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A VARIANT OF GREEN CONCRETE WITH INDUSTRIAL AND AGRICULTURAL WASTE

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Abstract
The research presented in this paper aim to analyze the effects of cement replacement by fly ash in 10 vol. %, 20 vol. %, and 30 vol. % and, afterwards, the effects of mineral aggregates substitution by 50 vol. % with vegetal aggregates. The used vegetal aggregates were shredded corn cobs, and were investigated the density, the compressive and split tensile strength of concrete. The results revealed that fly ash, as cement partial replacement, decreased the compressive strength comparing to the reference concrete, meanwhile, the splitting tensile strength was improved when were used 10% and 20% vol. of fly ash. Fly ash had a positive effect on the compressive strength of the vegetal concrete, in the case of the composition with 10% and 30% vol. of industrial waste, and also on splitting tensile strength in the case of 10% and 20% vol. of replacement rate. The concrete density diminished with 1.67%, 3.12% and 3.82% in the case of 10%, 20% and 30% vol. cement replacement by fly ash, respectively. Corn cob aggregates led to a concrete density decreasing with almost 25% compared to reference concrete.

Keywords: *corn cob, density, fly ash, mechanical properties*

Introduction
Today, in our society, the accent is put more and more on sustainability, environment protection and CO_2 emissions decreasing. That is why, in terms of concrete production, the most used material in the construction industry, has become a must to make it as environmentally friendly as possible. This can be achieved by partially replace the cement and/or aggregates from its composition by industrial and agricultural waste. Fly ash, because there are very high quantities of waste disposed as landfill, and corn cobs, because they represent an easy renewable natural resource.

Fly ash is an industrial waste generated by the thermal plants, in quantities equal to 30-40% of the burned coal (Sun et al 2003), that is usually placed into landfills and becoming, in this way, a threaten for the environment (Aprianti 2017).

The concrete with fly ash represents an ecologic material that has been studied a lot up to now, but in this paper it is presented as reference for a concrete with vegetal aggregates and fly ash. Fly ash was used in the corn cob concrete in order to enhance its properties.

Used as cement partial replacement, fly ash has, in general, positive effects on the strength, sulphate action resistance, permeability and workability of the concrete (Badur & Chaudhary 2008), but this depends on its properties derived from the

combustion method and type of coal used (Aprianti 2017). Also, it decrease the hydration heat, this being an advantage for the mass structures (Meyer 2009).
Corn cobs represent an agricultural waste that is, either burned on the field (Pinto et al 2012a), either used as such as fertilizer on the harvested field (Ashour et al 2013). The corn cob aggregates can be used for obtaining a lightweight and sustainable ecoconcrete, they having a density of only 212 kg/m^3 (Pinto et al 2012a). The use of different kind of vegetal aggregates for such purposes is the subject of many researches all over the world. The advantages of vegetals in concrete composition are represented by their renewability, low cost and sustainability (Saxena et al 2011). They also ensure thermal (Paiva et al 2012) and acoustic (Asdrubali 2007) insulation properties. The concrete with corn cobs as conventional aggregates replacement, in particular, has not been very studied up to now. Faustino et al (2015) used corn cob granules coated with cement paste in concrete composition, and obtained a lightweight material with a density of 1680 kg/m^3; this low density was accompanied by compressive strength decrease compared to normal concrete made with conventional aggregates, sand and gravel. Pinto et al (2012b) studied the concrete with granulated corn cobs with bigger dimensions than those used by Faustino et al (2015), in a ratio of 6/1/1 (corn cob granules/ Portland cement/ water), obtaining a material with a density of 382.2 kg/m^3, and a compressive strength of 120 kN/m^2.
The research presented in this paper aim to analyse the effects of cement replacement by fly ash in 10 vol. %, 20 vol. %, and 30 vol. % and, afterwards, the effects of mineral aggregates substitution by 50 vol.% with vegetal aggregates.

