Impact of a Thin Coating Layer of Calcium Aluminate and SulfoAluminate Cements on Algal Biofouling

Alexandre Govin[1], Philippe Grosseau[1], Christine Lors[2], Denis Damidot[2]

[1] SPIN-EMSE, CNRS:UMR5307, LGF, IMT Mines Saint-Etienne, Saint-Etienne, France

[2] IMT lille Douai, Univ. Lille, EA 4515 – LGCgE – Laboratoire de Génie Civil et GéoEnvironnement, département Génie Civil & Environnemental, F-59000 Lille, France

MORTARS

Cement

Sand

Water

Additives

FACADE COATING BIODETERIORATION

Building Facade

+

Climate

Carbonation

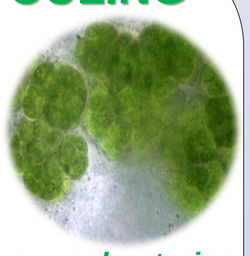
Local exposure conditions

=

Orientation

BIOFOULING

algae

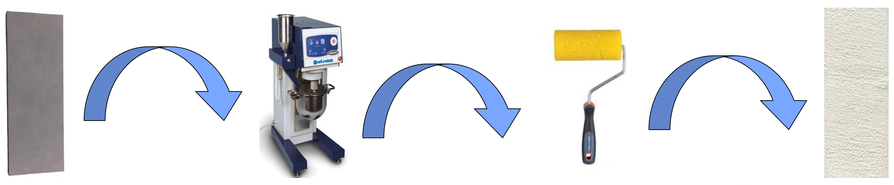


cyanobacteriae

fungi

Materials and Methods

Sample preparation



Cementitious substrate — *Thin coating* — *Biocolonization Test*

Composition
40,7% Cement (CEMI, CAC or SAC)
58,9% Limestone filler
0,4% Thickener
W/Solid= 0,30 (CAC)
= 0.37 (CEMI, SAC)

Deposit with a roller

Properties
Thickness of 1mm
Roughness ≈150µm

Hydration
t= 10 days
T= 20°C
95% HR

Carbonation
100% CO_2
T= 20°C
65% HR

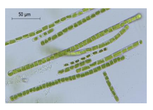
Experimental setup

Sprinkling cycles of *Klesbsormidium flaccidum* suspension
(sprinkling cycle of 90min/12h at 24L/h)
$[algae]_{initial}$=4mg/L
T= 20°C
Photoperiod: 12h/12h

Mortars with coating

+

Micro-algae
Klebsormidium flaccidum

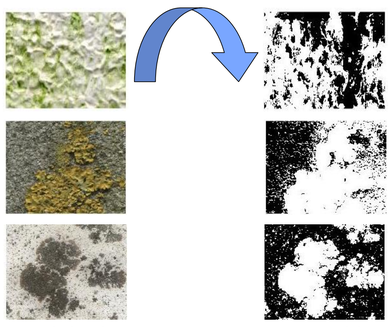


=

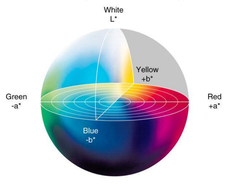
Quantification of Algal fouling by Image analysis

Detection of colonized pixels after learning through neuronal network

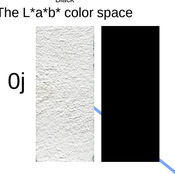
Segmentation of color image by combining thresholding operators (L*, a*, b*, Saturation)



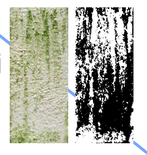
Original image — Segmented image considered as truth



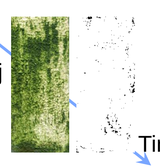
The L*a*b* color space



0j



35j



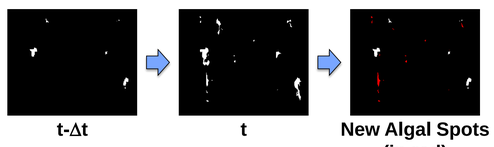
70j — Time

Colonization rate X(t)

$$X(t) = \frac{S_t}{S_0}(\%)$$

S_t : Colonized Surface Area at time t
S_0 : Total Surface Area

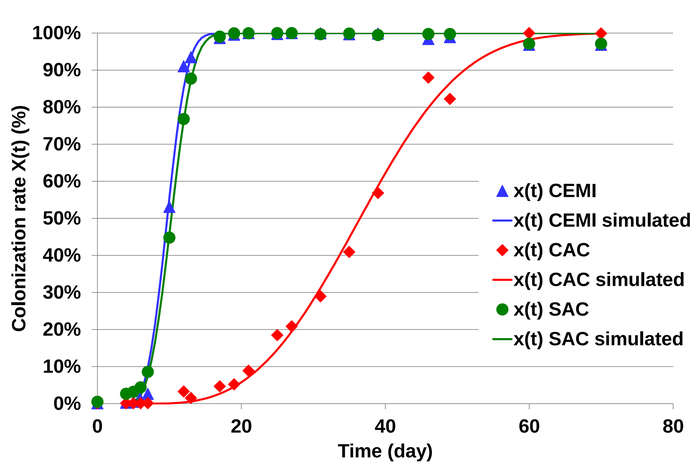
Identification and quantification of the new algal spots between two successive images by labeling and morphological reconstruction operators



t-Δt — t — New Algal Spots (in red)

