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Verification of compression resistance between a conventional concrete and its addition of 5, 10 and 15% in volume of fly ash replacing fine aggregate

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Abstract. A comparative analysis was performed with regarding the compression resistance of a conventional concrete mixture and its experimental addition of 5, 10 and 15% of fly ash with respect to the volume of its fine aggregate. The fly ash came from the thermoelectric Termotasajero located in the city of Cucuta in the Norte de Santander Department, Colombia, the previous studies performed on fly ash by the thermoelectric laboratories were useful as a reference to classify the ash. The results obtained in the compression tests for the experimental mixtures were compared to the results of the conventional concrete, where a superiority in the resistance of the experimental mixtures in early stages (7 days) was evidenced. Regarding tests performed on day 14 a minimum difference when comparing the mixtures was noted. The resistance test performed on day 28 showed superiority on the conventional mixture with a 2.03 Megapascals advantage with respect to the strengths of the experimental mixes.

1. Introduction

Concrete, a versatile and durable mixture that since its invention became the principal element in most engineering projects, has been object of diverse research studies in their urge to contribute on the sustainable development of engineering works, elaborating innovative mixtures through the inclusion of non-conventional materials with the purpose of conserving and improving its properties. There are various factors that condition the durable properties of concrete. Among them, from the internal perspective, are the composition and distribution of its components or raw material, as well as characteristics of its own structural design [1]. The inclusion of waste materials from industrial or discarded processes in concrete mixtures, is a booming practice in the scientific community that progressively and quickly advances in the search of non-contaminant materials that are friendly for the environment. The construction industry has evolved over time, and along with it, research about the raw materials it demands. In the past years, studies about materials that could be added to cement and concrete have been performed, with the purpose of benefiting the production process without decreasing its quality [2]. The decrease in the environmental impact from the extraction and fabrication of materials used in concrete is a subject of collective interest, the current environmental problems woke the ecological consciousness of humanity, showing in a tangible form the changes



inherent to its deterioration, for that reason the research is focused on good practices for the elaboration of concrete. The scientific community has researched about possible solutions to the environmental problems that emanate from the elaboration of concrete [3], being the material with the greatest demand for engineering projects, used in all kinds of infrastructure, with structural and non-structural purposes [4].

The researches performed have demonstrated that both natural and artificial pozzolanic materials, could be a viable option for replacement of cement in concrete mixtures. Fly ash are a type of artificial pozzolan, which improve the microstructure of hydrated cement and its durability [2], being the result of burned coal in industrial processes, its application to these types of mixtures considerably benefits its handling as waste, a beneficial condition for the environment.

The present research work shows the values obtained in the verification compression resistance of a conventional concrete mixture and its percentage addition of fly ash, in volume, as replacement of fine aggregate.

2. Materials and methods

Fly ash resulting from coal combustion was recollected in the thermoelectric Termotasajero, located in the city of Cucuta-Colombia. The performed analysis to the fly ash were taken as samples in the laboratories of the company, following the parameters described in the international standard ASTM C31 [5].

The project developed a type of experimental research that contemplated the elaboration of 12 mixing cylinders for 4 designs of different concrete mixtures, the cylinders were made according to the methodology described in the standard ASTM C31 and then were tested according to the stipulated in the standard ASTM C39 [6]. For the analysis of the results obtained in the laboratory tests, the factorial experiment method was implemented, since there were independent variables for each one of the mixture designs.

A conventional concrete mixture (MC) was elaborated with the values and quantities of materials stipulated for its design, its compression strength was verified through the elaboration of 3 cylinders that were tested at day 7, 14 and 28 in the universal machine IBERTEST from the Universidad Francisco de Paula Santander, Cúcuta. The 5, 10 and 15% of the fine aggregate for the design of mixes used in the elaboration of conventional concrete mixes were replaced with fly ash. Each % of fine aggregate replaced implied the elaboration of an experimental concrete mix (MC5, MC10, MC15), respectively, 3 mixing cylinders were taken and tested at day 7, 14 and 28, just as the conventional concrete mix. The results of verification for compressive strength of the concretes with fly ash were analyzed and compared to the results obtained for conventional concrete.

2.1. Evaluation of fly ash properties

Taking as reference the abstract of fly ash characteristics taken by Romero A and Hernandez J, from the thermoelectric Termotasajero, the characteristics of the waste material could be visualized in the Table 1.

2.2. Conventional concrete mixture design

Ordinary Portland Cement type I (Cemex Brand) was used. It met the established classification and nomenclature by the NTC30 [8] Standard along with the methods NTC121 [9] and 321 [10] for its analysis. The aggregates of the mix came from the company Transmateriales located in Cucuta, where the methods described in the NTC77 [11], 92 [12] and 176 [13] were applied for its evaluation, the dosage of the mix consisted on the quantification of the materials used in it with the purpose of determining the adequate quantities, in weight and volume, to meet the required characteristics in the standard ASTM C33 [14]. The water used in the mixture met with the established standards of the NTC3459 [15]. All the previously mentioned, was performed following the guidelines of the NSR-10 (Earthquake Resistant Standard) [16] in its Title C, which standardizes structural concrete.

Table 1. Fly ash characteristics Termotasajero [7].

