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IMPACT OF A THIN COATING LAYER OF CALCIUM ALUMINATE AND SULFOALUMINATE CEMENTS ON ALGAL BIOFOULING

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Abstract

The aim of the study is to evaluate the bioreceptivity to green algae of a thin layer of mortar based on Calcium Aluminate, SulfoAluminate and Portland cements. The results highlight the ability of Calcium Aluminate Cement (CAC) thin coating to inhibit the algal colonization on the duration of the test. SulfoAluminate Cement (SAC) did not affect the biocolonization. Through Avrami's model, it is shown that CAC strongly inhibits the growth of algae, while the SAC slightly inhibits the growth but strongly promotes the attachment of algal cells.

1. INTRODUCTION

Building materials are progressively and inevitably subjected to biological colonization [1]. More especially, the facades of buildings become more and more bioreceptive due to their exposition to weathering rain, wind, sunlight, and CO₂, etc. The term “bioreceptivity”, as defined by Guillitte, corresponds to “the ability of a material to be colonized by one or more groups of living organisms without necessarily inducing biodeterioration”[2]. Regarding facades of buildings, biological stains affect clearly their aesthetics and represent a significant economic loss, due to the costs of cleaning works. The color of the biofilm is mainly green, black or red, depending on the biological species, themselves depending on climatic conditions, geographic location, exposure ([3][4][5]). Several biological organisms can be involved in the biocolonization of façades, such as bacteria, cyanobacteria, algae, fungi and lichen. Among these microorganisms, cyanobacteria and algae are predominant in the biofilm formed on the substrates, and they are the first colonizers after bacteria [6].

The intensity and kinetics of biological colonization of buildings surfaces depends on the environment and the substrate [7][8]. Physical (roughness, porosity) and chemical (mineralogical/chemical composition, surface pH) characteristics of the substrate influence biological colonization [9][10]. It was shown that calcium aluminate cement (CAC) exhibits a greater resistance than ordinary Portland cement (OPC) to inorganic or organic acids produced by microorganisms, such as sulfur-oxidizing bacteria or fungi [11][12][13]. The growth of green algae, such as *Klebsormidium flaccidum*, is also slowed down by CAC [14].

The aim of the present study is to combine the potential resistance to the proliferation of green algae by CAC, while reducing costs by decreasing the amount of CAC used. A SulfoAluminate Cement (SAC) was also tested. The objective is to highlight the effect of the

chemical composition of the cement used in mortar on the attachment capacity of green algae and on their growth during a laboratory test. The experimental algal colonization was simulated by Avrami's model and the rate constants related to algal attachment and growth were extracted.

2. EXPERIMENTAL APPROACH AND RESULTS

In order to reduce the cost of the materials, a thin coating of 1 mm thick, of CAC-based mortar and of SAC-based mortar were deposited on the surface of an OPC-based substrate (labeled CEMI). An OPC-based coating, with the same composition, was also tested as reference. The bioreceptivity of the samples were tested using a biofouling laboratory test. During the experiments, a suspension containing the green alga, *Klebsormidium flaccidum*, was periodically sprinkled (1.5h each 12h) on the top of the tested samples inclined at 45°. A specific image analysis method, based on image segmentation using a pixel supervised classification, was developed and used to quantify the colonization rate of each sample. An *in situ* evaluation of the biofouling was also investigated. Samples with the same design were also exposed to natural conditions on a bench located outdoors in Douai (North of France) (device is described in [15]).

3. RESULTS

By applying Avrami's model (eq. 1), the colonization rate was then simulated and was described by two processes: attachment of algal cells and their growth. Indeed, the colonization is initiated by the attachment of algae on the surface of the samples. It results in the appearance of very small green spots on the surface, corresponding to algae, which can be assimilated to nuclei in the Avrami's model. These algal spots are detected after a specific time called latency time (t_l). The extension of the colonization results from the growth of the first algal spots and from the adhesion of new ones, as in the Avrami's model. These two processes are characterized by two rate constants, K_g (Spot.day⁻¹.µm⁻²) and K_c (µm.day⁻¹), corresponding to the attachment and the algal growth, respectively.

$$X(t) = 1 - e^{-K(t-t_l)^n} \quad (1)$$

with

$$K = AK_g K_c^2 \quad (2)$$

$$A = \frac{2}{(q+1)(q+2)(q+3)} \quad (3)$$

$$n = q + 3 \quad (4)$$

The rate constant correlated to algal attachment (K_g), as well as, (q) were determined from image analysis data by quantifying the number of new algal spots appearing between two images, using eq. 5.

$$\frac{dy}{dt} = K_g \times (t - t_l)^q \quad (5)$$

Where γ is the number of algal spots at time t per unit area (Spot/mm^2)

(q) was found to be equal to one for each formulation. Finally, the rate constant related to algal growth (K_c) was calculated from K , K_c and q previously determined.

