BIO BETON

New challenges on the uses of biomass in the building material construction industry

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Scientific Context : What type of material to reach the Ecologiacal target ?

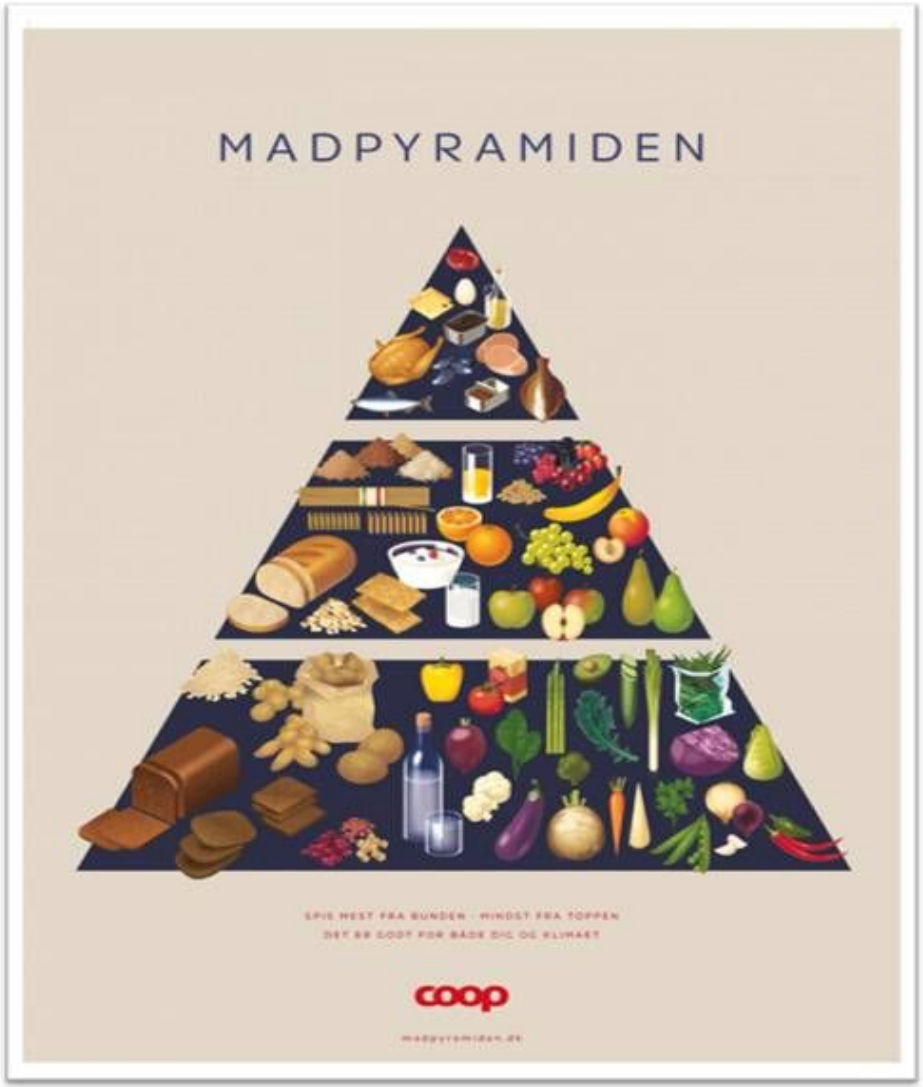
The usual concrete ?

4.8 tonnes of concrete produced annually for each person (We are 7,5 billions people)

