FROM CONCRETES TO BIORECEPTIVE CONCRETES, INFLUENCE OF CONCRETE PROPERTIES ON THE BIOLOGICAL COLONIZATION OF MARINE ARTIFICIAL STRUCTURES

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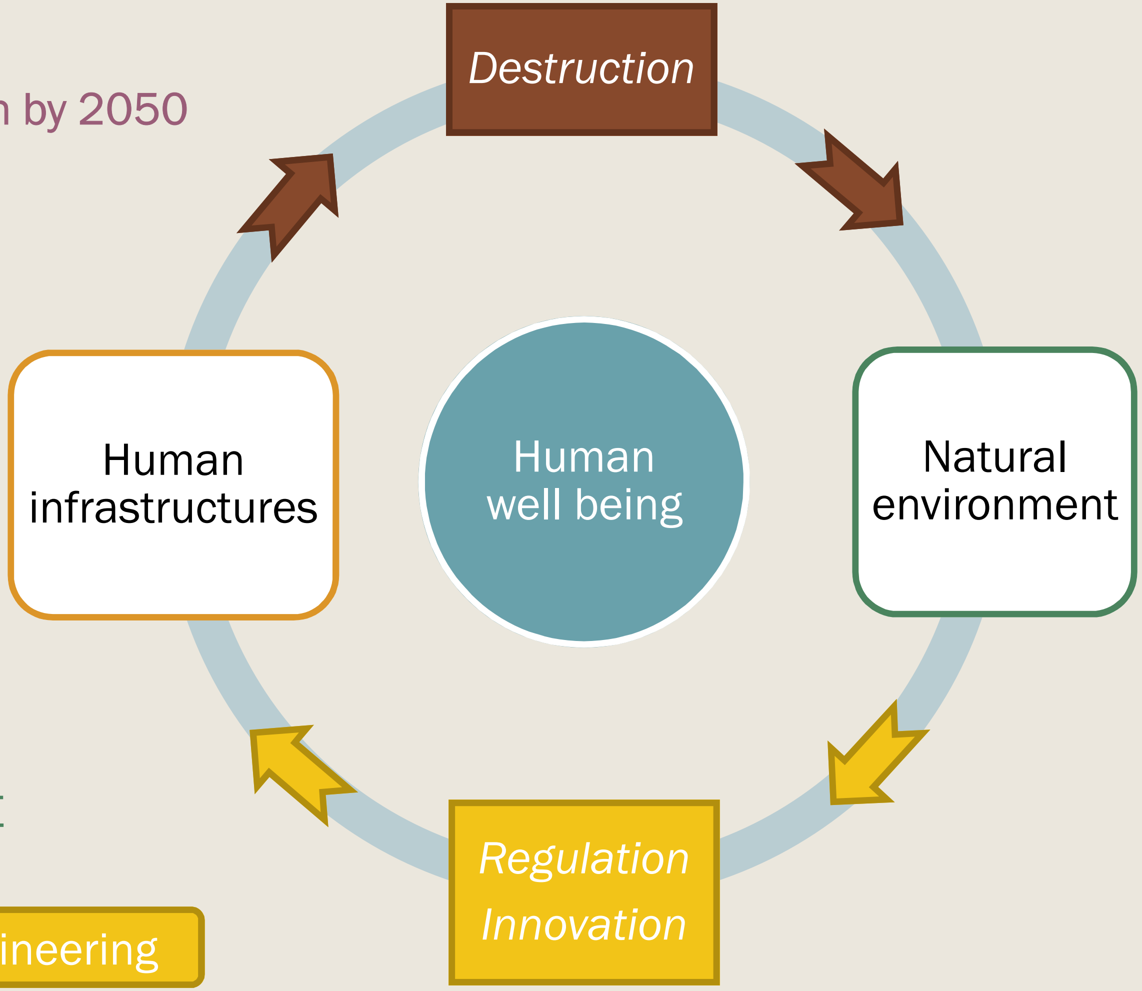
Context

39,400 km² of coastal and marine areas
The population is projected to reach 9 billion by 2050

