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THE EFFECT OF SHEEP WOOL FIBERS AND DIFFERENT WASTES ON THE PROPERTIES OF ECOLOGICAL CONCRETE

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Abstract: *The aim of this research was to study the effects of the sheep wool fibers (SWF), silica fume, tire waste powder and limestone powder, on the density, compressive and tensile strength of concrete. There were investigated five variants of mixes: a reference concrete, a concrete with SWF, then three mixes of concrete with SWF and with silica fume, tire waste powder and limestone powder, respectively. The experimental results have revealed that SWF had a negative effect on the mechanical properties of concrete but a positive (downwards) effect on its 28 days density; also, the three powdered residues led to very significant improvement tensile properties of the concrete with SWF. Compressive strength values were smaller for concrete with SWF and silica fume and for the one with SWF and tire waste powder and slightly bigger for concrete with SWF and limestone powder.*

Key words: *silica fume, tire waste, limestone, mechanical properties, density.*

1. Introduction

Because the concrete industry has a very significant impact on the environment and on the health of living organisms [9], production of ecological concrete became a must. This kind of concrete can be obtained by using different pozzolanic materials such as silica fume [1] or fly ash as cement partial replacement or for geopolymer concrete obtaining [2, 6], or by using different kinds of agricultural, animal or industrial wastes, such as corn cobs, sheep wool, tire or limestone powder [3, 7, 8].

The benefits of using natural renewable materials in concrete are related to smaller production cost, lightweight concrete obtaining, improved mechanical, thermal or acoustical properties [5], [7]. Natural fibers are used in concrete as disperse reinforcement for improving its tensile strength, ductility, post-cracking behaviour, resistance to impact, thermal shock or spalling [8]. SWF are natural fibers appropriate to use in ecological concrete composition due to their advantages: good insulation properties, with a thermal conductivity coefficient of 0.037 W/mk, very close to glass wool but with an embodied

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energy at half of the glass wool (0.4 GJ/m^3 versus 0.83 GJ/m^3) [5]. SWF are of different grades, the finest ones being usually used in textile industry; the low grade coarse SWF, which have no use in textile industry, can be used in concrete composition, instead of its disposing. According to Štirmer et al., 2014, in European Union are about 90 million sheep producing 270000 tons of wool, and large amounts of this type of natural fibers are burnt or landfilled [5].

Silica fume is a by-product waste which is largely used as hydraulic admixture for obtaining high and ultra-high performance concrete with high resistant capacity, better behaviour to frost-thaw cycles and abrasion, resistant to chemical attack, and less permeable. It is used also for obtaining self-compacting concrete, fiber reinforced concrete, polymer concrete [1].

Concrete with tire wastes have high plastic energy capacity and show high strains under impact effects, present smaller density, higher elastic moduli [10], decreased mechanical properties, good thermal and acoustic performances, good behaviour to chemical attack and abrasion resistance [1, 3].

Limestone powder is used as alternative for natural conventional aggregates in concrete composition, being an inert waste which can improve the mechanical properties and workability of conventional and polymer concrete [1, 4].

The aim of this study was to determine the effects of the sheep wool fibers, silica fume, tire waste powder and limestone powder, on the density, compressive and tensile strength of concrete.

2. Experimental Protocol

The research implied five cement concrete mixes, as follows:

- a reference concrete (RC) mix made with cement, river aggregates, water and a superplasticizer additive;
- a concrete with SWF (CSW), based on the reference concrete plus 0.35% wt. SWF (from total quantity of concrete);
- a concrete similar to CSW with silica fume (CSWS);
- a concrete similar to CSW with tire waste powder (CSWT);
- a concrete similar to CSW, with limestone powder (CSWL).

The samples used for density determination and compressive strength test were cubes with sides of 150 mm. For flexural tensile strength test were used prisms with sides of 100x100x550 mm, and for splitting tensile strength test were used prism ends resulted after performing the tests for flexural tensile strength. Each test was made on three samples from each studied concrete mix.