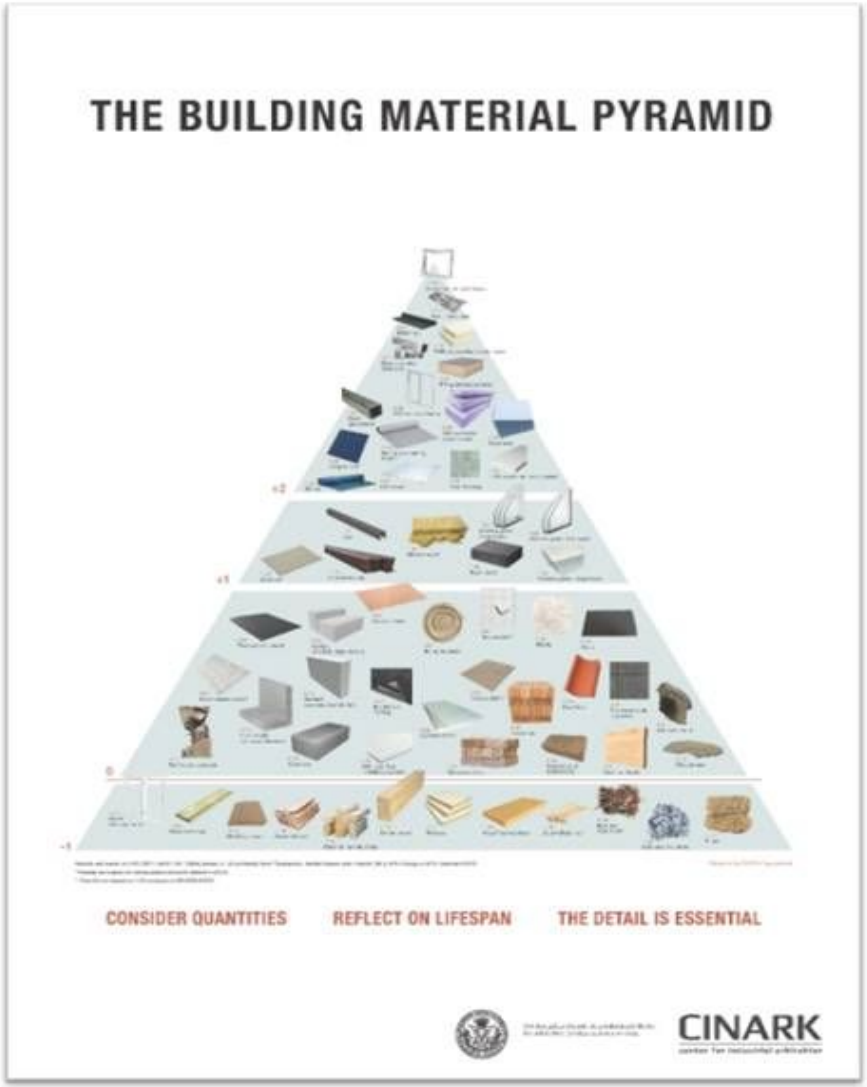
Calcination of limestone ($CaCO_3$)
Cement production is responsible for 5.6% of emissions
From fossil fuel

CONCRETE
≈2350 $kg.m^{-3}$
≈20-50 Mpa
≈2 $W.m^{-1}.K^{-1}$
≈400 Kg CO^2/m^3

You are what you eat, and you become what you build! The digital version of Construction Material Pyramid with carbon impacts



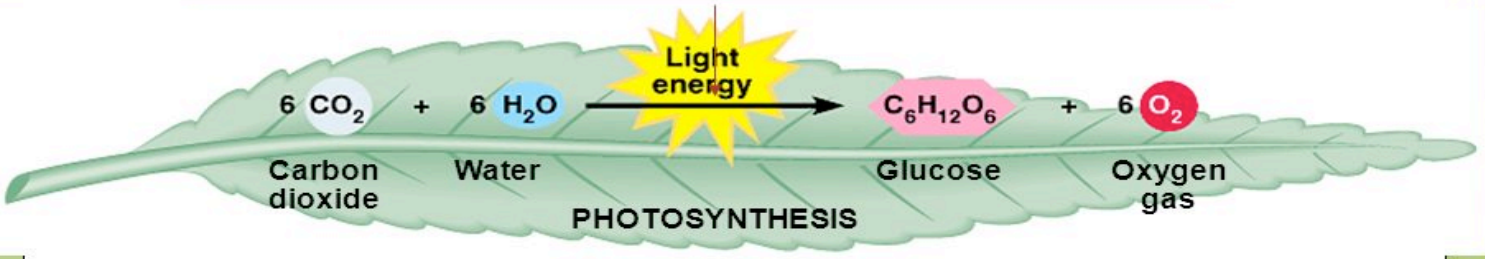
iconic Food Pyramid



PHOTOSYNTHESIS

- Photosynthesis is the process by which autotrophic organisms use light energy to make sugar and oxygen gas from carbon dioxide and water

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$



carbon dioxide + water → glucose + oxygen + water + energy

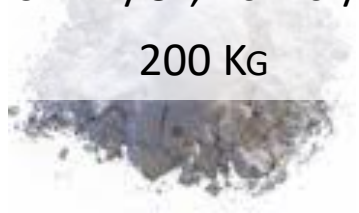
1851 kg CO2 + **1082 kg H2O** ----------> **1000 kg wood** + 1392 kg O2 + **541 kg H20**

BIO BETON

0.13 T Co2 / 0,2 T Ca(OH)2

MINERAL BINDER (NHL, CL,CP/ METAKAOLIN/CL, POZZOLANA/CL, PUMICE/CL ….)