Change in the natural environment
New structures = New ecosystems



1st AVOID - 2nd REDUCE - 3rd COMPENSATE

Eco-Design/Eco-Engineering

Context and global objectives

Eco-Design
Eco-Engineering

Concept of building WITH nature

Habitats designed to mimic natural habitats and attract target species

*Eco-design of Marine Infrastructures : Towards Ecologically-informed Coastal and Ocean Development
Sylvain Pioch (Auteur), Jean-Claude Souche (Auteur), Iste Editions
https://www.iste.co.uk/book.php?id=1803

Environmental and economical benefits
Insuring the functionality and the durability of structures at reasonable cost

State of the art

Concrete

Many feedbacks
Various compositions and textures
Complex design

Structural and long–lasting [Guilbeau] [Fitzhardinge]

Easy to design	Manipulation and transport (heavy)
Moderate cost	Weakness in tropical zones
Surface adapted to organisms fixation	Possible release of heavy metals [Hillier]
	Basic pH surface which evolves rapidly in seawater [De Weerdt]

Substratum

Exposition, environnemental conditions, seasons … [Blouet] [Anderson] [Choi][Somsueb]

Materials parameters: pH, surface texture, hydrophobicity, composition,…

Scientific locks :

Comparison lab and in-situ tests

Influent parameters

Objectives of the study

Understanding of marine microorganisms/materials interactions

Effect of cementitious materials on the marine environment

Effect of cementitious materials parameters and of the manufacturing process on it surface biocolonization

How to assess the biocolonization of concrete over time?

Develop an experimental approach to assist in the design of more environmentally friendly marine structures by specifying the cementitious material (type and physicochemical properties), the surface texture, the manufacturing process

Materials and Methods – materials

2 types of binder

CEM I OPC 52.5 N, provided by Calcia

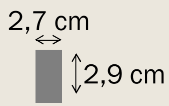
Blastfurnace slag cement CEM III : 40% CEM I - 60% ground granulated blast-furnace slag NF EN 15167-1, provided by ECOCEM

2 agents

SikaCem® Cure, applied on the top surface 1 h after stripping

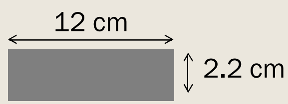
vegetable oil, BIODEM SI 3, spread on the molds before the mortar was poured

Mortars



W/C ratio = 0.5
Storage 20°C for 30 days

Concrete



W/C ratio = 0.45
Storage 20°C for 30 days

Materials and Methods – surface texture



@CLI Ecopode Artelia

SMOOTH

PATTERNED

BIOMIMETIC

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Materials and Methods – summary

6 mortars

4 parameters (binder, surface roughness, curing agent, formwork oil)

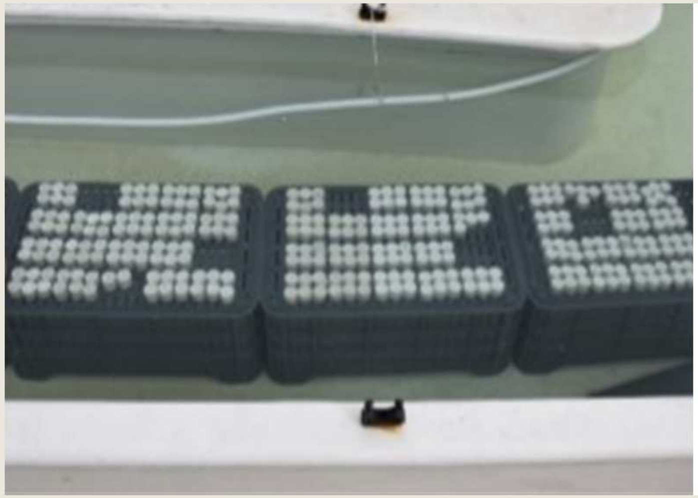
Mortar Specimen		Binder	Curing Agent	Formwork Oil
Control mortar (SMOOTH)	Ref	CEM I	-	-
Cured mortar (SMOOTH)	CM	CEM I	+	-
Oiled mortar (SMOOTH)	OM1	CEM I	-	+
	OM3	CEM III	-	+
Biomimetic mortar (BIOMIMETIC)	BM1	CEM I	-	-
	BM3	CEM III	-	-

