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OPTICAL ASPECTS ON THE MINERAL MATRIX – FIBRE BONDING (PART 2)

BY

RALUCA ONOFREI*

„Gheorghe Asachi” Technical University of Iași, Faculty of Civil Engineering and Building Services, Iasi, Romania

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Abstract. Concrete is one of the most used construction materials but there is also the need to continuously improve it. The high consumption of natural resources and energy when manufacturing cement demand a “greener” approach. One possibility is to partially replace the cement with other admixtures, transforming the material into a more ecological version. In the present paper is also continued the experimental analysis of the possibility to embed various textile structures with a modified mineral matrix.

Keywords: mineral matrix; textile reinforcement; ecologic; embedment.

1. Introduction

The desire for better products and materials always existed in the mind of the humankind. Not all nature given materials are what the man needed thus he started shaping his own products to fulfill the requirements. Starting from the first used material, the stone, passing to wood, steel, bricks, concrete and more modern the plastics or the composite materials there was always a concern upon obtaining the best solution.

*Corresponding author: *e-mail*: raluca.onofrei@academic.tuiasi.ro

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Concrete is one of the most used materials and the concrete technology brought the knowledge on it so far. The trend nowadays is upon discussing concrete as a composite material. The basic microstructure of this material, mixture of cement, sand and water, fits very well the composite profile.

The development of cement based composite materials was possible due to (Guerrini, 2000):

- usage of new reinforcing systems
- optimizing the adhesion properties at the fibre-matrix interface
- developing high performance cement based matrices
- improvement of the fabrication processes
- controlling the chemical reactions.

When we think upon the development or improvement of any material there are many aspects to be considered. Maybe not all the desired improvements could be applied on one material because it could generate a multitude of changes in its behavior, one improvement could bring the decrease of another property.

2. Mineral Matrix Improvement

2.1 Ecological Improvement

The international sustainable development assumes the concept of “green economy”. In the Europe 2050 project, the European Union is aiming towards a low-carbon society through circular resource utilization and CO₂ emissions reduction technologies regarding the cement industry (Lim *et al.*, 2020).

The cement is one of the main constituents of concrete and thus the most used material in the entire world, and for the modern society dependent on infrastructure, housing and industry development has become indispensable (Damtoft *et al.*, 2008; Flatt *et al.*, 2012). Globally, the cement production increased from 594 million tons in 1970 to 2284 million tons 2005 and 3.6 billion tons in 2011 (Cembureau, 2011). In the year 2020 we had 4.1 billion tons (Garside, 2021) and it is assumed that the cement requirement will be doubled by 2030 (Taylor *et al.*, 2006).

Unfortunately, obtaining cement involves emissions of Carbon dioxide (CO₂), Sulphur dioxide (SO₂), Nitrogen oxide (NO_x) and dust (WBCSD, 2012). Substantial quantities of CO₂ are emitted during the process of obtaining clinker, each ton emits between 600 and 900 kg of CO₂. Globally, the cement production emits approximately 2 – 2.5 billion tons of CO₂.

The production of clinker involves resources (limestone, clay) consumption and is an energy intensive process (calcination at temperatures of 1450°C) (Flatt *et al.*, 2012).

Some proposals to make the process “green” are: changes in the fabrication processes (WBCSD, 2009), replacing the usual fuels with alternative ones (Cembureau, 2009) or adjusting the cement composition (Damtoft *et al.*, 2008).

Changing the cement composition has shown a multitude of benefits but adopting this procedure worldwide was slowed down by the complex procedure in developing a new industrial standard. In the past years we have an increased number of researches looking into the possibility of introducing in concrete various admixtures or alternative raw materials. Such admixtures vary from country to country, for example in United States and China the substitute is added when producing concrete while Europe is more familiar with them added directly in the composition of cement.

Such a product is patented in France and is obtained by processing of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The gypsum is a natural material and can be found in many regions in the world, but the innovating technology is the usage of industrial gypsum as phosphogypsum, FGD, lactogypsum and citrogypsum (Aranda *et al.*, 2010). The obtained product is a β type anhydrous calcium sulphate (SCA) and it is a mixture between a hemihydrate ($\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$) and anhydrite III (CaSO_4), Fig. 1.