Characteristic	Value %
Humidity content	0.17
Loss of ignition	7.96
Silicon oxide (SiO ₂)	53.21
Aluminum oxide (Al ₂ O ₃)	26.74
Iron oxide (FeO ₃)	9.15
Calcium oxide (CaO)	0.59
Magnesium oxide (MgO)	0.45
Sodium oxide (Na ² O)	0.16
Potassium oxide (K ² O)	0.64
Titanium dioxide (TiO ²)	1.28
Phosphorus pentoxide (P ₂ O ₅)	0.52
Sulfuric oxide (SO ₃)	0.01
Barium oxide (BaO)	0.14
Stronium oxide (SrO)	0.03
Density	2.103
Combustibles	7.8
Classification	Class F

2.3. Designs of experimental mixtures

With the data of the quantity of materials to use in the design of the mix for conventional concrete along with its weights in relation to the preparation of 1m³, we proceeded with the calculation of the volume of the percentages of fly ash that would replace the fine aggregate for each of the experimental mixtures (Table 2).

Table 2. Mixture design for 1m³ of conventional concrete.

Material	Density (g/cm ³)	Humid weight (Kg/m ³)	Volume for 1m ³
Cement	3.1	396.15	0.127
Fine aggregate	2.42	681.57	0.281
Coarse aggregate	2.5	924.33	0.369
Water	1	238.32	0.238

The process in the designs of experimental mixes was supported by the method ACI-211.1 [17] where the steps for the procedure of designs of mix with fly ash is described. The resulting of the coal combustion is considered waste and must be used to change its state from waste to useful material [18].

The Table 3 describes the proportions of fly ash added to the MC and the corresponding % quantity in volume based in the total volume of fine aggregate for 1m³ of concrete (MC+).

Table 3. Substitution proportions of fine aggregate for ashes.

Mix	% aggregated ash	Volume m ³
MC	-	-
MC5	5	0.0140
MC10	10	0.0281
MC15	15	0.0422

3. Results

In the past 30 years, fly ash has been increasingly used as an additive for different purposes, giving benefits to the characteristics and properties of the intervened mixtures, the useful application of the material significantly reduces its environmental impact as waste of an industrial process [19].

The comparative analysis of the results obtained in the mechanic tests that proves the compressive strength of the conventional concrete compared to the experimental mixes, shows resistance superiority at 7 days on the mix MC10 (Figure 1).

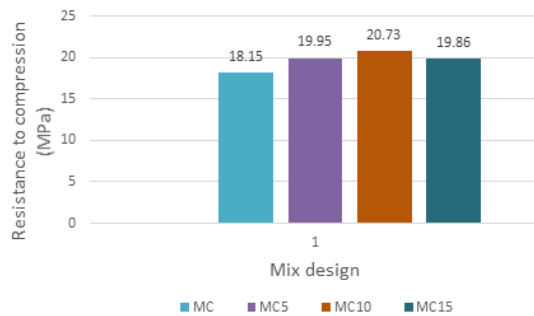


Figure 1. Resistance to compression at 7 days.

The compression resistance comparison at day 14 assumed by the mixes shows results with minimum differences between the mixtures MC, MC5 and MC15, and it also shows the mix MC10 with the highest resistance, but with a minimum superiority compared to the rest (Figure 2).

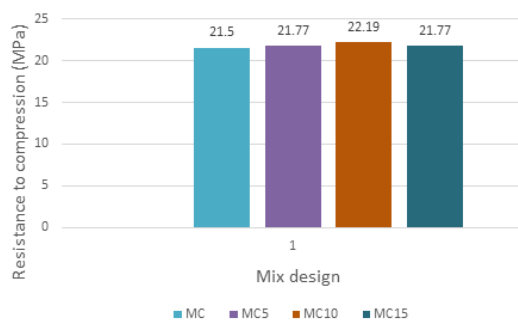


Figure 2. Resistance to compression at 14 days.

In the data obtained in the compression test on day 28, a considerable change is observed, where the mix MC significantly increased its resistance compared to the experimental mixes, which maintained a minimum difference between each other (Figure 3).

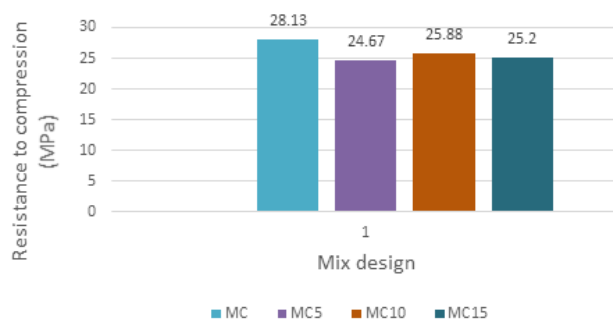


Figure 3. Resistance to compression at 28 days.

4. Conclusions

In the experimental research project performed, results of interest were evidenced, which give a lead to successful conclusions regarding the usage of fly ash from the thermoelectric Termotasajero in Cucuta as a replacement of fine aggregate for the elaboration of concrete mixes. The compression resistance of the experimental mixes on day 7 was superior to the conventional mix by an average of 2.03 Megapascals (Mpa). At day 14 the compression resistances of the mixes MC5 and MC15 did not get a great advantage with respect to the MC mix, with a difference of only 0.27Mpa. The resistance obtained on day 28 from the MC mix, considerably exceeded the experimental mixtures with an

advantage of 2.25Mpa compared to the mix MC10, which had the highest resistance out of the 3 experimental mixes. According to the information obtained from previous studies of fly ash from Termotasajero and the chemical laboratory test made by Cemex, we were able to conclude a classification type F, according to NTC3493, characteristic that makes viable its usage as aggregate in concrete mixtures. The concrete industry consumes raw materials massively. As the demand for cement increases, one of the efficient ways to minimize the detrimental effect of concrete, is to improve its structural performance, efficiency and durability, leveling or improving its characteristics through the usage of waste elements or materials from industrial processes, a beneficial replacement for the environment since it would give utility to waste.

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