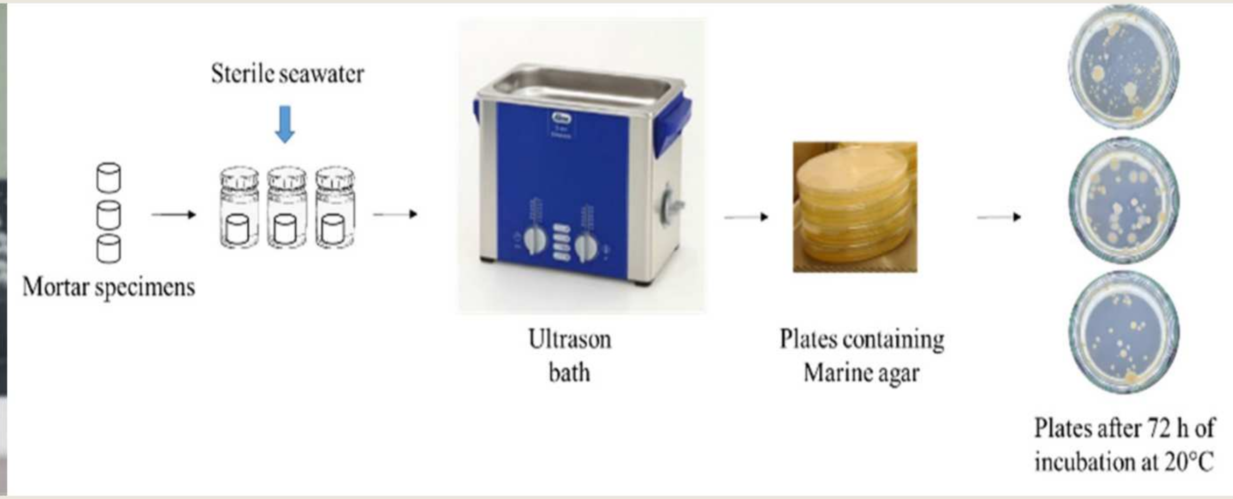
7 concretes

4 parameters (binder, surface roughness, curing agent, formwork oil)

Mortar Specimen		Binder	Curing Agent	Formwork Oil
Control concrete (SMOOTH)	Ref	CEM I	-	-
Cured concrete (SMOOTH)	CC	CEM I	+	-
Oiled concrete (SMOOTH)	OC	CEM I	-	+
Ecopode concrete (PATTERNED)	EC1	CEM I	-	+
	EC3	CEM III	-	+
Biomimetic concrete (BIOMIMETIC)	BM1	CEM I	-	-
	BM3	CEM III	-	-

Materials and Methods – performed tests on mortars





Immersion in a flat-bottomed basin at the IFREMER station, Palavas-les-flots

average conditions during 28 days
Water 20 °C - pH 8

Time 0, 1, 2, 6, 8, 15, 24, 26, 28 days

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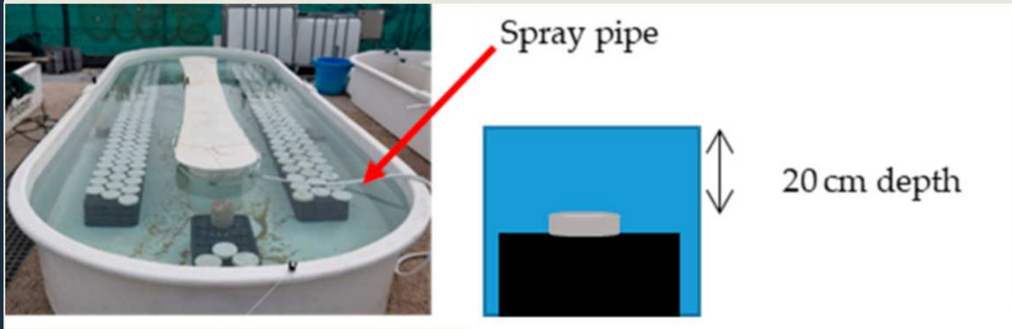