The results show that Avrami's model is suitable to simulate the algal colonization of cementitious materials. The results from laboratory test highlight that the CAC coating inhibits the algal colonization of the samples. Conversely, the SAC did not seem to affect the colonization rate. However, despite the same colonization rate, the SAC promoted the attachment of algae (higher K_g) but partially inhibited their growth (lower K_c), compared to the OPC. The inhibition of the algal growth was strongly increased by the CAC, since K_c was around ten times lower than for CEM I. Moreover, the latency time seemed to be affected by the chemical composition of the coating. Indeed, CAC exhibited higher latency time than the two other cements.

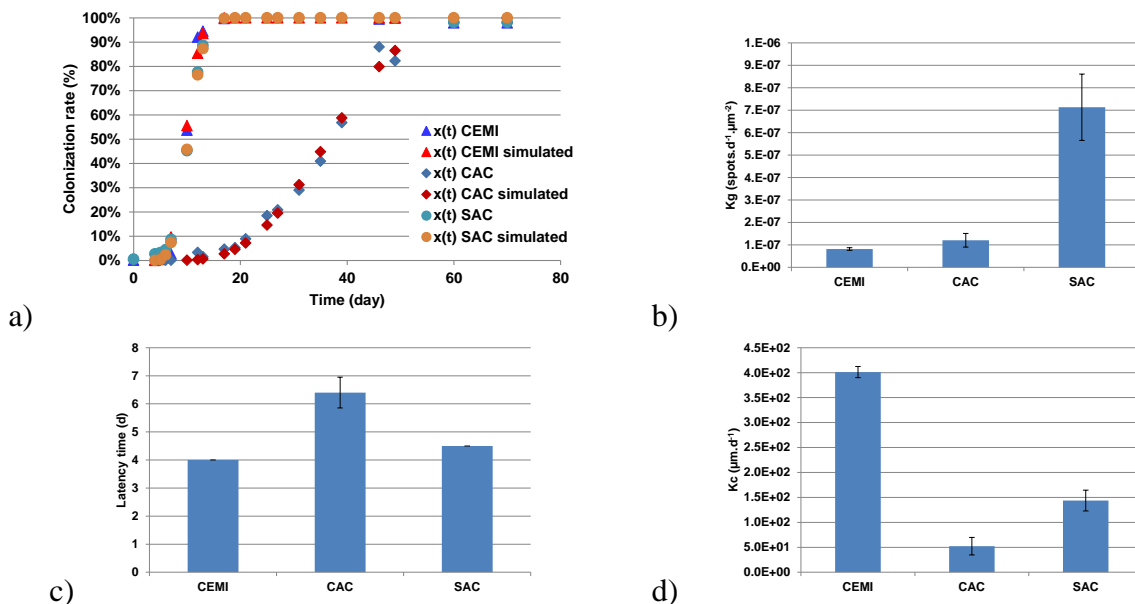


Figure 1: a) Evolution of the experimental and simulated Colonization rate for each tested mortar, b) attachment rate constant, c) latency time, d) growth rate constant

3. CONCLUSIONS

- The results confirmed the ability of CAC to exhibit an algaecide effect, even if the deposit was only a 1 mm thick coating, conversely to SAC.
- Avrami's model is suitable to simulate the colonization rate of cement-based mortars.
- The attachment rate constant (K_g) was weakly affected by CAC but strongly by SAC.
- The growth rate constant (K_c) and, to a lesser extent, the latency time (t_l) are affected by the chemical composition of the mortar. The growth rate constant was around ten times lower for CAC-based mortar than for the reference. The CAC strongly inhibits the algal growth.

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