Proceedings of the 7th International Conference on Mechanics and Materials in Design
Albufeira/Portugal 11-15 June 2017. Editors J.F. Silva Gomes and S.A. Meguid.
Publ. INEGI/FEUP (2017)

PAPER REF: 6616

EXPERIMENTAL INVESTIGATION ON THE PROPERTIES AND PERFORMANCE OF SELF-COMPACTING CONCRETE WITH VEGETABLE AND SYNTETIC FIBERS

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ABSTRACT

The development of self-compacting concrete (SCC), has recently been one of the most important discovery in the construction industry. Knowing that by incorporating fiber, crack resistance and ductility improves.

The latest research involves interests and much biosourced new materials that meet environmental impact. Vegetable fibers are increasingly used as reinforcing materials in the constructions. They are indeed a renewable resource naturally biodegradable, and have many mechanical and hydric quality. Among these fibers, hemp or cannabis, from an annual plant with rapid growth in Asia and Europe. Featuring a high tensile strength and are advantageous for use in a number of products such as paper, textiles and fibers reinforced concrete.

The aim of this work is to achieve an eco-composite material self-compacting concrete combined with hemp and chenvotte fiber while considering the role and the influence of these reinforcements on the performance of these concretes. For this purpose, a comparative study was conducted on a SCC without fiber (SCC-C), SCC with polypropylene fibers (SCC-PP), SCC with DISS fiber (SCC-DIS), SCC with ALFA fiber (SCC-ALF) and SCC with Date palm fiber (SCC-DP).

The rheological properties were determined using the slump flow tests, slump flow time T_{500}, L-box, J-ring, V-funnel, entrained air percentage and wet density percentage. The mechanical properties include compressive strength, tensile strength at 3, 7, 14, 28 and 90 days and the elastic modulus at 7 and 28 days and capillary porosity. The results show that it is possible to use the fibers vegetable as a reinforcing element in the production of fiber reinforced self-compacting concrete. They showed good strength and a slight decrease in the workability of self-compacting concrete.

Keywords: self-compacting concrete, plant fibers, DISS fiber, ALFA fiber, Date palm fiber, rheological properties, mechanical performance.

INDRODUCTION

The compacting concrete (SCC) is a concrete from a recent innovation in recent years is considerable occupy an important place in the concrete because of the benefits it offers industry requiring no vibration, with a flow under its own weight, even in environments dense reinforcement. SCC have been developed in Japan in the 1980 for use mainly for highly reinforced structures. Recently, this concrete has gained wide use in many countries for different applications and structural configurations.

The inclusion of fibers in the SCC will extend its advantages. These benefits would be to delay the propagation of cracks in structures and improve the tensile strength and flexural strength and toughness of the hardened concrete. Therefore, the use of fibers can increase the scope of application of SCC (Shihada 2011, Bouziani, Benmounah et al. 2014).

Plant materials are a source of renewable products used in recent decades in buildings. One way to achieve an industry more sustainable construction and more adequate to environments. While proceeding to the consumption of materials in reduction of raw materials by adding byproducts or biosourced materials (de Almeida Melo Filho, de Andrade Silva et al. 2013).

Given that the plant fibers are characterized by a higher water absorption value; in which the question arises, can we achieve self-compacting concrete containing vegetable fibers with acceptable workability without touching the mechanical and physical performance?

This study examines and quantifies how the addition of different types of plant and synthetic fibers affect the flow characteristics of self-compacting concrete, mechanical and physical properties. Experimental studies were performed on concrete mixes several times in order to achieve a workability of SCC according to the type and amount of fiber.

THE PROPORTIONS OF MIXTURES

The SCC mix design was determined using the Bétonlab-Pro (Larrard and Sedran 1996). All the various data relating to the used materials were taken into account. In total, five formulations were prepared, with one fiber content 2 kg / m^3 with the volume percentages of 0.22%, 0.14%, 0.16% and 0.14% for SCC-PP (SCC with polypropylene), SCC-DIS (SCC withe Diss), BAP-DP (SCC with date palm) and BAP-ALF (SCC with alfa) respectively. A fixed constant point of binder (cement + limestone filler) equals to 520 kg / m^3 was selected with the same granular skeleton and a slight adjustment on the water content and the superplasticizer. The purpose is to obtain a good fresh characteristic for the five mixtures.