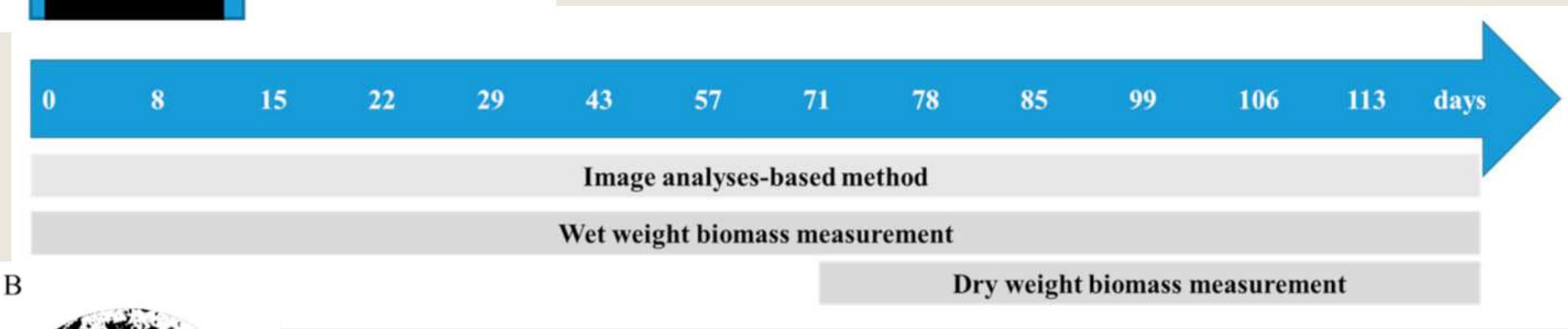

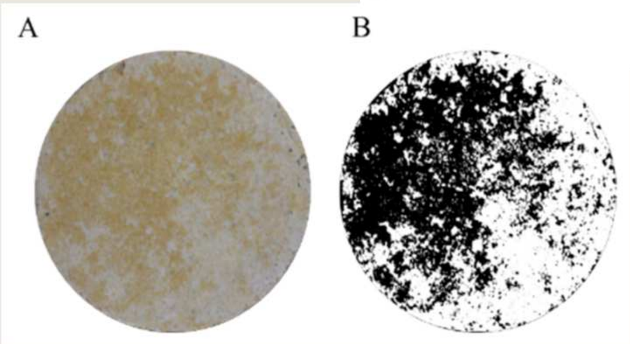

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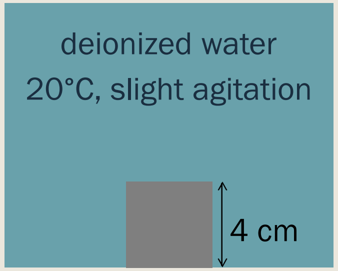
Materials and Methods – performed tests

Contaminant release evaluation

Leaching test with a solid-liquid ratio of 1:8



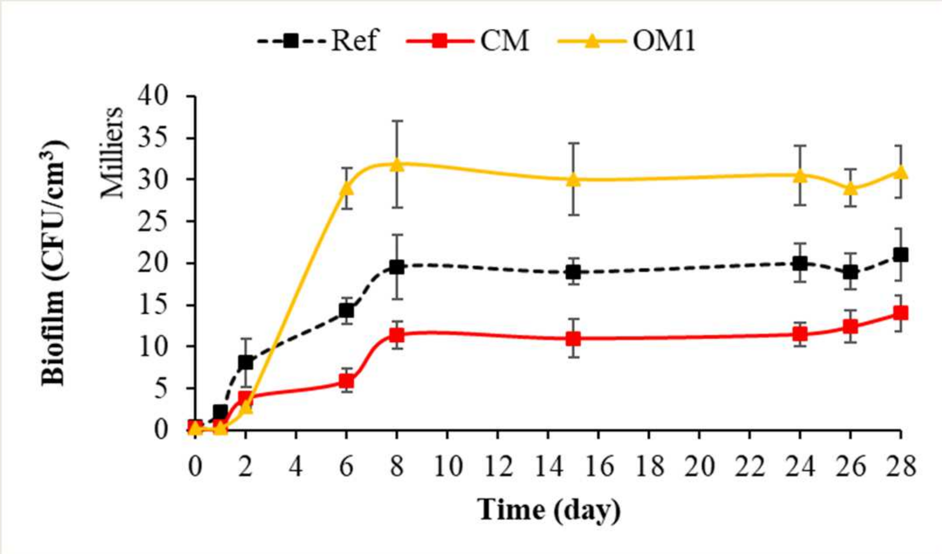
After leaching, 20ml of the solution is filtered and the pH is adjusted to 2 with 1N nitric acid

Inductively coupled plasma atomic emission spectroscopy (detection limit 10µg/L)

- ✓ no copper and lead detection

No release of toxic heavy metals was detected during the leaching test in water. Further experiments need to be done using a leaching test in seawater with more precise equipment (ICP-MS).