200 KG



PLANT AGGREGATE

100 KG

WATTER

200 L

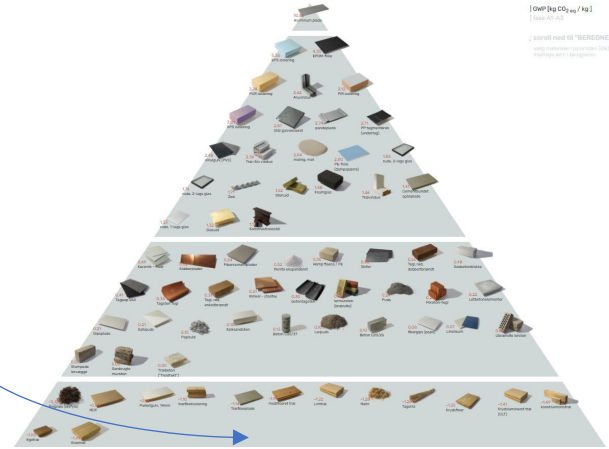
AGRI-CONRETE

≈350 kg.m^{-3}

≈0,2-0,5 Mpa

≈0,1 W.m^{-1}.K^{-1}

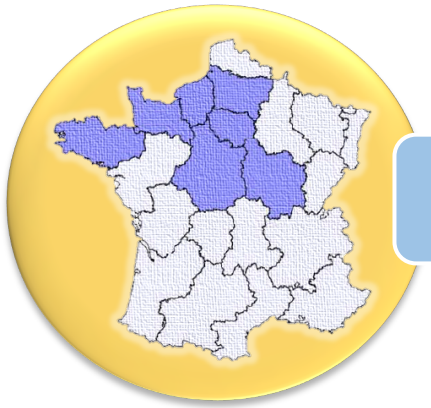
≈ - 150 Kg CO^2/m^3



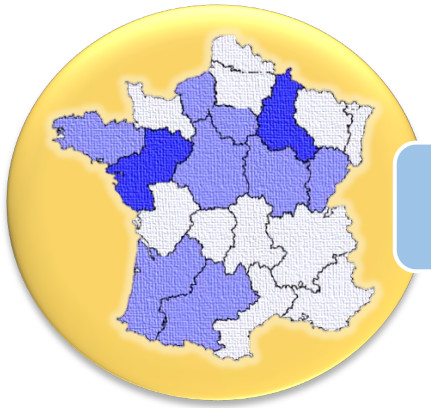
Main producer of vegetable fibers in Europe with 80% (169 000 tonnes) [1]

Planted surfaces of over 85 000 hectares [1] + 675 000 Ha of Sunflower …..!

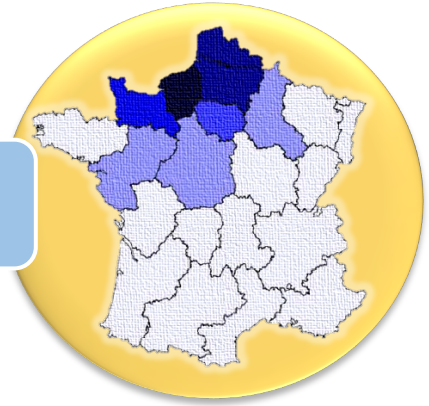
The biogenic storage of carbon by bio-based materials is taken into account within the framework of the RE2020.



Miscanthus
2 000 ha

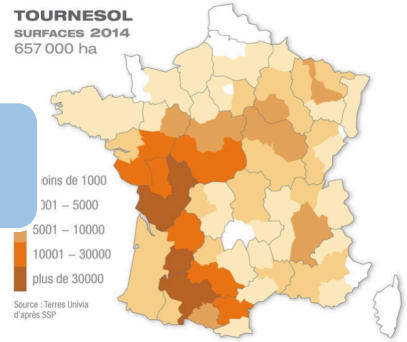


Hemp
8 000 ha



Flax
75 000 ha

Sun Flower
657 000 ha

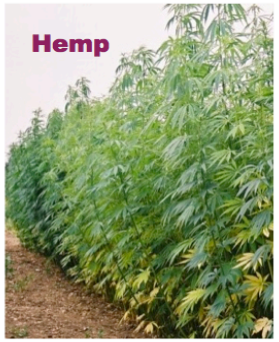


[1]

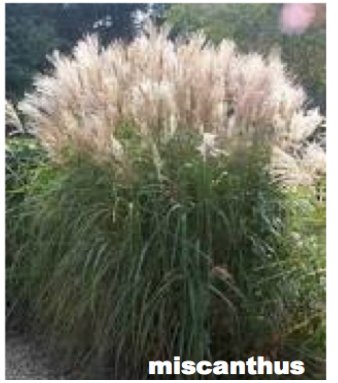
Prediction of huge increase of biomass in building industry from next year !