3. Materials and Methods

The composition of the studied cement concretes involved the following raw materials:

- river aggregates: natural sand with the diameter up to 4 mm and two sorts of gravel with diameter of 4-8 mm and 8-16 mm, respectively;
- cement, type CEM II/B-M (S-LL), with granulated blast furnace slag and limestone [12], of strength class of 42.5R, produced in Romania;
- SWF of Ţurcana, a Romanian breed; the fibers were cut in 2-3 cm length (Figure 1) and were used in 0.35% of total concrete mass;
- silica fume, tire waste powder and limestone powder (Figure 2), each of them added in a quantity equal to 10% of cement weight.

Fig. 1. *Sheep wool fibers of 2-3 cm length, used in concrete composition*

(a) (b) (c)

Fig. 2. *The aspect of waste powders additions:*
(a) silica fume, (b) tire waste powder, (c) limestone powder

The RC recipe was of C25/30 class, made by 360 kg/m^3 of cement, 803.16 kg/m^3 of sand, 384.12 kg/m^3 of river gravel, 558.72 kg/m^3 of river gravel 8-16 mm, 180 L/m^3 of water and 4.7 L/m^3 of a polycarboxylate ether superplasticizer type Viscocrete-1040® (manufactured by Sika Group).

For RC was used a water/binder ratio of 0.5, for the CSW, CSWS and CSWL one of 0.56 and for the CSWT 0.59. These different water/binder ratios were necessary to maintain the same level of concrete workability (SWF absorbed 12% more water and tire waste powder another 6% above the quantity used for RC). The aggregates were mixed with cement, or cement plus one of the three types of wastes (silica fume, tire waste powder and limestone powder), water and superplasticizer. SWF were added into the fresh concrete before the final mixing. The concrete was poured into the cube and prism molds and kept in 95% humidity conditions, at 20^{0}C until the age of 28 days.

There were determined the concrete density, in the fresh state and after 28 days of curing, and its compressive and tensile strength , according to SR EN 12350-6:2010, SR EN 12390-7/AC:2006, SR EN 12390-3:2009/ AC:2011, SR EN 12390-5:2009 and SR EN 12390-6:2010 [13, 14, 15, 16, 17].

4. Results and Discussions

RC had a density of 2314 kg/m^3 after 28 days of curing, with 3.62% smaller than in the fresh state (Figure 3). The addition of SWF led to a higher density of the fresh mix due to the addition of supplementary water, but, after 28 days, it decreased, the final value being with 1% smaller than that of the RC. Between the three types of powders, the tire waste powder led to the smallest density of concrete, with 6.23% than CSW (Figure 3).

