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BIOBASED CEMENT COMPOSITES FOR MORE SUSTAINABLE FARM CONSTRUCTIONS

J.Claramunt[1], H Ventura[2], L. Gonzalez-Lopez[2], F. Pares[2], M. Ardanuy[2]*

[1] Universitat Politècnica de Catalunya, Departament d'Enginyeria Agroalimentària i Biotecnologia, Barcelona, Spain

[2] Universitat Politècnica de Catalunya, Departament de Ciència dels Materials i Enginyeria Metal·lúrgica, Terrassa, Spain

*Corresponding author; e-mail: monica.ardanuy@upc.edu

Abstract

The aim of this research is to test the potential use of calcium aluminate cement-based composites, reinforced with flax fabrics, as materials for application in farm constructions. To this end, the effects of some chemicals typically present on farm constructions—such as acetic acid, ammonia, propionic acid, and valeric acid—on the mass loss and flexural behavior of the cement composites are analyzed. The performance of these calcium aluminate cement-based composites is compared to the Portland cement-based ones. Moreover, the durability to accelerated aging is also evaluated. The results show that the calcium aluminate cement based composites maintain their performance after being in contact with the chemical agents studied.

Keywords:

Calcium aluminate cement; Flax fiber; Cement based composites; Farm constructions

1 INTRODUCTION

In recent years, there has been an increasing concern about sustainability of building sector due to its large contribution to climate change. Despite over 80% of the emissions are generated during the operational phase, there is still a not negligible percentage—around 10 to 20%—which takes place during materials manufacturing and transportation, construction, maintenance renovation and demolition [United Nation Environment Programme, 2009]. The cement industry accounts about 7% of the total worldwide CO_2 emissions [Ali, 2011].

A particular case are farm constructions, since intensive animal farming entails the manipulation of a large amount of effluents, from the cowshed to the final treatment industry. The transport and storage of these effluents is performed through canalizations and tanks, mainly made of Portland cement due to its availability and low-cost. These constructions are subjected to a highly aggressive chemical environment, since the animal's slurry contains excrement, urine, cleaning water and remains of animal feed [MARM 2017]. Moreover, the abrasion produced by the animals and the pressure cleaners contribute to eliminate external layers of deteriorated material, exposing even more the surface of the concrete. However, the repair of the damaged parts is often difficult, making necessary their substitution.

Portland hydrated cement is mostly composed of calcium hydroxide and calcium hydrated silicate or C-S-H. The calcium hydroxide is an element especially sensitive to the action of certain chemical agents and acids. Animal excrements, especially pig slurry, contain different types of acids, various sources of sulfur salts and a significant concentration of ammonium, as well as a very variable composition and pH depending on the animal's race and age, and on the type of exploitation [Massana, 2013]. Therefore, Portland cements suffer a severe degradation when subjected to this environment.

A possibility to solve this durability problem is the use of other types of cement. In this study, we evaluate if the use of natural fiber reinforced calcium aluminate cement based composites—instead the traditional materials—can contribute not only to improve the flexural strength and ductility of the final material but also to increase the durability to chemical attack. This could lead to more sustainable solutions, owing to both a lower need for repair and the use of natural fibers instead the steel ones typically used as reinforcement.

2 MATERIALS AND METHODS

2.1 Materials

Two types of cements were used to produce the pastes: a Portland cement "Super Dragon" (type CEM I 52,5 R, according to the EN 197) and a calcium aluminate cement "Electroland" (type CAC, according to the EN 14647), both provided by Ciments Molins Industrial (Spain). Flax fibers of a length of 60 mm, provided by Fibers Reserche Development of the Technopole de l'Aube en Champagne (France), were used to produce nonwoven reinforcing fabrics—of 2 mm of thickness and 275 g/m^2 of areal weight—following the methodology described in previous works [Ventura, 2014].

2.2 Dosage and sample preparation

Composite plates of CAC or Portland matrix and 5 layers of flax nonwoven reinforcement were obtained by a laminate technique, following the methodology used in previous works [Claramunt 2014; Claramunt 2016]. It consisted of soaking each nonwoven layer in the cement paste—that had a water/cement ratio of 2—, placing them in a mould, and then applying two vacuum-assisted steps for water extraction, followed by a 3.3 MPa compression during 24h. Samples were cured for 28 days in a climatic chamber at 20 ºC and RH >95%. Each composite plate, of 300x300 mm^2 and 10 mm thickness was cut into four specimens of 140x140 mm^2 for their immersion in the chemical solutions.

2.3 Exposure to chemical attack

Two specimens per sample where exposed to different agents under the conditions defined in Tab. 1 in order to determine the resistance against chemical attack.

Tab. 1: Exposure conditions.

Ref.	Chemical attack conditions		
	Time (days)	Immersion solution	T (ºC)
Control	-	-	-
CT5	91	Pig slurry	5
CT20	91	Pig slurry	20
CR	91	Pig slurry	Room
CAA	91	Acetic acid (1.28M)	20
CAP	91	Propionic acid (1.28M)	20
CAV	91	Valeric acid (1.28M)	20
CAM	91	Ammonia (1.28M)	20

2.4 Mechanical characterization

After the exposure, specimens were cleaned in distilled water, and cut into 40x140 mm^2 specimens. These were tested to determine their flexural strength under a 3-point bending method, according to the UNE-EN 196-1:2018 standard with some modifications: 100 mm anvil separation and speed of 4 mm/min.

3 RESULTS

The flexural strength values of the samples are presented in Tab. 2.

Tab. 2: Flexural strength of the samples subjected to different chemical attacks. Values in brackets correspond to the standard deviations.

Ref.	**Flexural strength (MPa)**	
	Portland-based composites	*CAC-based composites*
Control	11.4 (1.1)	13.3 (1.5)
CT5	7.5 (0.5)	14.6 (1.7)
CT20	6.6 (0.7)	12.6 (0.6)
CR	6.3 (1.2)	15.8 (3.0)
CAA	6.5 (3.4)	11.6 (1.2)
CAP	6.3 (2.9)	12.9 (0.4)
CAV	8.4 (1.0)	12.9 (1.7)
CAM	11.5 (0.5)	12.0 (1.8)

Samples with Portland cement matrix revealed lower strength values, even in the control (not exposed to chemical attack). The specimens exposed to the real environment of pig slurry (CR) showed a drop of ~40% in the flexural strength, while the ammonia environment had the lowest effect in these composites.

On the other hand, samples with CAC matrix presented similar behaviors after any of the exposures to the chemical attack. Lowest values correspond to exposure to acetic acid, resulting in a reduction of 13% with respect to the control sample. Regarding the results in the real conditions (CR), the exposure to pig slurry seemed even to increase the composite strength. This could be due to the presence of water, which could have increased the hydration of cement particles. Anyhow, no severe attack was observed under any of the exposure conditions for the CAC composites.

4 SUMMARY

The results revealed that calcium aluminate cement-based composites reinforced with flax fabrics could maintain their performance after 3 months exposure to different chemical agents typically found in farm constructions. Thus, this paper proves the potential use of these composites reinforced for application in farm constructions.

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