Several opportunities

AGGREGATE



Rape straw



We need :
5 to 10 tons of plant aggregate / house which represent around 1 to 2 Ha / house
200 euros / 500 euros (cost of the ton of aggregate in europe)

Multiscale use of biomass

ASH

AGGREGATE

FIBRES

STRUCTURE

Calcination 700 °C 1h

ASH

XRD of amorphous elephant grass ash vs. silica fume as potential mineral addition to OPC

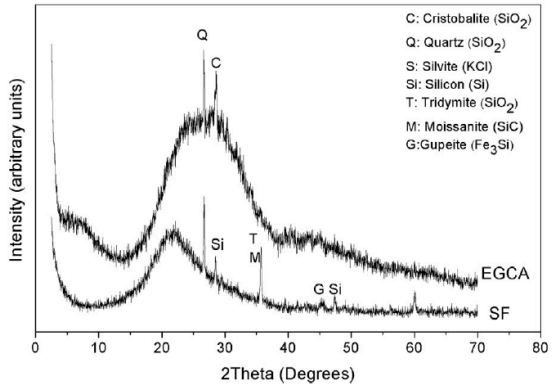


Fig. 1. XRD patterns of the treated cameroon ashes (EGC) and silica fume (SF).

According to the results from XRD and TG/DTA analysis, **CSH gels and tetracalcium aluminate hydrate** were the main reaction products in 20% blended cement pastes. **The same reaction products were identified when the addition was silica fume (SF), but in different concentrations.**

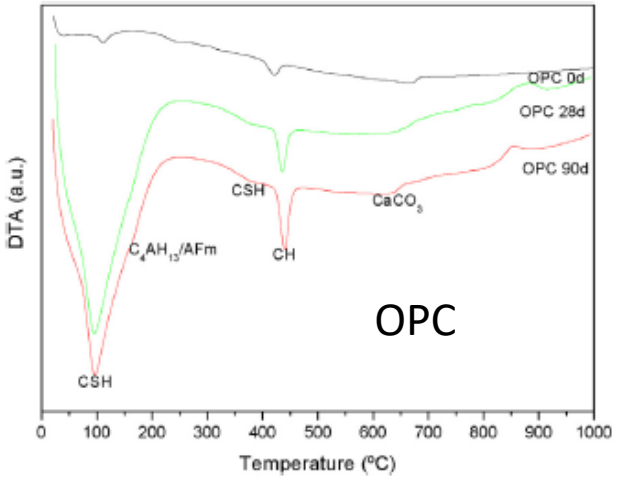


Fig. 6. DTA curves of OPC pastes at different ages of hydration.

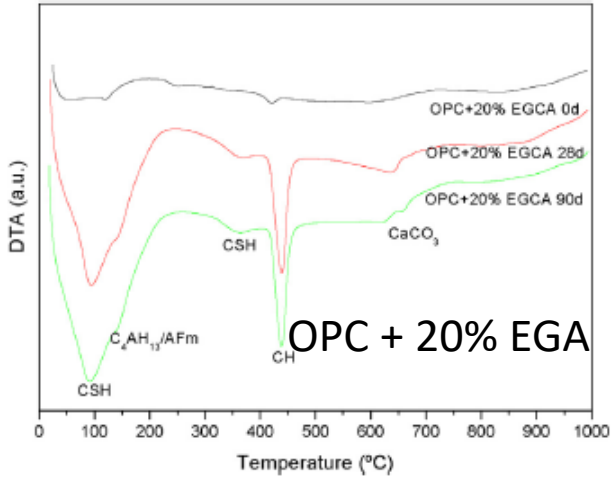


Fig. 7. DTA curves of OPC+20% SF pastes at different ages of hydration.

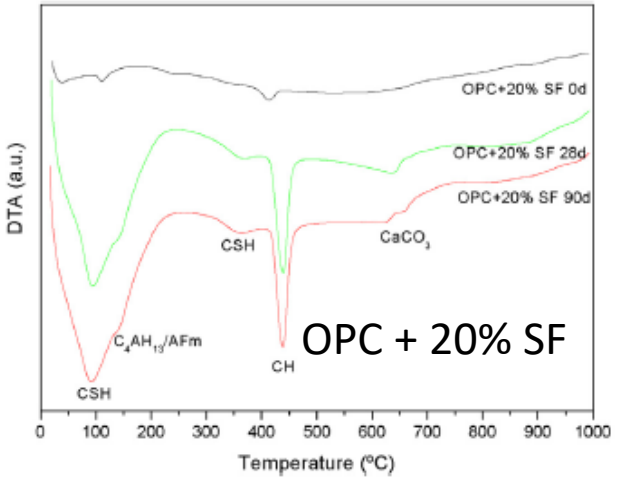


Fig. 8. DTA curves of OPC +20% EGCA pastes at different ages of hydration.

