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Presenter Information

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Abstract. The objective of the research was to experimentally examine the corrosion of steel fibers in two media: a solution containing potato dextrose and calcium chloride (S1) (nutrient of the biological agent *Oomicetum Pythium aphanidermatum* that facilitates the self-healing of cementitious matrices), and water (S2). The corrosion process was accelerated by the Cebelcor method for 15 days, with immersion/emersion cycles of 5 and 19 hours, respectively. The results revealed that the corrosion of the fibers in solution S1 was 10.64% higher than that in S2. Regarding cross-sectional loss, the corroded fibers in S2 showed linear behavior, unlike those in S1, which exhibited pitting corrosion that varied along their longitudinal section. Therefore, it is recommended that future investigations evaluate this behavior using the galvanostatic method. Additionally, future research should evaluate the mechanical response of steel fiber-reinforced cementitious matrices incorporating self-healing mechanisms through the biological agent and its corresponding nutrient.

Keywords: Corrosion, Steel fiber, Self-healing, Solution.

1 Introduction

In recent years, the construction industry has shown that concrete is one of the most required materials in building structures [1]–[3]. This is due to its favorable properties when fresh (workability) or already hardened (high strength and durability) [4], [5]. Despite these properties, concrete has low ductility and tensile strength [3], so the use of reinforcing materials, such as steel fibers, is necessary [6]. On the other hand, concrete is a brittle material, therefore, thermal expansion, freeze-thaw cycles and load variation causes the appearance of cracks [7]–[11], same that facilitate the access of external agents that can compromise the performance of the reinforcement materials [12]. In view of this, maintenance and reconstruction costs increase, and can even be higher than that of new structures, in developed countries [13].

To reduce repair costs and extend the service life of structures, several researchers have worked on a cementitious matrix capable of repairing itself. Malinskii et al. [14] were among the first to study the phenomenon known as self-healing concrete. Subsequent research indicates that, in the process of concrete self-healing, there are two classifications: autogenous and autonomous [15]. Hossain et al. [16] pointed out that the autogenous process is based on the natural ability of the cementitious matrix to repair itself, whereas an autonomous process requires the use of elements external to the conventional composition of the matrix [17]. The latter being, pointed out by Guo & Chidiac [18] and Rajczakowska et al. [19], as the process in which favorable results are achieved.

Recent research has proposed using microorganisms as external elements, Mesquita Junior et al. [20] evaluated the use of *Oomicetum Pythium aphanidermatum* as a biological agent in the self-regeneration of a cementitious matrix. This process includes the production of CaCO3 by the microorganism to repair the cementitious matrix. The results achieved were favorable since cracks of ~576.28μm were repaired in 98.43%. However, for the development of the biological agent (CaCO3 production), the nutrient is composed of calcium chloride (CaCl2). To speak that this compound can cause corrosion to correlate with the following idea. In this sense, the present research aims to study experimentally the corrosion process of submerged steel fibers in water and the nutrient (potato dextrose + calcium chloride) used in the development of the biological agent *Oomicetum Pythium aphanidermatum*.

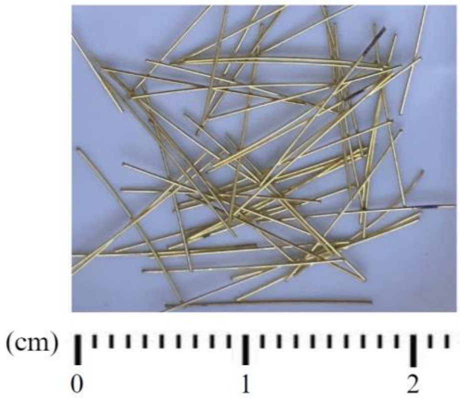
2 Methodology

2.1 Material

2.1.1 Test samples

A total of 40 copper-coated CSF(S) type steel fibers, whose properties are presented in Table 1, were used for this experiment.

Table 1. Properties of CSF(S) type steel fibers



Description	Data
Smooth	Shape
Density (g/cm^3)	7.8
Length (mm)	13
Diameter (mm^2)	0.03
Tensile strength (MPa)	1220

2.1.2 Liquid solution

As for the solution used as nutrient for the biological agent *Oomicetum Pythium aphanidermatum* (S1), 6 grams of Potato Dextrose Broth (K25-610106) and 36 grams of calcium chloride (CaCl2) were used, which were dissolved in one liter of distilled water, the solution obtained a pH of 3.95. To compare the corrosive effect, distilled water (S2) from the Federal University of Lavras, with a pH value of 7.7, was used. It should be noted that both solutions were autoclaved for 8 hours.

2.2 Method

To accelerate the corrosion process, the Cebelcor method [21] was applied for 15 days at room temperature (± 23°C). The submersion and emersion cycles were 5 and 19 hours, respectively. The liquid solutions were changed every three cycles. The mass variation was controlled by means of a Shimadzu precision balance, whose sensitivity is ±0.0002, while the fiber diameter section was measured with the Olympus BX51 optical microscope, using Wincell software. Finally, an analysis of the percentage of mass loss in relation to section loss was performed.

3 Results

Figure 1 shows the corrosion process of steel fibers in liquid solutions S1 (distilled water) and S2 (potato dextrose + calcium chloride). On day 3, it can be observed that the steel fiber in the presence of S1 presents higher/more corrosion in relation to S2. On the other hand, on the surface of the steel fibers in S1, pitting corrosion is noted,

whereas, with S2 the corroded surface is more uniform (Day 3, 6 and 9). In both cases, the texture of the steel fibers is irregular and fragmented. This effect is analyzed by Chen et al. [12] who indicate that this result is very common in experimental processes applying the Cebelcor method [21], so the galvanostatic method [22] results in a good alternative to avoid pitting corrosion.
Regarding the quantification of the corrosion effect, Figure 2 presents the values of mass loss in each cycle, in addition to the percentage variation, which, up to five days do not show a significant difference. After this period, the corrosion process was greater in solution S1, since the difference of the mass loss averages is 0.3142 (mg) higher than that of the fibers in S2, in percentage (10.64%).