Experimental determination of the algal attachment kinetics dγ/dt=f(t)

Colonization rate



- No significant impact of SAC on the algal colonization
- Inhibition of the algal colonization by CAC, even with thin layer (coating thickness ≈ 1 mm)

↓

Confirms previous results obtain with full CAC samples (E. Dalod, PhD thesis, 2015)

- Good matching of experimental data and Avrami's model

Kinetics Model Based on Avrami's Model

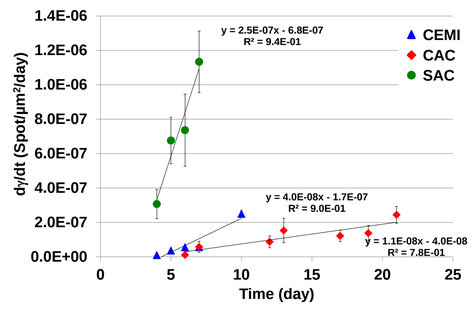
$$X(t) = 1 - e^{-K(t-t_l)^n}$$

with $K = AK_gK_c^2$

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

$$n = q+3$$

where t = time (day)
t_l = **latency time** (day) = time experimentally determined for **X(t) > 0.5%**
K_g = **attachment rate constant** (Spots.d^{-1}.µm^{-2})
K_c = **growth rate constant** (µm.d^{-1})



Attachment kinetic law: $\frac{d\gamma}{dt} = K_g \times (t - t_l)^q$

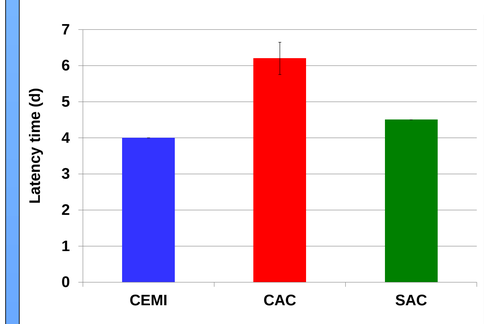
For $t \geq t_l$ and **X(t) < 40%**

Linear correlation ⇒ **q=1, n=4, A=1/12**

Slope = K_g

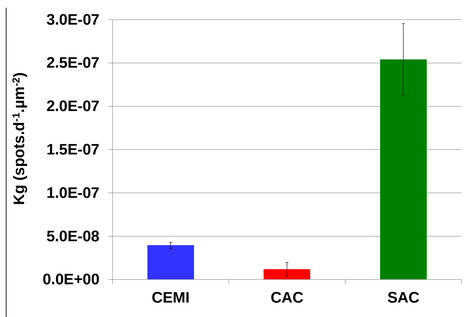
Determination of K_c by model adjustment with experimental data

Kinetic parameters attracted from the model

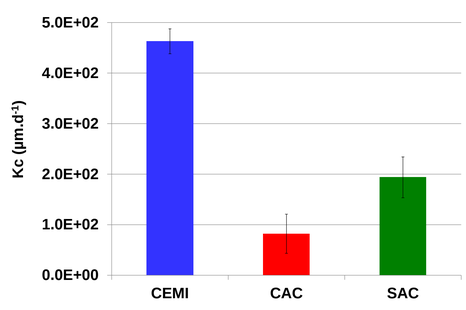


$t_{l\ CEMI} < t_{l\ SAC} < t_{l\ CAC}$

Latency time slightly affected by the chemical composition of the coating



$K_{g\ CAC} < K_{g\ CEMI} << K_{g\ SAC}$



$K_{c\ CAC} < K_{c\ SAC} << K_{g\ CEMI}$

Inhibition of the algal fouling by **CAC** is the consequence of the decrease in the attachment of the algal cells and of the strong reduction of their growth kinetics.

Reduction of the growth kinetics is annihilated by the increase of the attachment kinetics for **SAC**. ⇒ **Similar colonization rate than CEMI**

Conclusions

- Avrami's model is suitable to simulate the colonization rate by green algae of cement-based mortars.
- The results confirmed the ability of CAC to inhibit the algal fouling, even with a thin layer coating (thickness ≈ 1 mm).
  - by increasing the latency time, decreasing the attachment rate constant and strongly decreasing the attachment rate constant.
- No impact of the SulfoAluminate Cement on the colonization rate.
  - decrease in the growth rate constant compensated by the strong increase in the attachment rate constant.