NAKANISHI, ERIKA Y. ; FRÍAS, Moisés ; SANTOS, SÉRGIO F. ; RODRIGUES, MICHELLE S. ; VIGIL DE LA VILLA, RAQUEL ; RODRIGUEZ, OLGA ; **JUNIOR, HOLMER SAVASTANO** . Investigating the possible usage of elephant grass ash to manufacture the eco-friendly binary cements. Journal of Cleaner Production , v. 116, p. 236-243, 2016.

EUROPE : Constructions based on fibers

Chaumière – **FRANCE**

Moulin de Berkmeer– **PAYS BAS**

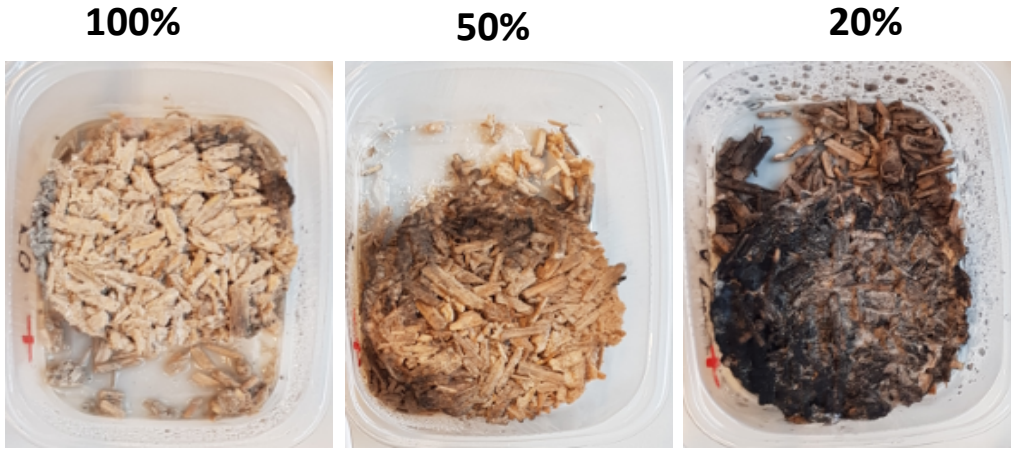
Cabane de pêcheurs – **PORTUGAL**

Corps de ferme en torchis – **FRANCE**

Crédits : Ziouclesi, Gérard Janot, Quistnix, DR, CRATerre-ENSAG

Vegetal description
Mechanical Tests
Hygrothermal Tests
Acoustical performances
Durability Tests

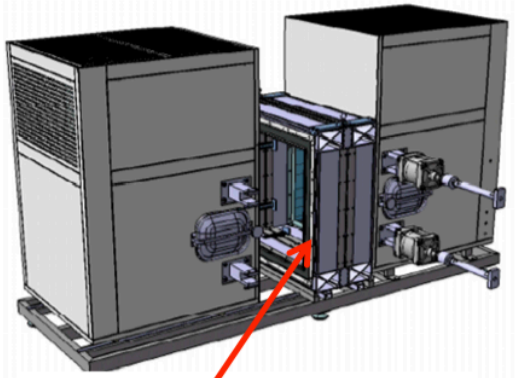
BIODEGRADEBILITY

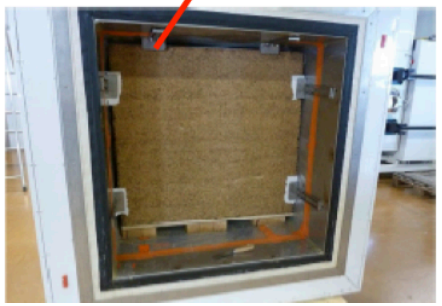


From left – FHL-100, FHL-50, FHL-20 (%)

