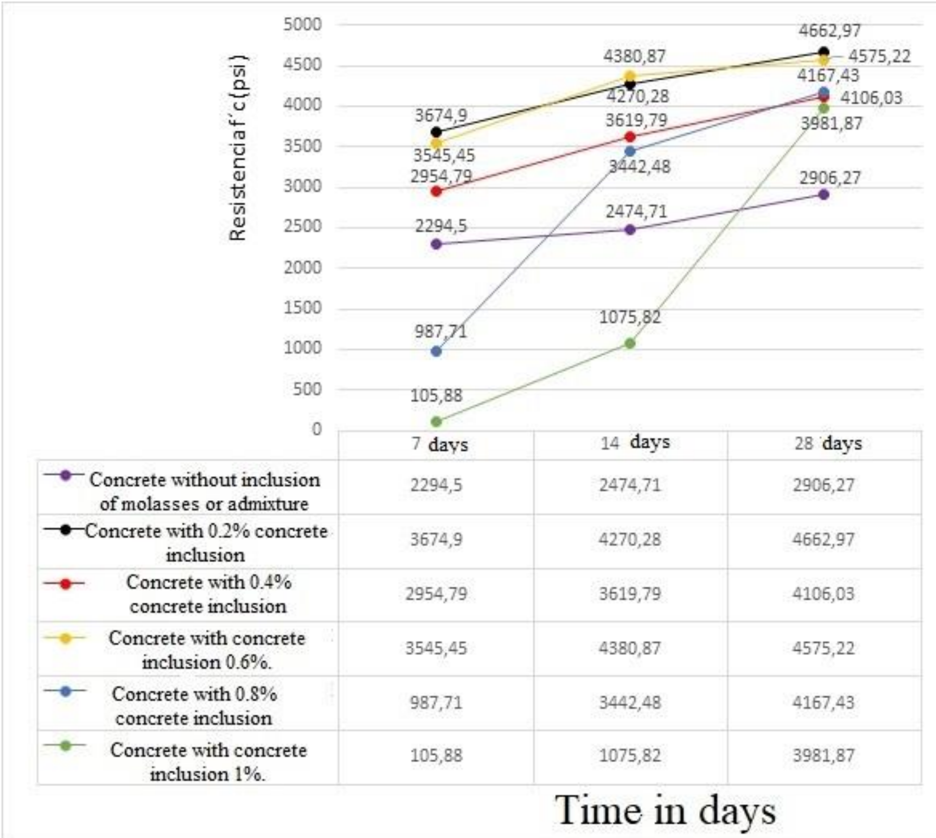


Figure 3. Average resistance values of the different mixes.

In addition, Figure 4 shows the trend of increasing average strength values at 7, 14 and 28 days for the different concrete mixes.

3.3. Variation of concrete behavior

Figures 5 and 6 show detailed images of the interaction of the cementitious paste with the molasses with a degree of detail varying from 130µm to 40µm. In general, a typical structure of interaction of the cementitious matrix with the aggregates can be observed, and a particularly rough surface can be seen.



	7 days	14 days	28 days
Concrete without inclusion of molasses or admixture	2294,5	2474,71	2906,27
Concrete with 0.2% concrete inclusion	3674,9	4270,28	4662,97
Concrete with 0.4% concrete inclusion	2954,79	3619,79	4106,03
Concrete with concrete inclusion 0.6%.	3545,45	4380,87	4575,22
Concrete with 0.8% concrete inclusion	987,71	3442,48	4167,43
Concrete with concrete inclusion 1%.	105,88	1075,82	3981,87

Figure 4. Trend graphs of the average strength values of the different mixes.

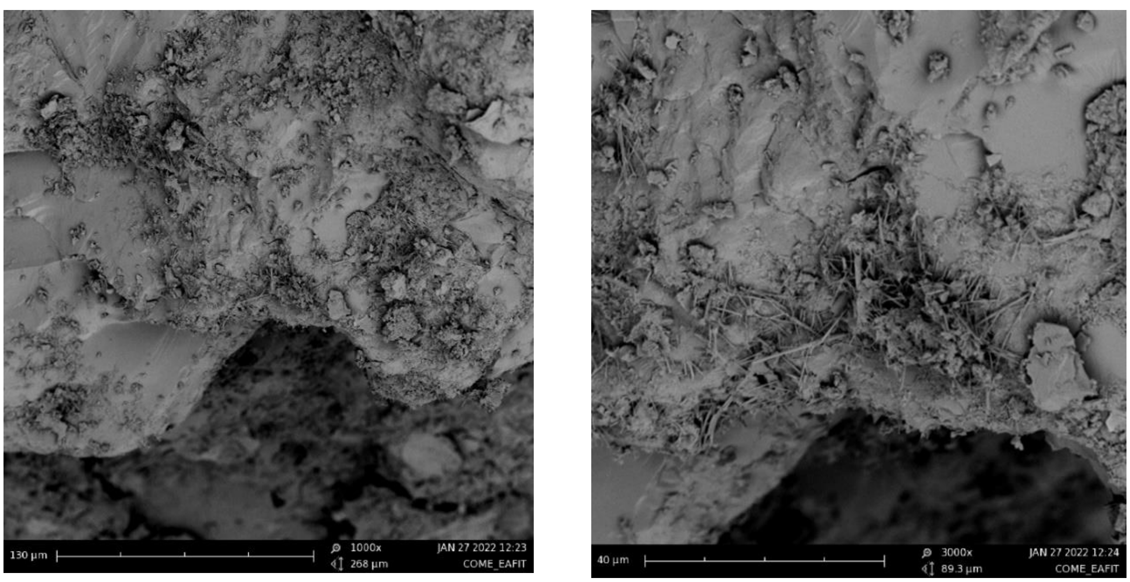


Figure 5. Images of the concrete sample with 0.2% molasses.

