

A Novel Application Technique for Polymer Nanofibers in the Construction Industry

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ABSTRACT

During 2008 about 3 billion tons of concrete were produced all over the world, making it the most important industrial product produced in the history of mankind. Therefore, any technological improvement in this product will affect any part of the globe money wise and environment wise. Concrete is mainly a mix of three different components that work together to produce such extraordinary material. Hence, depending of the size of the sand grains and the size of the rocks mix, the final concrete obtain their mechanical characteristics. The scope of this research is to create atomic devotion in the final mix, since it is presume that the concrete aggregates only have mechanical forces and lacks of atomic bonds between its final components. Hence, it is report that concrete only have about 10% of tensile resistance in relation to compression resistance. In order to achieve atomic adherence between components our research explores the use of nanofibers made out of polyethylene. Our work studies the phenomena and the interactions of the nanofibers with the growth of crystals in the cement and its atomic interface at the time of formation of the substrate.

Keywords: concrete, nanofibers, nanotechnology, cement, crystals

1. INTRODUCTION

Now days, the main component both in infrastructure as well as works in buildings is the hydraulic concrete (in which the agglutinant or binder is the hydraulic cement), which help in the development of earthquake resistant elements or the seismic behavior. "The understanding of the seismic behavior of structures has required the identification of all those elements that have led to failure or, at a good structural

behavior, and also the analysis of the types of damage and their causes." [1]

Among the most common faults that can occur in cementations' materials applied to construction can include: inadequate shear, diagonal tension in beams and columns, fails for lack of grip and fault planes between the cement paste and rock aggregates. Given that the cement paste has a ratio of 10:1 between mechanical strength of compression and tension, respectively, is that it can reveal the need to make progress on the issue of homogenized material properties.

Currently what in use is the application of additives to micro or macro scale for densifying or strengthening the paste at the time of manufacture, also macrofibers from polymer or metal materials were applied as enhancers to be included in the manufacturing material. However, these solutions do not fully satisfy the need for a balanced material in terms of mechanical strength and does not need to include elements that reinforce its mechanical weaknesses. Hence, this research, study the effect of Polyethylene Nanofibers (NFPs) produced thru electrospinning, in the process of hydraulic cement paste hydration, gel formation, and the chemical reaction to comprehend the outcome in its final properties.

Polyethylene is a linear, amorphous polymer, which like most polymers is relatively chemically inert; it has been used for many years as a low cost resin, because of this, its use has grown over the years, being now one of the most polluting polymers worldwide. [2]

The technique of electrospinning is a process in which micro and nano fibers are synthesized thru a high voltage application where a strong electrostatic field is created used to attract electrically charged particles from a polymer solution (polymers can be used

because they possess the physical and chemical properties for the formation of fibers which are resistant , elastic, and durable) pouring from an injector tip that has a conical shape called Taylor cone into a surface to collect the fibers once they solidifies to form micro or nanofibers.[3]

A nanofiber is a nanometer structure in the form of a fiber, tube, cables, or rods. Due to their scale, they have properties such as high surface area relative to its volume, flexibility in the surface, high porosity and interconnected pores, and a superior mechanical performance, that are not present in the same structures at higher scale. [4] [5]

This study focused on understanding the effects of incorporating NFPs at the time of formation and hydration of the cementitious gel, and to observe if the nanofibers have played a role in the homogenization of the mechanical properties of the material.

2. EFFECT OF NFPs WITH THE HYDRAULIC CEMENT PASTE

Recent studies had shown that nanofibers had especial characteristics that enhance the mechanical properties of certain composites. [6]

2.1 Synthesis and Recolection of NFPs

The working conditions of the electrospinning process are described on table 1.

Table 1. Electrospinning system conditions.

Voltage (kV)	Distance (cm) Nozzle- Colector
10.0	5.0

The substrate use to collect the fibers is aluminum.

2.2 Mineralogical evolution of the General Use Cement (GUC) during the hydration process

The hydration of general use cement (GUC) for the use in the manufacture of concrete for various

buildings , it is a process that has been studied in depth before. The cement used for this investigation is a material that meets international Costa Rican national standards (383:2004 RTCR UG) and (ASTM C1157 GU). GUC is an agglomerate of chemical compounds that once in contact with water produced a hardening mixture while hydration phases are formed. Ettringite ($C_3A \cdot 3CS \cdot H_{32}$) is formed from anhydrite (CS), C_3A , and water during the aluminate reaction. [7] The crystals of ettringite are elongated in shape, usually fibrous clusters or as elongated rods that resemble a three-dimensional network, which gives cohesion to the concrete.[8]The silicate reaction describes the formation of portlandite (CH) and an amorphous calcium silicate hydrate gel (CSH) from tricalcium silicate (C_3S) and water . This amorphous gel is known as tobermorite and is responsible for the internal frame of the cement paste, and the adhesion of the aggregates in mortars and concrete and, ultimately, the strength of these clusters. [9] The crystals of portlandite are hexagonal crystals flattened that agglomerate parallel in massive deposits, stored in the later stages of the reaction (after 48 hours).