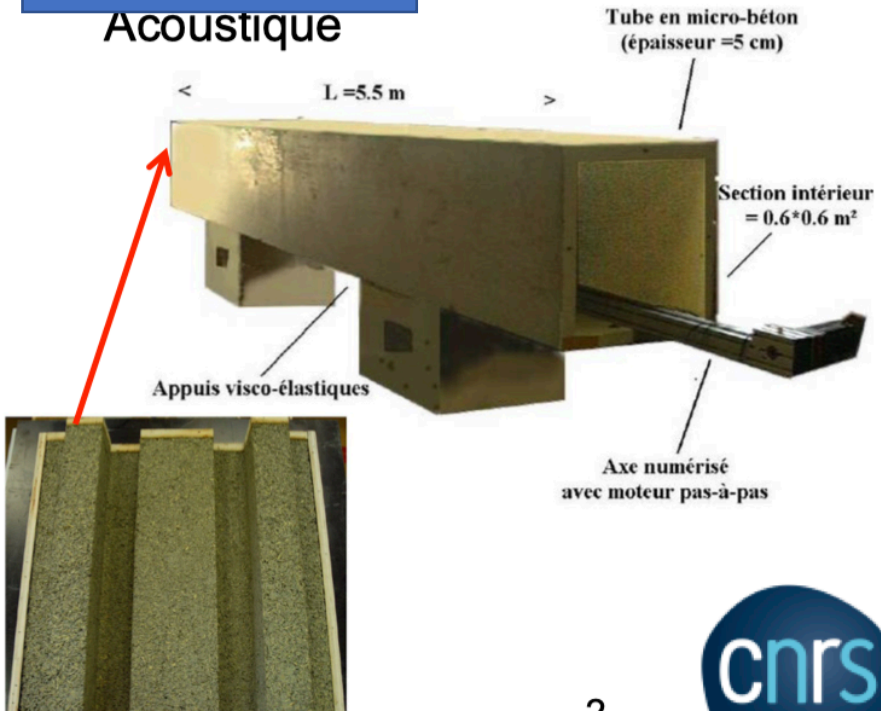
Mechanical test (compression, Bending) of Rice Husk Concrete

Hygrothermal Test





Acoustical Test



State-of-the-Art Report
Rilem TC 236 BBM
Bio based Aggregate Building Materials

Chapter 1. **Chemical composition of bioaggregates and their interactions with mineral binders**

Chapter 2. **Porosity, pore size distribution, micro-structure**

Chapter 3. **Water absorption of plant aggregate**

Chapter 4. **Particle Size Distribution**

Chapter 5. **Bulk density and compressibility**

Chapter 6. **Hygric and thermal properties of bio-aggregate based building materials**

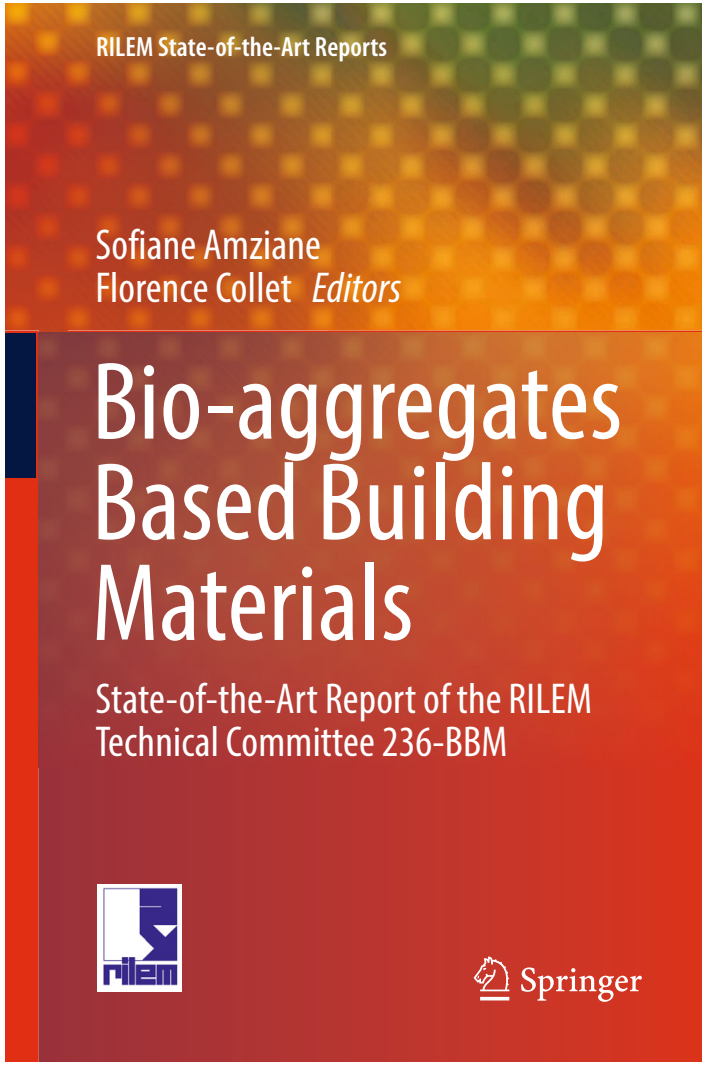
Chapter 7. **Bio-aggregate based building materials exposed to fire.**

