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CORN COB ASH AS SUSTAINABLE PUZZOLANIC MATERIAL FOR AN ECOLOGICAL CONCRETE

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Abstract: *The present research aimed to reveal the effects of 5%, 10% and 15% volume replacement of cement by corn cob ash (CCA) on the concrete density, compressive strength, flexural and splitting tensile strengths. According to the experimental results, CCA decreased the values for compressive and tensile strength of the concrete, but it improved its density. There can be mentioned that, in spite of the negative effect on the mechanical properties of the concrete, an economy of 5% of cement led to a concrete appropriate to be used in building lighter structures with around 6%, an important gain from the point of view of seismic building behaviour.*

Key words: *vegetal ash, mechanical properties, density.*

1. Introduction

"Ecologic" is a general concept met all around us. Building materials industry is no exception as it has a very significant share in environmental pollution. As the concrete is the most common material of this industry, its greening is very important, this being an over studied subject for decades all over the word. The main component of the concrete that is responsible for important green house gas emissions is the Portland cement. Its substitution with alternative puzzolanic powders can help to reduce the environmental pollution. Such a puzzolanic material can be represented by corn cob ash (CCA). Its puzzolanic properties are due to the presence in its composition of a significant proportion of SiO_2, between 37.00 - 67.33%, substance that is directly implied in the puzzolan reaction [4].

CCA can be a sustainable puzzolanic material due to the fact that the production of grain maize and corn cob mix is on the third place in total EU-28 grains production. In Romania, the corn crop has an important share in the country's agriculture, in 2015 Romania being ranked in the second place in Europe in corn production [3].

Corn cobs represent around 15% of the maize total production [1]. They are usually used as animal feed, soil fertilizer [1] and, sometimes, for domestic heating, but are mainly considered as agricultural waste disposed by burning on the field [6]. According

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to [3], the corn production has an increasing trend, therefore the waste derived is also increasing, this being another reason to find solutions to reduce their environmental impact.

CCA specific weight was reported as 1.15 g/cm^3 by [7], 2.18 g/cm^3 by [5], or 3.11 g/cm^3 by [2]. Its dry density is 2180 kg/m^3, and its bulk density is 923 kg/m^3 [5]. A study made on concrete with CCA as partial replacement of cement revealed that 8% CCA improves the compressive strength of the concrete with 10% by using an accelerator additive, with 14.3% by using a water reducer and retarder, and with 29.1% by using a plasticizer. The density of concrete decreases with around 8% in the case of 40% CCA using [5].

The present research aimed to study the effects of 5%, 10%, and 15% volume replacement of cement by corn cob ash, on the concrete density, compressive and tensile strength.

2. Experimental Protocol

In this research were studied four cement micro concrete mixes, as follows:

- a reference concrete mix (RC) that contained the conventional elements: cement, river aggregates, water, and the super plasticizer additive.
- a concrete mix with CCA, based on RC, were 5% of the cement volume were replaced with CCA (CCCA5).
- a concrete mix with CCA, based on RC, were 10% of the cement volume were replaced with CCA (CCCA10).
- a concrete mix with CCA, based on RC, were 15% of the cement volume were replaced with CCA (CCCA15).

Cylinders with 100 mm diameter and 200 mm length were used as samples for density determination, compressive strength, and splitting tensile strength tests. For flexural tensile strength tests, were used prisms with transversal section of 100x100 mm and 550 mm length. Each test were performed in three replicates for each micro concrete mix.

3. Materials and Methods

The composition of the developed cement concrete mixes implied the following raw materials:

- three sorts of river aggregates: gravel sort 4-8 mm and sort 8-16 mm, and sand with the diameter up to 4 mm.
- cement, type CEM II/B-M (S-LL), with granulated blast furnace slag and limestone [8], of 42.5 R strength class, produced in Romania.
- a super plasticizer additive.
- corn cob ash (Figure 1) obtained by free burning in an enclosed brick oven of corn cobs gathered from Botosani county, Moldova region, Romania.

a. *b.*

Fig. 1. *The aspect of corn cob ash (a), comparatively presented to cement (b)*

The RC mix was a micro concrete of C30/37 strength class. For RC, CCCA5 and CCCA10 was used a w/c ratio of 0.50 by volume. In the case of CCCA15 was necessary to maintain the same level of workability; increasing the volume of the CCA in the mix led to the decrease of the micro concrete workability. For a volume of CCA higher than 10% of the cement, a w/c ratio of 0.5 was insufficient to provide a workable concrete mix, so that this ratio was increased to 0.52.