Fig. 1 – Aspect of anhydrous calcium sulphate (SCA).

2.2 Technological Improvement

Compared to the polymeric matrices the mineral matrices have a hard time when it comes to embedding fibres or to perfectly cover complicated reinforcement.

To benefit from the behavior of a good composite one must be careful with the technological aspect of the material. As it was previously analysed, see (Onofrei, 2020) the classic cement based matrix had difficulties in spreading over the textile reinforcements, penetrating the fibres and embedding the filaments to obtain a good interfacial connection.

Improvement can be obtained by designing a more fluid material. Increasing the workability requires the addition of water. The downside of

adding water in a mineral material is that the extra water will result in pores and develop cracks thus reducing the strength and stiffness of the material.

A more viable solution is through the use of admixtures. In the present paper is analysed the particular addition of SCA as a replacement for cement. Therefore in the classic cement based matrix, Fig. 2a, analysed previously, see (Onofrei, 2020) the cement was replaced with SCA in proportion of 30% and 50% respectively, Fig. 3b and 3c.

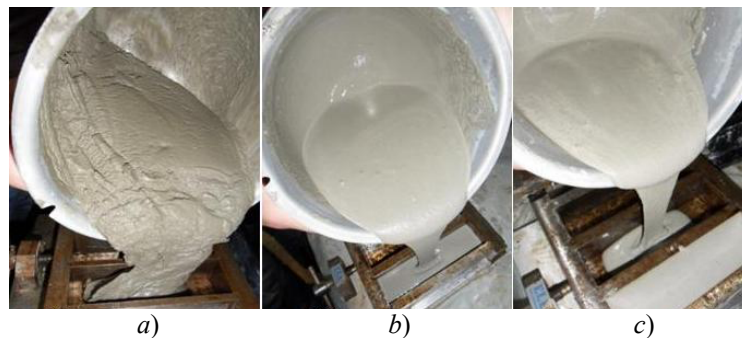


Fig. 2 – Mixture with SCA replacement of 0% (a), 30% (b) and 50% (c).

The resulted samples showed a considerable improvement in the workability of the final mixture without increasing the water percentage; the higher the SCA percentage the more fluid was the final mixture.

Other aspect recorded during the experimental procedure is the setting time and hardening of the material. Compared to the traditional matrix, the modified mixture hardened 5-6 times faster.

Due to the nature of the SCA we consider the newly formed material as being an ecological mineral matrix.

3. Experimental Samples

To analyse the behavior of the proposed matrix on the fibre–matrix bonding several samples have been casted. The textile structures are kept the same as in the first study, see (Onofrei, 2020).

The first samples was a unidirectional reinforcement, Fig. 3, and a bidirectional reinforcement, Fig. 4, both textile structures with no or small mails. The modified mineral matrix spread on the surface of the reinforcements but a complete covering was not possible. When detaching the textile structures deep marks were noticed on the surface of the matrix, aspect confirming that in this case, the matrix had a deep passing through the fibres, but was not able to completely embed the textile structure.



Fig. 3 – Modified mineral matrix with unidirectional reinforcement.

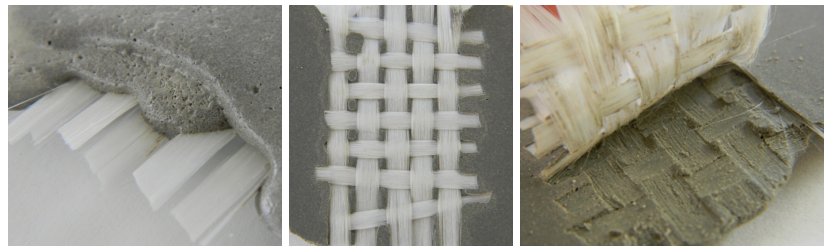


Fig. 4 – Modified mineral matrix with bidirectional reinforcement with mails (0.1x0.1cm).