Chapter 8. **Durability of bio-based concretes**

Chapter 9. **Effect of testing variables (method of production).**

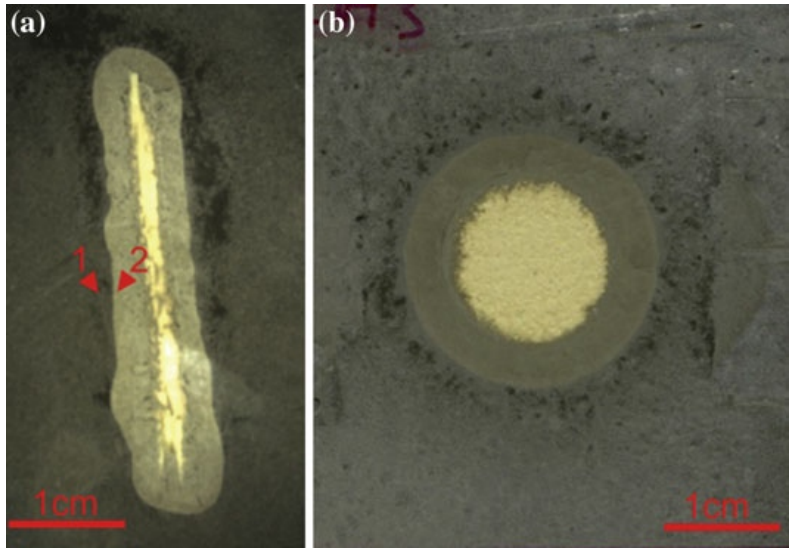
Appendix

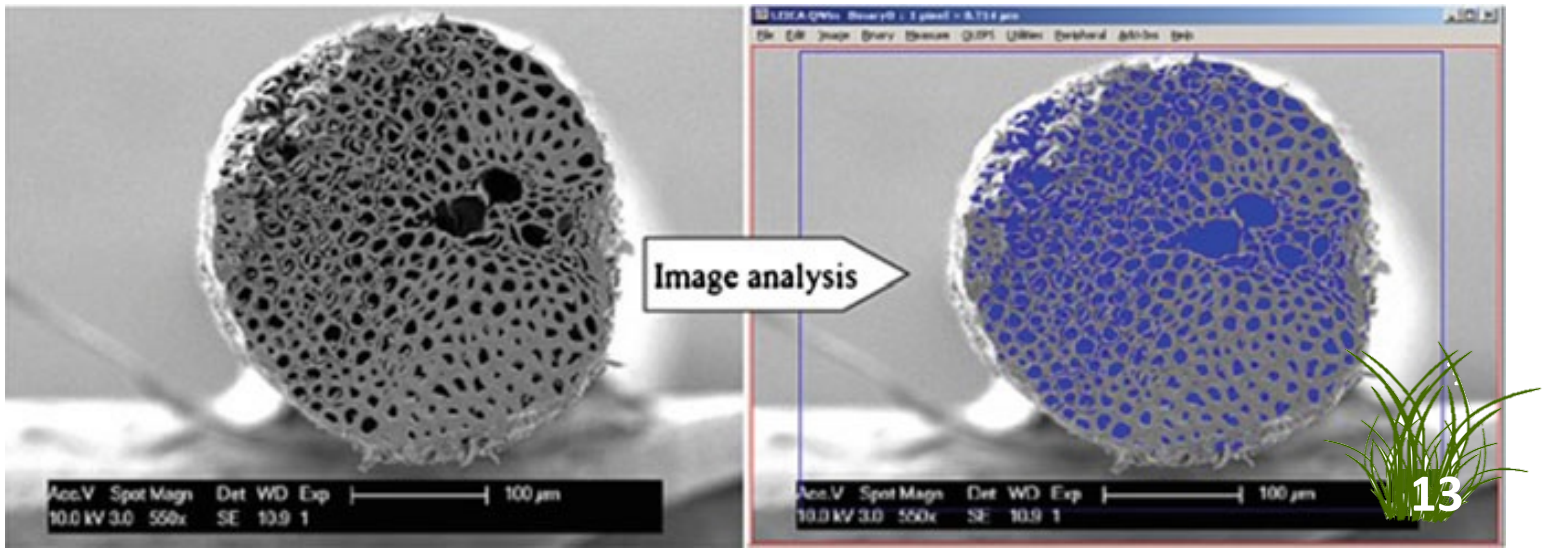
Round Robin Test → RECOMMANDATION OF RILEM TC 236-BBM: CHARACTERISATION TESTING OF HEMP SHIV TO DETERMINE THE INITIAL WATER CONTENT, WATER ABSORPTION, DRY DENSITY, PARTICLE SIZE DISTRIBUTION AND THERMAL CONDUCTIVITY.