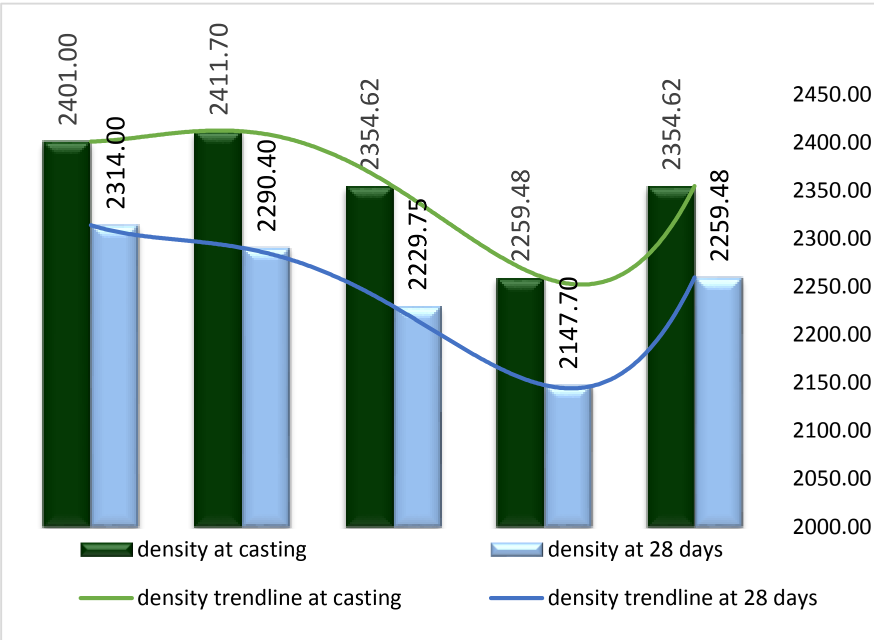

Fig. 3. *Density of the fresh and cured concrete*

SWF led to a decrease of the compressive strength with 28%, mainly due to the bigger water/binder ratio than in the case of RC (Figure 4).

Silica fume decreased the concrete compressive strength with 10% than CSW, in the condition of the same water/binder ratio. In another study of the authors, about the effect of the fly ash on the concrete with SWF, it was obtained an increase of the compressive strength in the case of addition of SWF of 2-3 cm length [8].

The concrete with limestone powder obtained the best results, higher than CSW with 1%. CSWT, the concrete recipe with the greatest amount of added water, registered instead the smallest compressive strength from all studied variants (Figure 4). The compressive strength and the density measured at 28 days of all concrete recipes had the same trend (Figure 5).

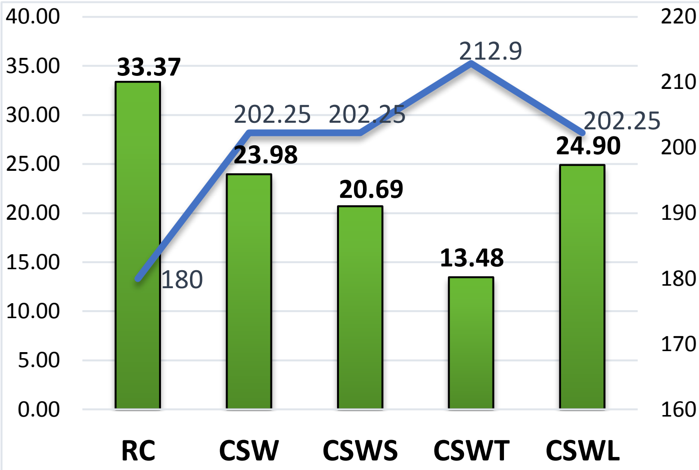

Fig. 4. *Concrete compressive strength at 28 days [N/mm^2] and the water quantity used in concrete composition [L/m^3]*

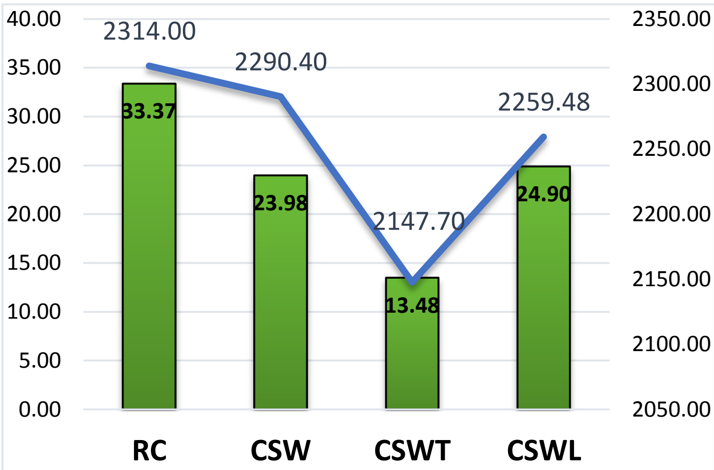

Fig.5. *Concrete compressive strength [N/mm^2] and its density at 28 days [Kg/m^3]*

In the case of flexural tensile strength, SWF did not improve at the concrete performance, the results obtained being half of the ones obtained by RC (Figure 6). But by silica fume usage, it was obtained a higher value even than RC. Tire waste powder and limestone powder gave close values to each other and improve the CSW flexural properties with around 60% (Figure 6).