2.3 Interaction of polystyrene nanofibers in the process of grain growth.

In this work three sets of samples were prepared: control , in which GUC was mixed with distilled water at a 2:1 ratio , respectively : another sample was prepared with a solution of NFPs dispersed with an ultrasonic bath with the substrate material and then centrifuged for two hours and then brought to a decantation processes ; this was incorporated into the cement holding with the aforementioned ratio (relative to control) . The third set was a direct application of NFPs in a mixture that kept the same water-cement ratios from the other two. The three sets were cryofracture at 24 hours and the resulting material was observed with scanning electron microscope (SEM) Hitachi TM- 3000.

2.3.2 Sample in aqueous solution of NFPs.

In Figure 4, the delayed formations of structures such as portlandite, as well as the ettringite formations exhibit a more mature appearance relative to the control sample as shown; this can be seen in Figures 5 and 6. Hence, it reveals an accelerated hydration of cement compounds relative to the control due to capillarity present at the surface area of the NFPs.

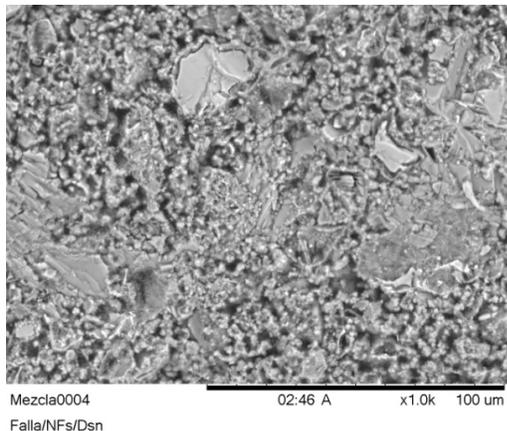


Figure 6. Fail plane of aqueous solution at 24 h (x1000 – 100µm)

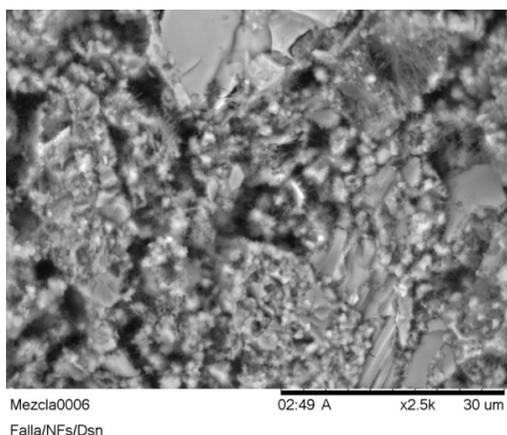


Figure 7. Fail plane of direct application at 24 h (x2500 – 30µm)

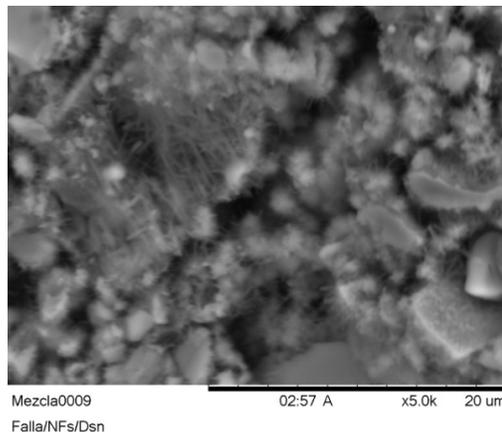


Figure 8. Fail plane of direct application at 24 h (x5000 – 20µm)

2.3.3 Sample with direct application of NFPs.

In terms of failure occurrence is apparent undispersed clusters of NFPs, these cause the appearance of highly densified formation of high crystallinity portlandite which are deposited in parallel (Figure 7). Such interface interacts with the compact fibrous network of ettringite (Figures 8, 9 and 10). In these clusters, one can observed a more accelerated and intense process than the previous two sets. Hence, the little homogeneity in the mixture is due to the lack of an efficient method of dispersion; which is mechanically counterproductive.