In Figure 6, cracks can be identified both in the cementitious paste and in the surrounding zone of the aggregate, the cracks range from 11.1 µm to 8.94 µm, these cracks in the aggregate-cement interaction space suggest a dehydration of the concrete or are associated with the internal process that the concrete undergoes when it shrinks during setting.

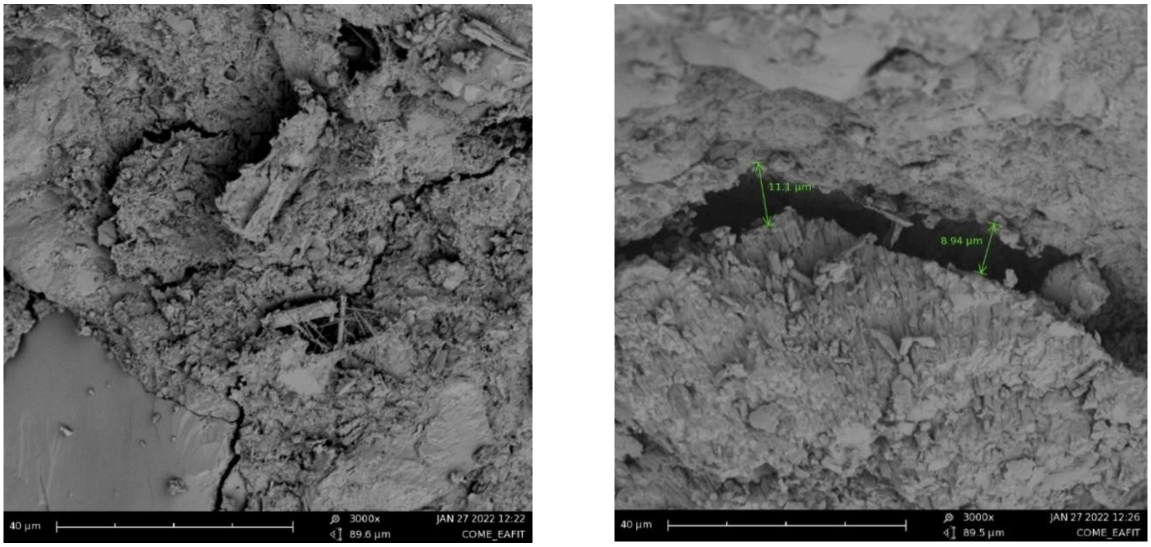


Figure 6. Microcracks in the cementitious matrix.

The data collected suggest that the incorporation of molasses into the concrete mix, although it could compromise the load-bearing capacity of the material, is adequately integrated into the mix, allowing good adherence between the paste and the aggregates. Subsequent studies could analyze the setting of the material at the microscopic level to identify whether the presence of microcracks is due to dehydration of the material or to setting shrinkage.

4. CONCLUSION

The research developed proposed the incorporation of molasses in concrete mixtures in dosages of 0.2%, 0.4%, 0.6%, 0.8% and 1.0%. The physical properties of the material indicated that in the dosages of 0.4% and 1% of molasses, results similar to those of a plasticizer of commercial use, in this case PLASTOL, are achieved after the mixing process, an adequate workability is maintained up to 30 min after the mixing process. In addition, an incorporation percentage of 0.4% achieved the best results in time, maintaining workability up to 60 minutes after mixing.

With respect to the mechanical properties of the material, which were measured from the compressive strength tests, it was identified that the incorporation of molasses causes a substantial improvement in the ultimate strength of the concrete; this property may be related to the reduction of mixing water, improving the water/cement ratio; it also provides better results than the conventional plasticizer in terms of strength for the different ages (7, 14 and 28 days) and with the dosages of 0.2% and 0.6%, the highest strength values were achieved at the different curing ages. 2% and 0.6%, the highest strength values were achieved at the different curing ages, but from 0.8% onwards, a drop in the average strength values is observed.

The analysis performed with scanning electron microscopy (SEM) images showed that the molasses was adequately integrated into the mix, allowing good adherence between the paste and the aggregates. However, it was possible to identify microcracks that could be associated with dehydration of the material or shrinkage due to setting. From the results obtained, it is evident that the use of molasses as a plasticizing and retarding agent is a viable alternative considering the physical and mechanical properties of the material. This achieved substantial improvements in the workability of the mixes and in the strength of the concrete. With the percentage of 0.4%, the highest workability in the mixes was achieved and with 0.6%, the highest strengths were achieved.

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