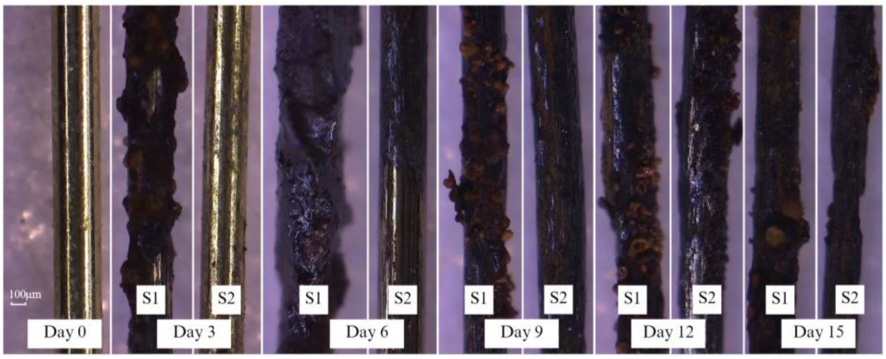


Fig. 1. Periodic drying-wetting cycles.

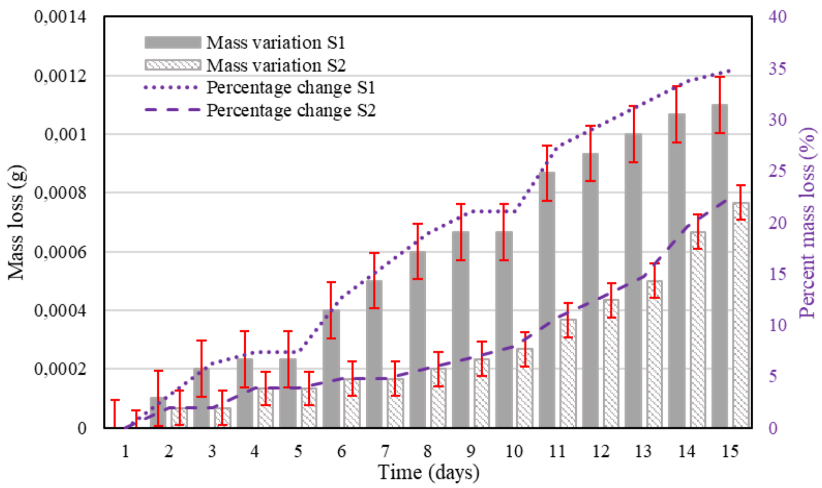


Fig. 2. Mass variation.

In relation to the cross-sectional area of the steel fibers, Figure 3 shows that there is a linear trend in terms of section loss in the presence of S2 (R2=0.95). Whereas, solution S1 presents a variable section loss, so the behavior is not linear (R2=0.5889), this may be due to pitting corrosion, so evaluating this trend requires the application of the galvanostatic method.

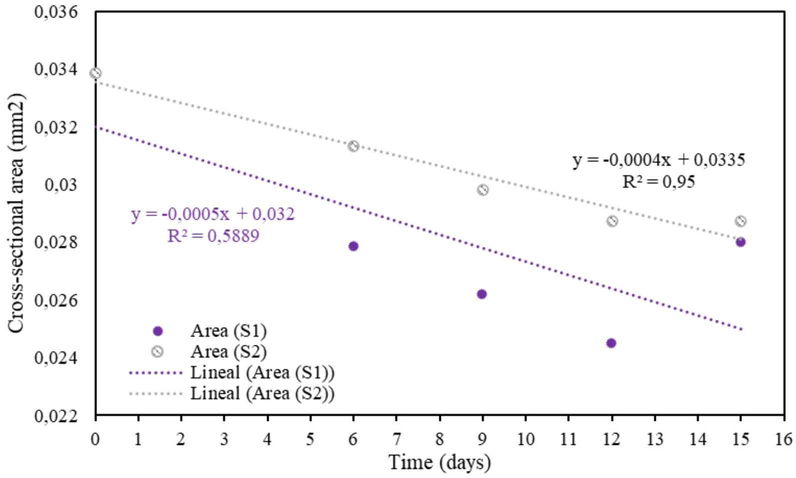


Fig. 3. Variation of the cross section.

4 Conclusions

The experimental study presented the corrosion behavior of steel fibers exposed in different solutions (S1 and S2). It was appreciated visually and quantified (mass loss), that the solution used in the development of the biological agent *Oomicetum Pythium aphanidermatum* (S1), is more corrosive compared to water (S2), whose solution is already a significant problem in steel. On the other hand, the section loss in S1 does not present a linear behavior, so it is recommended to carry out experimental processes involving the application of the galvanostatic method.

The study was limited to an evaluation of up to 15 days, therefore, there is no compression of the corrosion process for later ages. However, the results present a trend that can be useful for future research. On the other hand, it is recommended to evaluate the mechanical performance of the fibers, and tensile strength, before and after the test to verify the influence of the agents used.

Finally, it is recommended to carry out an evaluation of the mechanical response of a cementitious matrix reinforced with steel fibers, involving self-healing, including the biological agent and its respective nutrient.

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