The method used to produce the studied micro concrete mixes was as follows: the cement was mixed with CCA before to be added over the aggregates in the portable concrete mixer, and they were mixed as such up to a homogeneous mix obtaining, then was added the water mixed with the super plasticizer. The micro concrete was poured in the cylinder and prism moulds, it was determined the fresh concrete density according to [10], and than was unmoulded after 24 hours and kept in 65% humidity at 20^0C until the age of 28 days. After the curing period the concrete density, the compressive and tensile strength were determined according to [11-14].

4. Results

RC registered a density of 2260 kg/m^3 after the period of 28 days of curing, having a decrease of 4.2% than in the fresh state (Figure 2).

The addition of CCA led to a smaller density of the fresh and cured concrete, but not in the same proportions between the two states: CCCA5 had a density diminish in fresh state of only 0.13% but in the cured state of 2.44%; a value of 10% of the cement replacement led to a smaller density of RC with 1.21% in fresh state and 2.05% after 28 days; in the case of CCCA15, was registered a density decreased of 2.56% and 1.99% compared to RC, in the fresh and cured state, respectively, this bigger decrease of the density in the fresh state being due to the little-higher w/c ratio needed to provide an easy workability of the material. Overall, the lightest micro concrete studied mix was CCCA5, with a density of 2204.5 kg/m^3.

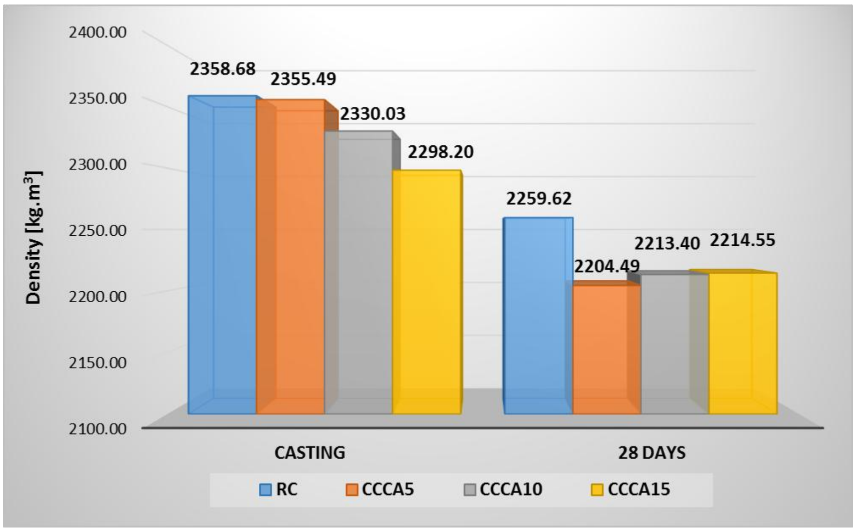

Fig. 2. *The density of the studied microconcrete mixes [N/mm²]*

Regarding the compressive strength (Figure 3), the replacement with CCA led to its decrease with 30%, 37.3% and 45.8% for an addition of 5%, 10%, and 15%, respectively.