Table 1 - The mixing proportions of concrete developed in this study.

Quantities (kg/m^3)	**SCC-C**	**SCC-PP**	**SCC-DIS**	**SCC-ALF**	**SCC-DP**
Cement	400	400	400	400	400
Limestone powder	120	120	120	120	120
Sand	804,8	804,8	804,8	804,8	804,8
Gravel (3/8)	161,3	161,3	161,3	161,3	161,3
Gravel (8/15)	648,8	646,8	646,8	646,8	646,8
Water	203,2	220,2	205,54	206,5	206,5
Superplasticizer	9,5	10,11	10,1	9,8	10,1
fibers	/	2	2	2	2

After the completion of preliminary tests in the fresh state, it appears from Table 1 that the water and superplasticizer adjustment differ from one fiber to another precisely in the SCC-PP probably due to the fibers flexibility and diameter, which cause an impediment to the aggregates flow, as well as the fibers absorption degree and their nature. This affects the values of the slump flow. About the plant fibers, we find almost the same amount of water and superplasticizer.

RESULTS AND DISCUSSION

PROPERTY FRESH AND HARDENED

The properties in the fresh state and mechanical (compressive strength, flexural strength) of tested concretes before heating are presented in Table 2. Table 2 shows that through comparison of results with the criteria of SCC, we can see that all SCCF mixtures presented satisfactory properties as an fresh concrete except polypropylene represent is a blockage in confined environments. The content of the fibers we chose as expected caused a slight negative effect on workability and self-compacting characteristics of SCC (Shihada 2011, Bouziani, Benmounah et al. 2014). For polypropylene fibers the slump flow value considerably reduced from 73 to 60 cm.

Table 2 - The results of the characterization in the fresh state

The tests		SCC-C	SCC-PP	SCC-DIS	SCC-ALF	SCC-DP
Slump flow (cm)		73	60,5	71,5	68	69,25
T50 (s)		2.3	3.5	3,8	3,9	3,6
J ring (cm)		0,15	3,05	1,43	1,7	1,61
DJ (cm)		71,5	49	65.4	62	64
V funnele (s)		10,73	8,44	16,3	11,98	13,88
L Box		0,91	0,45	0,75	0,84	0,83
Sieve stability (%)		15,4	4,043	7,87	5,412	6,13
air content (%)		1,9	1,80	1,95	2,0	1,8
Density (t/m^3)		2,34	2,31	2,37	2,36	2,39
	3	39,15	23,09	24,19	27,11	31,23
	7	46,06	27,76	28,39	28,495	39,06
Rc (MPa)	**14**	48,3	35,43	37,315	42,585	42,45
	28	50,29	37.5	39,53	45,312	46,5
	3	7,25	4,8	5,82	5,095	6,46
	7	8,46	7,47	6,745	6,391	7,64
Rt (MPa)	**14**	8,89	7,6	7,185	7,285	8,515
	28	9,74	8,15	7,89	7,78	8,98

For the mechanical characteristics we observed that the introduction of vegetable and synthetic fibers systematically reduces strength to compressive and flexural these results confirmed by several researchers (Topçu and Uygunoğlu 2010, Bouziani, Benmounah et al. 2014). Nevertheless it is sufficient for structural applications. The difference in results between the fibered BAP that can be explained by the form, different size and nature of fiber that significantly affect the porous structure of concrete consequently a considerable change on the mechanical performance. We also note that the kinetics of the evolution of the resistance between the concrete with the fibers and not containing fibers is different. We explain these phenomena according to the literature that the delay of cementitious composites, mainly due to the dissolution of extractable of the fiber surface in the cement mixture that disrupts the hydration of cement (Sedan, Pagnoux et al. 2007, Diquélou, Gourlay et al. 2015) (Tonoli, Savastano et al. 2010). According to D. Sedan et al (Sedan, Pagnoux et al. 2007) showed that the vegetable fibers of hemp in the cementitious matrix, high in pectin, bind to their surface the calcium ion Ca2 + and hydroxyl ions OH-. They observed deficit in ions hydroxides and calcium the interstitial phase, causing inhibition of calcium silicate hydrates (CSH) and, consequently, inducing delayed setting and promotes decrease of the mechanical properties of cementitious materials (Tonoli, Savastano et al. 2010). According to N. Banthia and J. Sheng (Banthia and Sheng 1996) have reported that the interfacial bonding between the polypropylene fiber and matrix cement is low due to their smooth surface. However, polypropylene is chemically inert and hydrophobic, which eliminates the possibility of a chemical bond. Consequently, fibrillation has a considerable effect on binding (Toledo Filho, Scrivener et al. 2000). By against we note that the vegetable fibers give better mechanical performance than the PP fibers after 28 days because of the rough surface that enhances the interaction between the fibers and the matrix (de Almeida Melo Filho, de Andrade Silva et al. 2013) (Mouhoubi, Osmani et al. 2012).