Results – additional agents influence on biofilm development



Ref : control mortar (CEMI binder)
CM : Cured mortar (CEMI binder)
OM1 : Oiled mortar (CEMI binder)

Curing agent effect

Inhibition of the bacterial colonization
- Composition : anti-biofilm molecules
- Hydrophobic surface coating

Formwork oil effect

Improvment of the bacterial colonization
- carbon source for marine bacteria
- nutrients

Untreated surface (Ref)

Treated surface (CM)

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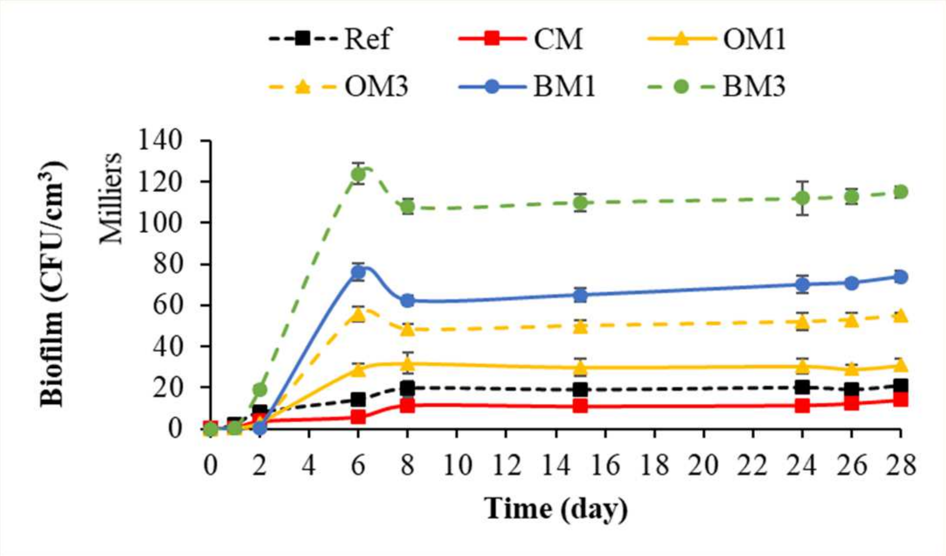
Results – binder and surface influence on biofilm development