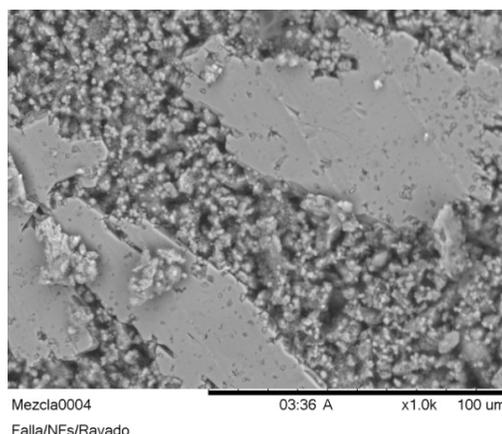
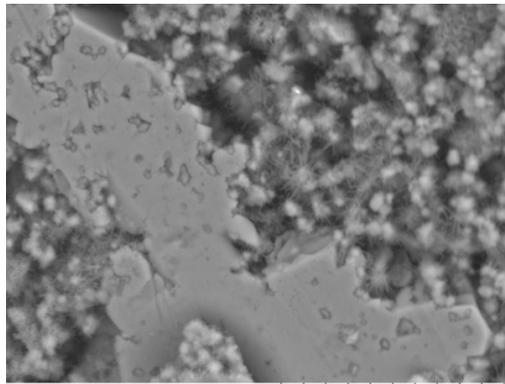
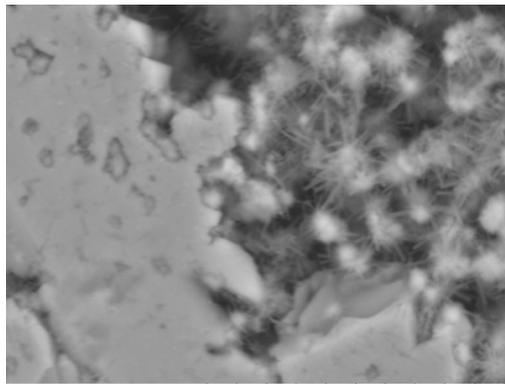


Figure 9. Fail plane of direct application at 24 h (x1000 – 100µm)



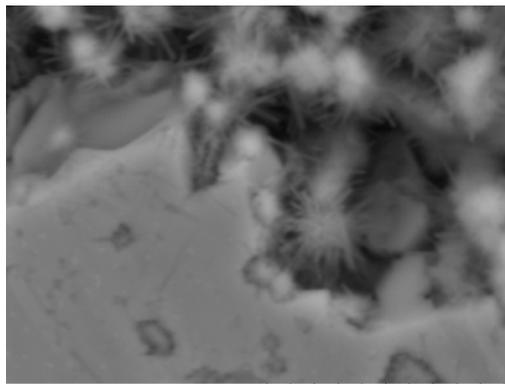
Mezcla0006 03:39 A x2.5k 30 um
Falla/NFs/Rayado

Figure 10. Fail plane of direct application at 24 h (x2500 – 30µm)



Mezcla0008 2014/04/11 03:42 A x5.0k 20 um
Falla/NFs/Rayado

Figure 11. Fail plane of direct application at 24 h (x5000 – 20µm)



Mezcla0010 03:44 A x8.0k 10 um
Falla/NFs/Rayado

Figura 12. Plano de falla aplicación directa a 24 h (x8000 – 10µm)

3. CONCLUSION.

This work reveals several points to consider. First to mention is that the NFPs synthesis need to be a well-established process, since is of great importance the homogeneity of the fibers. In our particular case the substrate used as collector material (aluminum) was not appropriate for this study since it chemically alter the performance of the binder. Another improvement that our study is working on is in getting a better dispersion method to add the NFPs into the hydraulic cement paste. Further observations reveals; that the paste prepared with the aqueous solution of NFPs structures presented late origin, as is the portlandite at 24 h of manufacture. Likewise, in the clusters in the sample with direct added NFPs the formations portlandite showed high crystallinity (massive conglomerates). With the NFPs a greater density of material was observed in terms of formation of crystals.

4. REFERENCES

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5. ACKNOWLEDGEMENTS

We will like to extend our gratitude to the brothers, Jason David and Héctor William Agüero Barboza, for their work with the electrospinning process.

Additionally, our thanks to the Nanotechnology Laboratory and the Center for housing and living of the Construction School at the Instituto Tecnológico de Costa Rica, and the School of Electronics Engineering. Finally, our thanks to the Instituto Tecnológico de Costa Rica Foundation (FUNDATEC).