Materials and Methods

The start point of the research was a reference concrete of 25/30 strength class, and on this basis, were developed concrete recipes with 10 vol. %, 20 vol. % and 30 vol. % cement replacement by FA, a concrete recipe with 50 vol. % of mineral aggregates replacement by corn cob aggregates and than these two variants were combined in order to study interconnection between fly ash and corn cobs.
The ingredients of the studied concrete recipes were as follows:
- natural sand (diameter 0–4 mm);
- river gravel (diameter 4–8 mm);
- cement type CEM II, with mineral additives and of 42.5R MPa strength,
- fly ash from CET Holboca, Iasi;
- two types of additives (a super plasticizer and an accelerator for concrete hardening);
- vegetal aggregates of corn cobs, shredded in granules smaller than 5-6 mm in diameter.

The developed variants of concrete were:
- RC – a reference concrete of 25/30 strength Class (manufactured according to NE012-1:2007);
- CFA10 – a concrete with 10 vol.% of FA as cement partial replacement;
- CFA20 – a concrete with 20 vol.% of FA as cement partial replacement;
- CFA30 – a concrete with 30 vol.% of FA as cement partial replacement;
- CCC50 – a concrete with 50 vol.% of corn cob granules as partial replacement of mineral aggregates;

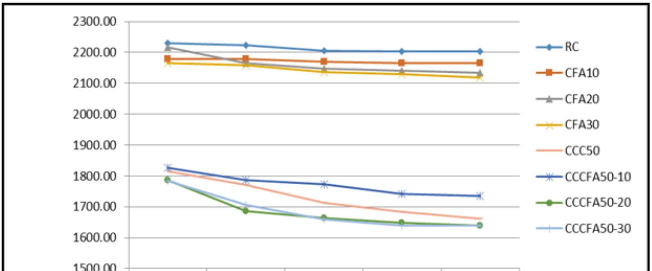
- CCCFA 50-10 – a concrete with 50 vol.% of corn cob granules as partial replacement of mineral ones and 10 vol.% of FA as partial replacement of cement;
- CCCFA 50-20 – a concrete with 50 vol.% of corn cob granules as partial replacement of mineral ones and 20 vol.% of FA as partial replacement of cement;
- CCCFA 50-30 – a concrete with 50 vol.% of corn cob granules as partial replacement of mineral ones and 30 vol. % of FA as partial replacement of cement.

The concrete was poured into cylinder moulds with 100 mm diameter and 200 mm length and were made three samples for each recipe. On the resulted samples was measured the apparent density and than were performed tests to determine compressive and splitting tensile strength, according to the norms in force (SR EN 12350-6:2010); (SR EN 12390-3:2009/AC:2011); (SR EN 12390-6:2010); (SR EN 12390-7/AC:2006). Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

Results and Discussion

Concrete density

Regarding the evolution of concrete density from casting till 28 days of curing (Figure 1), RC registered a 1.2% density decreasing and the CCC50 a 8.42% smaller density. The smallest density decrease of all was registered by CFA10, with 0.58%, and the biggest one by CCC50, with 8.42%. From the CFA category, the highest diminish was of CFA20, with 3.74%, and from the CCCFA group, the smallest diminish was of CCCFA50-10, with 4.99%.



	Casting	7 days	14 days	21 days	28 days
RC	2229.30	2222.93	2205.73	2202.55	2202.55
CFA10	2178.34	2178.34	2168.79	2165.61	2165.61
CFA20	2216.56	2166.24	2147.13	2140.13	2133.76
CFA30	2165.61	2159.24	2136.94	2129.30	2118.47
CCC50	1814.37	1769.8	1712.51	1683.86	1661.58
CCCFA50-10	1825.48	1785.35	1771.97	1742.68	1734.39
CCCFA50-20	1787.26	1685.35	1663.06	1648.41	1638.85
CCCFA50-30	1783.44	1705.73	1659.87	1638.85	1638.85

Figure 1. The evolution of concrete density, from casting till 28 days of curing [kg/m^3].

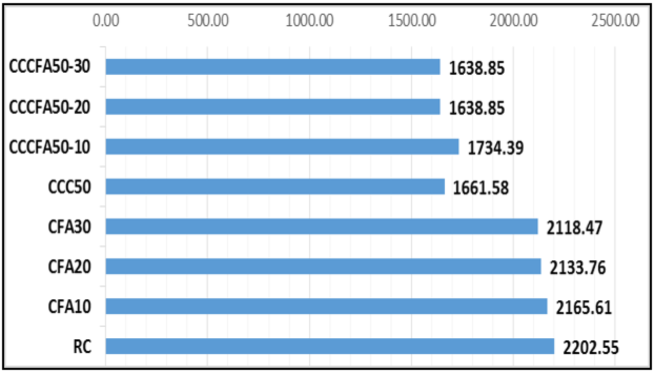


Figure 2. Concrete density at 28days, [kg/m^3].