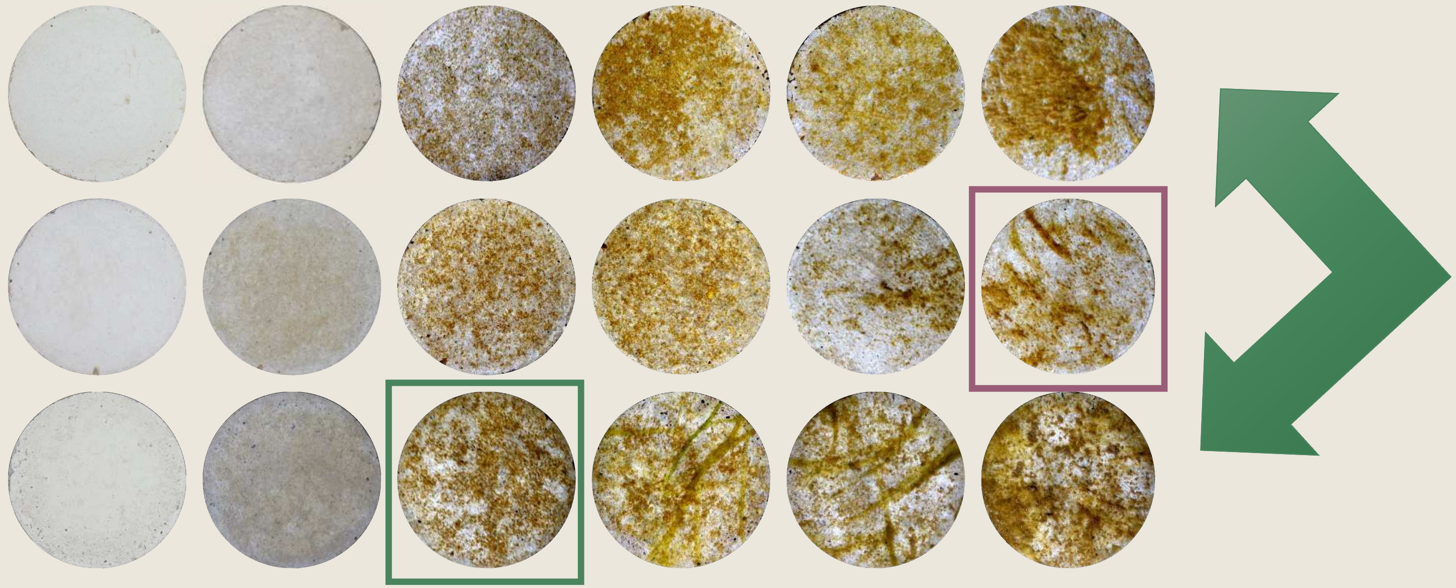


CEM III mortars > CEMI mortars
surface topography (BM1 vs. BM3)
formwork oil use (OM1 vs. OM3)

rough mortar surface > smooth mortar surface

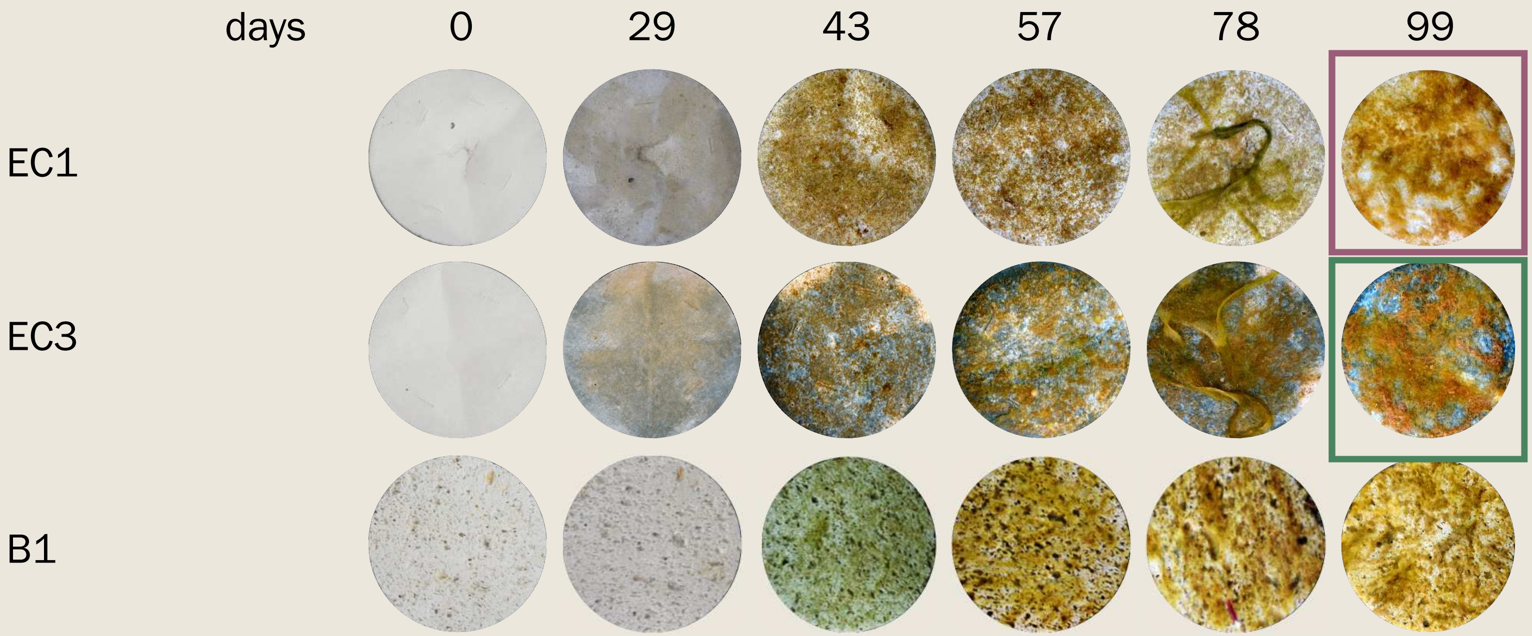
surface roughness > binder > surface treatment with green formwork oil