The third structure was a bidirectional reinforcement with thick fibers and 0.7x0.7cm mails dimension, Fig. 5. The matrix was able to pass and partially embed the fibers. When detaching there were predominant marks left on the hardened matrix and particles of the matrix were visible between the fibres suggesting a deep embedding.



Fig. 5 – Modified mineral matrix with bidirectional reinforcement.

The fourth and fifth textile structures were represented by the unidirectional mesh, Fig. 6, and the bidirectional mesh, Fig. 7, both with mail dimensions of 0.5x0.5cm and 1.2x1.2cm respectively. The matrix was able to easily pass through and perfectly embed the entire textile structure. The detaching of the reinforcement from the hardened matrix was no longer possible, without breaking the sample.

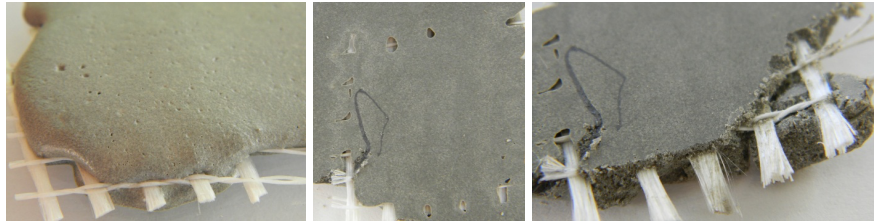


Fig. 6 – Modified mineral matrix with unidirectional mesh.

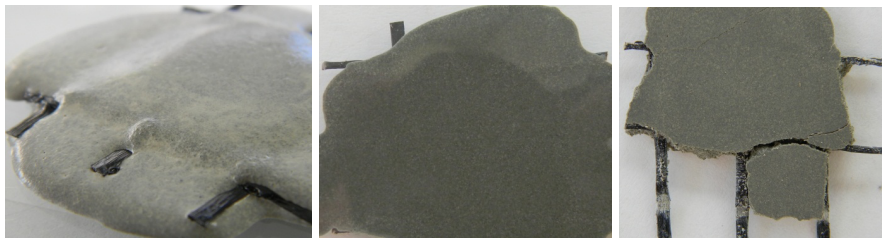


Fig. 7 – Modified mineral matrix with bidirectional mesh.

The last textile structure in this study was a bidirectional mesh with big mail dimensions, 2.7x2.7cm, and thick strands, Fig. 8. The passing through the textile structure was easy and the embedding was almost perfect. Since, in this case, fibers composing the strands are glued together the goal for the matrix was just to cover the strand.



Fig. 8 – Modified mineral matrix with bidirectional mesh.

4. Conclusions

A good adherence at the interface between the matrix and the fiber is a very important aspect for the composite materials, and the mineral based matrices are no exception.

The first and second types of textile structures, with thick, multiple fibers and no mails, do not give favorable results in combination with mineral matrices. The third structure had only a partial embedding, showing the importance of the mails in a textile structure when using a mineral matrix. The

fourth, fifth and even the sixth structure had a perfect embedding and complete covering. Thus, textile structures with bigger mail dimensions and thinner strands are the best choice for mineral based matrices.

Looking at the results obtained in this study, and comparing them with the results obtained previously, we observe a big improvement in terms of fiber embedment and fiber-matrix bond. Due to the increased workability of the mixture, generated by the addition of SCA, in all 6 cases the pouring was significantly easier; the matrix spread well and managed to better penetrate the textile structures.

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ASPECTE OPTICE ASUPRA LEGĂTURII FIBRE-MATRICE MINERALĂ
(PARTEA 2)

(Rezumat)

Betonul este unul dintre cele mai folosite materiale de construcții dar prezintă, de asemenea, nevoia de a fi continuu îmbunătățit. Consumul ridicat de resurse naturale și energie pentru fabricarea cimentului solicită o abordare mai „verde”. O posibilitate este cea de a înlocui parțial cimentul cu alte adaosuri, transformând materialul într-o variantă mai ecologică. În prezentul articol se continuă și analiza experimentală a posibilității de a îngloba diferite structuri textile într-o matrice minerală modificată.