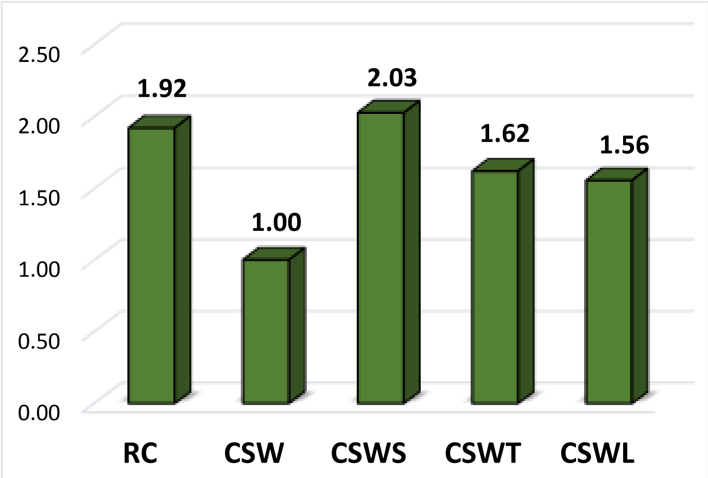

Fig. 6. *Concrete flexural tensile strength at 28 days [N/mm^2]*

Regarding the splitting tensile strength, CSW registered also the smallest value, with around 70% than RC (Figure 7). Silica fume, tire waste powder or limestone powder led to significant improvement of this tensile strength between 264% and 320%, the biggest value being obtained by the concrete with limestone powder (Figure 7).

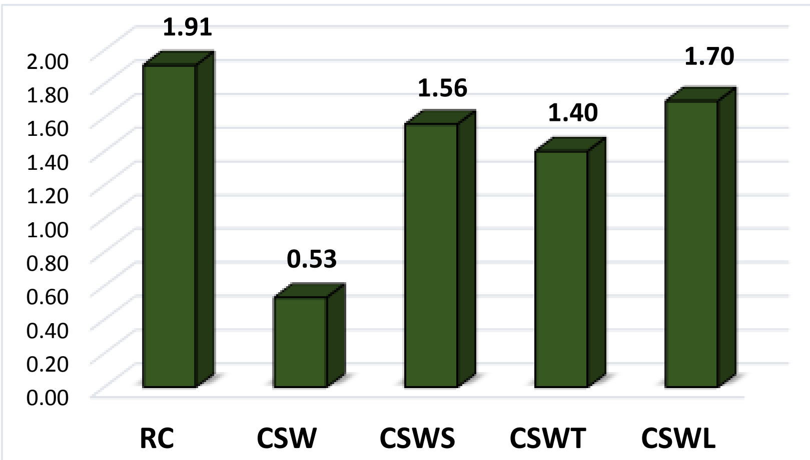

Fig. 7. *Concrete splitting tensile strength at 28 days [N/mm^2]*

The mechanical properties decreasing from the case of CSW can be explained by the reaction between SWF and cement paste, reaction which involves the fibers swelling in the fresh state of concrete; during the concrete curing, SWF are drying and this lead to the formation of very small voids around the fibers and, therefore, the bond between SWF and cementitious matrix is weakened [11].

5. Conclusions

This research studied the density and the mechanical properties of the concrete with SWF and three types of wastes: silica fume, tire waste powder and limestone powder. Experimental results led to the following conclusions:

- SWF led to an overall decrease of compressive strength of the CSW, but limestone powder improved its mechanical properties;
- Silica fume produced a very high improvement of flexural tensile strength of the CSW by 100%, and of splitting tensile strength by 294%;
- CSWT had the smallest density and compressive strength from all the studied variants of concrete, but bigger values for flexural and splitting tensile strength with around 60% and 264%, respectively, than CSW;
- Limestone powder improved all mechanical properties of CSW: compressive strength by 1%, flexural tensile strength by 56% and splitting tensile strength by 320%.

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