The cement replacement by fly ash determined the density decreasing of the concrete, the smallest density from the CFA group being registered by CFA30 with a value of 2118, 47 kg/m^3, with 3.82% smaller than of the RC (Figure 2). The concrete recipe with corn cobs only registered a density diminish with 24.56% compared to RC. The group of CCCFA registered density values smaller than 1750 kg/m^3, the decrease being between 25,59% and 21.25 % compared to RC (Figure 2).

Compressive strength of the concrete

From compressive strength point of view (Figure 3), FA led to the decreasing of this property with 7.98%, 17.47% and 34.19% for 10 vol. %, 20 vol. % and 30 vol. % of cement replacement, respectively. The 50 vol. % of mineral aggregates replaced by corn cob ones determined a strong compressive strength diminish, with 85.90%.

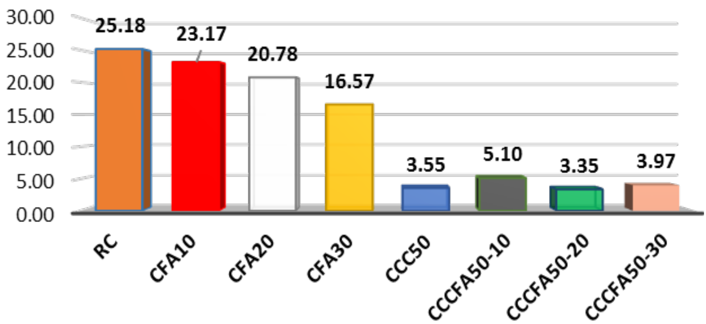


Figure 3. Compressive strength of the concrete [N/mm^2].

Fly ash association with corn cob aggregates revealed an improvement of the compressive strength in the case of 10 vol. % and 30 vol. % cement replacement, than CCC50, with 43.66% and 11.83%, respectively.

Tensile strength of the concrete

Regarding the tensile strength of the studied concrete recipes (Figure 4), FA led to the increase of the splitting tensile strength with 9.39%, 15.96% for 10 vol. % and 20 vol. % of cement replacement, respectively. The 50 vol. % of mineral aggregates replaced by corn cob ones determined a strong splitting tensile strength diminish, with 76.05%.

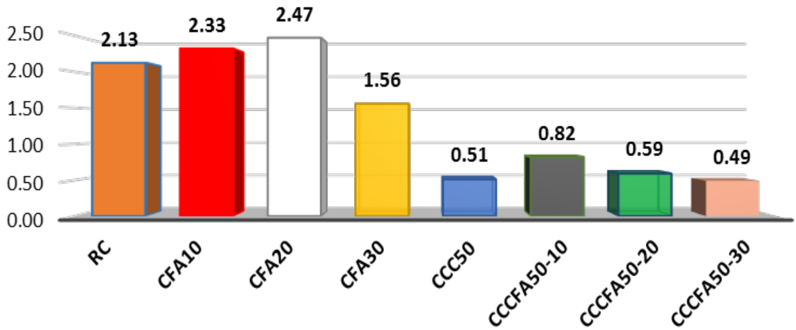


Figure 4. Splitting tensile strength of the concrete [N/mm^2].

Fly ash association with corn cob aggregates revealed an improvement of splitting tensile strength in the case of 10 vol. % and 20 vol. % cement replacement, with 62.19% and 15.68%, respectively, than CCC50.

Conclusions

A source of vegetable waste for building materials is represented by corn cobs. Analyzing the mechanical properties of concretes with corn cob aggregates, these had values much lower compared to the standard concrete. It seems that the association of fly ash with corn cobs aggregates had very positive effects on the vegetal concrete. In conclusion, the use of vegetable waste is adequate to achieve sustainable development in the constructions field. An advantage of these concretes is their weight, the obtained densities fitting them into the category of lightweight concrete which may have non-structural applications such as screeds, plasters or closures in the form of masonry blocks or panels.

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