CAPILLARY POROSITY

Capillary porosity is a micro-structural characteristic that influences the transfer properties and the mechanical performance of concrete (Hadjoudja 2014).

The porosity test results of different hardened SCC-F are given graphically in Figure 1.

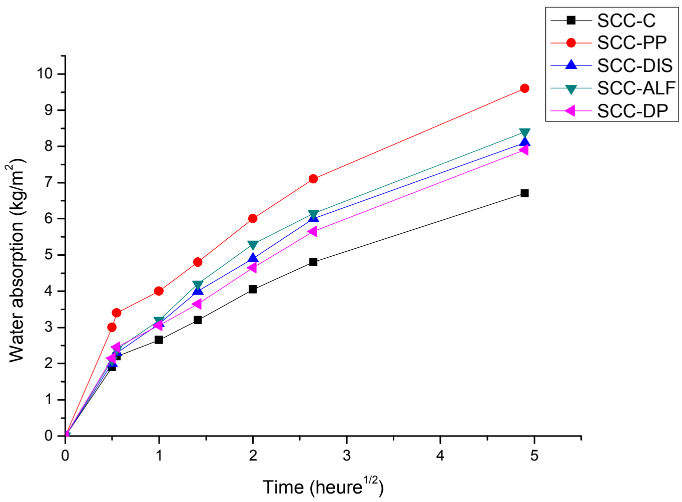

Fig. 1 - Effect of fibers on the water absorption by capillarity

The values in Fig. 1 show an increase depending on the depth of the water penetration according to the time for all mixtures. Noting that samples with the fibers show a higher capillary absorption than the control samples (without fibers) (Hadjoudja 2014). As an example for plant fiber the percentages are varying between 10% and 22% compared to control. So we can say that the higher capillary absorption, the more the material is able to be quickly invaded by the liquid in contact. It is also a property which characterizes the arrangement of the material pores which absorb and transmit water by capillarity. However vegetable fibers after drying preconditioning will facilitate the creation of air pores that benefit the liquid absorption, this means that the compactness decreases. Therefore this phenomenon depends on the initial water quantity adjusted W/C, the fibers nature, their size and their absorption capacity. (Xiao and Falkner 2006).

This leads to the conclusion with other research that the addition of fibers has an important influence on the initial network structure with respect to the porous permeability (Behnood and Ghandehari 2009). This difference in porosity confirms that the fibers create a space between the concrete particles which is considered a very important parameter in order to avoid spalling of the concrete under the temperature rise.

CONCLUSION

The study in this paper aims to contribute to better understand the effects of plant and synthetic fiber type on the réhologique behavior, physical and chemical performance and temperature evaluation. Three fibers (hemp, chennevotte and polypropylene) and a fixed dosage of 2 kg / m3 were studied. The following conclusions are drawn based on the results of the various tests and analyzes:

- The introduction of plant fiber in the concrete, leads to a virtual increase of water. Since the fibers tend to water absorption.
- However, the compactness of SCCF decreases consistently view the empty created by these fibers.
- The evolution of the workability of SCC bundles decreases over time, especially in confined areas.
- The SCC bundles provide compressive strengths with a slight decrease in the non-fiber BAP. However fluctuation results in the same range as a structural concrete.

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