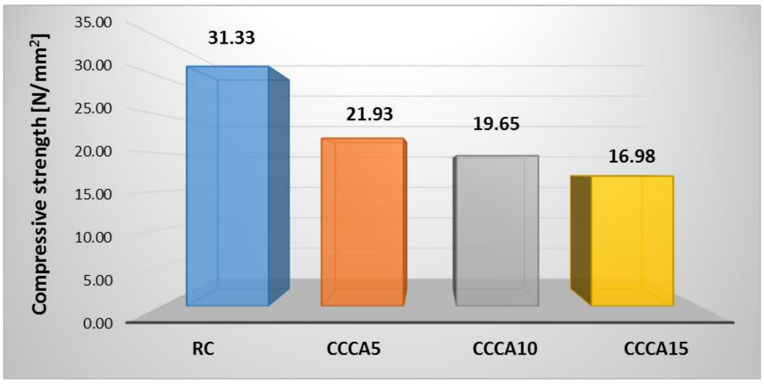

Fig. 3. *Compressive strength of the studied microconcrete mixes [N/mm²]*

In spite of the density trend, the compressive strength evolved in the opposited direction, the lightest mix, CCCA5, had the higher compressive strength between the micro concrete mixes with CCA. Even if a 5% of cement replacement with CCA decreased the compressive strenght by 30% compared to RC, increasing the level of cement replacement with another 5% (CCCA10) led to a smaller decrease of only 7.3% compared to CCCA5, and then, in the case of the third 5% replacement of cement (CCCA15) led to a 8.5% decrease compared to CCCA10. The 10% and 15% cement replacement with CCA led to a micro concrete mix with the same strength class, C16/20, that is considered a normal strength concrete used in structural purposes [9].

According to the experimental results of flexural tensile strength testing (Figure 5), it can be observed that CCCA5 had a very small decrease of 5.12% compared to RC. The CCCA10 and CCCA15 registered much smaller values than RC, with almost 31% and 39%, respectively. The 10% cement replacement with CCA determined a bigger level of flexural tensile strength decreasing compared to the 5% and 15% cement replacement with CCA, if the mixes with CCA are compared between them.

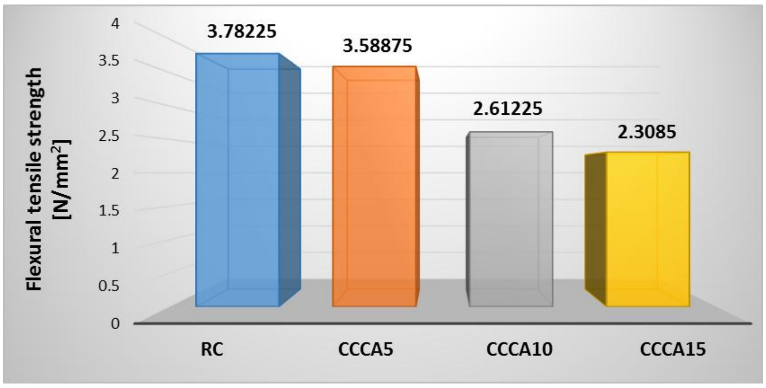

Fig. 4. *Flexural tensile strength of the studied microconcrete mixes [N/mm^2]*

Splitting tensile strength test results revealed that a 5% of CCA led to a smaller strength with 39.43%, and a 15% of CCA to a decrease with 49.45%, compared to RC (Figure 5). CCCA10 registered the biggest decreased compared to RC, of almost 62%. This can be explained by the fact that the CCCA5 and CCCA10 have the same w/c ratio of 0.5, and in the same conditions the increase of CCA amount decreased the splitting tensile strength of the micro concrete mixes. In the case of CCCA15 w/c ratio was a little higher, 0.52, and this led to a better result than CCCA10, even if the CCA amount was higher.

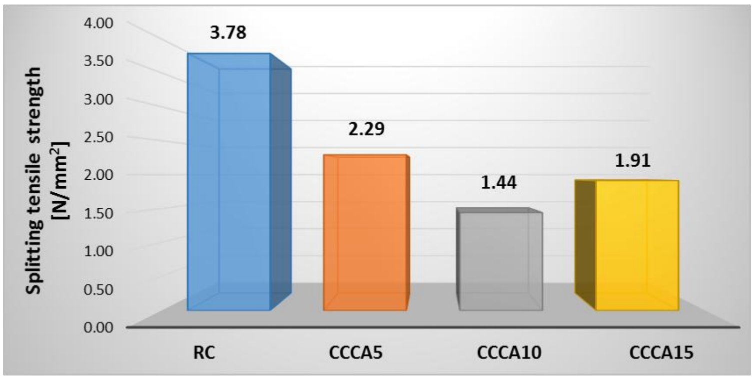

Fig. 5. *Splitting tensile strength of the studied microconcrete mixes [N/mm^2]*

5. Conclusions

According to the experimental results, CCA decreased the values for compressive and tensile strength of the concrete, but it improved its density**.**

From the point of view of all analysed parameters (density, compressive strength, flexural tensile strength and splitting tensile strength), can be concluded that the optimum level of CCA to be used in a micro concrete mix is 5%.

Acknowledgements

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