Results – the follow-up of macro-fouling, visually



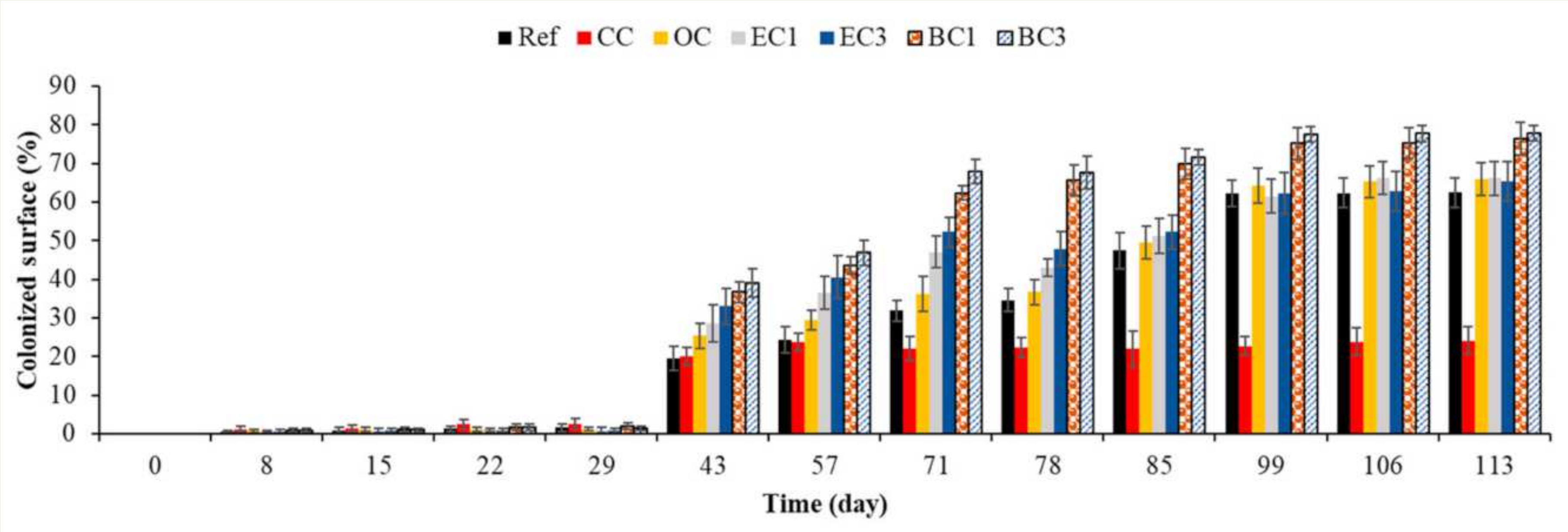
*credit photo M. Hayek

Results – the follow-up of macro-fouling, visually



*credit photo M. Hayek

Results – the follow-up of macro-fouling, image analysis



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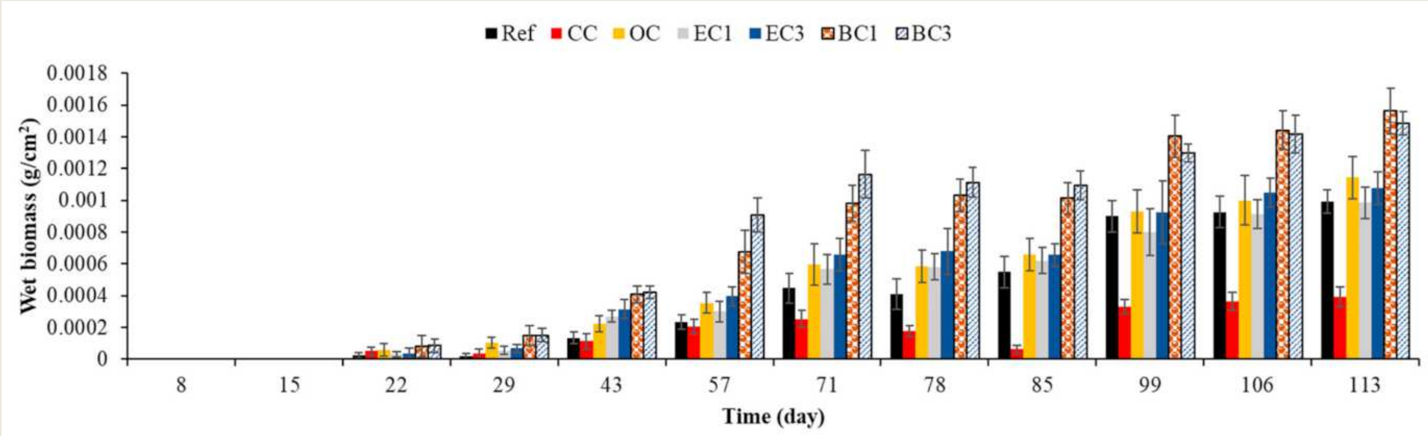
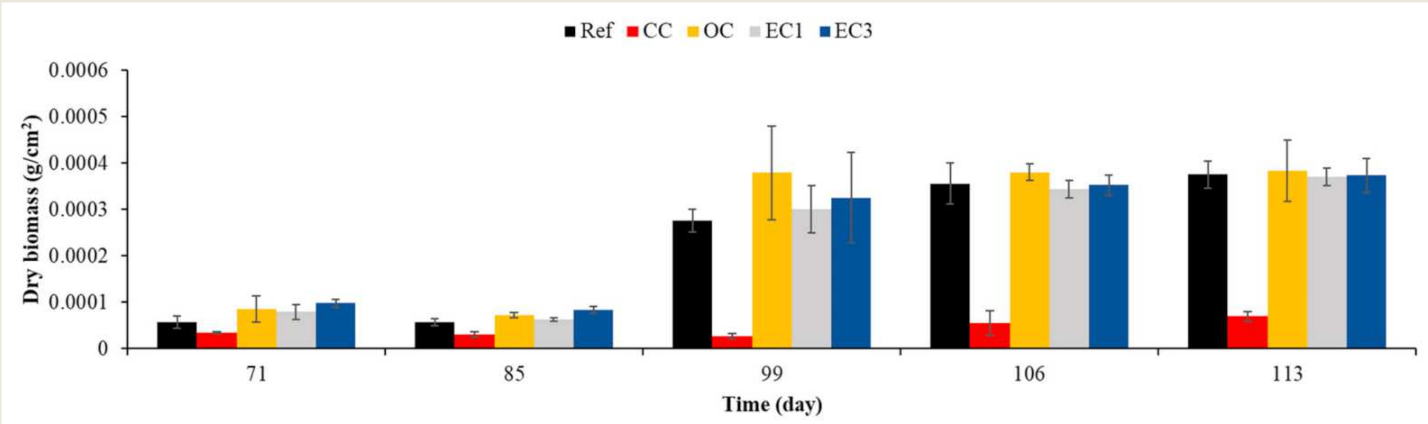
Results – the follow-up of macro-fouling, weighing of biomass





MARINEFF

Conclusion and outlooks

Work practices such as the use of a curing agent and/or formwork oil have an impact on biocolonization :

- the surface treatment with green formwork oil enhance the biocolonization
- the application of curing agent is harmful for biocolonization

The use of rough surface and CEM III binders increases the bioreceptivity of cementitious materials and surface roughness proved to be the factor that promotes biocolonization most effectively.

At the material scale, after 120 days, only surface roughness seems the most effective factor in designing bioreceptive concrete that enhances marine biodiversity. Faceted and patterned surfaces or the use of green formwork oil seem to improve the initial colonization stages.

To assess the bioreceptivity of the material, quantify the bacterial biofilm adhered to the surface of the mortar specimens using “culture-based methods” in lab seems to be a valuable option.

Study on the durability of biocolonized concrete in marine environment

Global vision of construction project involving ecology consideration and life cycle anlalysis optimisation

ANY QUESTIONS?

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To go further : Hayek, M.; Salgues, M.; Souche, J.-C.; Cunge, E.; Giraudel, C.; Paireau, O. Influence of the Intrinsic Characteristics of Cementitious Materials on Biofouling in the Marine Environment. Sustainability 2021, 13, 2625. https://doi.org/10.3390/su13052625

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