Chemical Interactions Between Bio-aggregates and Mineral Binders

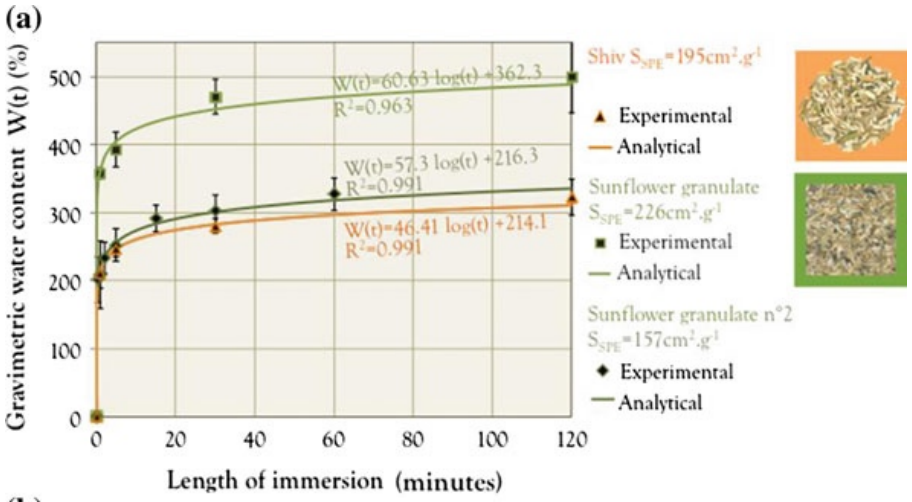
Image analysis to measure the porous area of the fibre cross-section using the software Leica QWin (Tran et al. 2015)

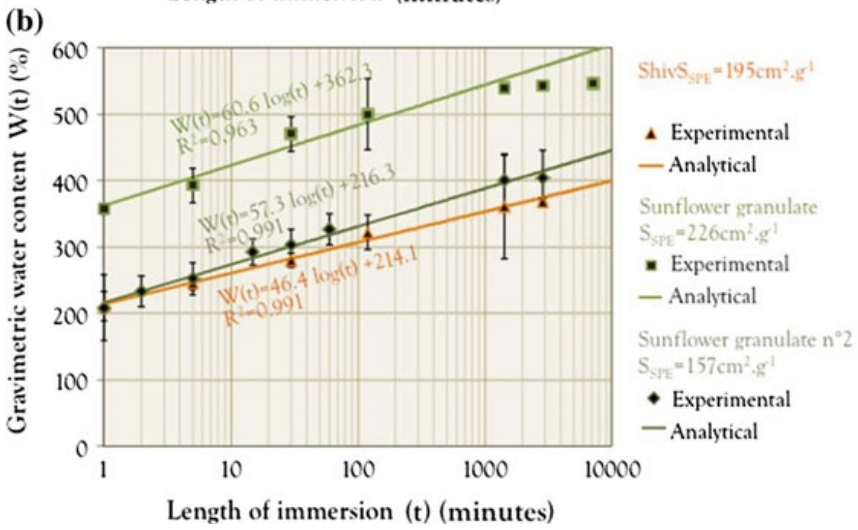


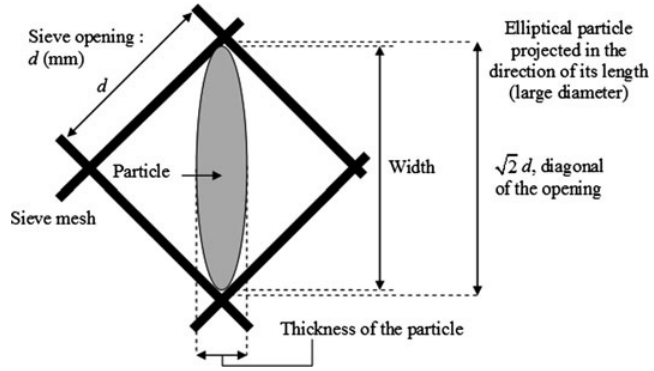


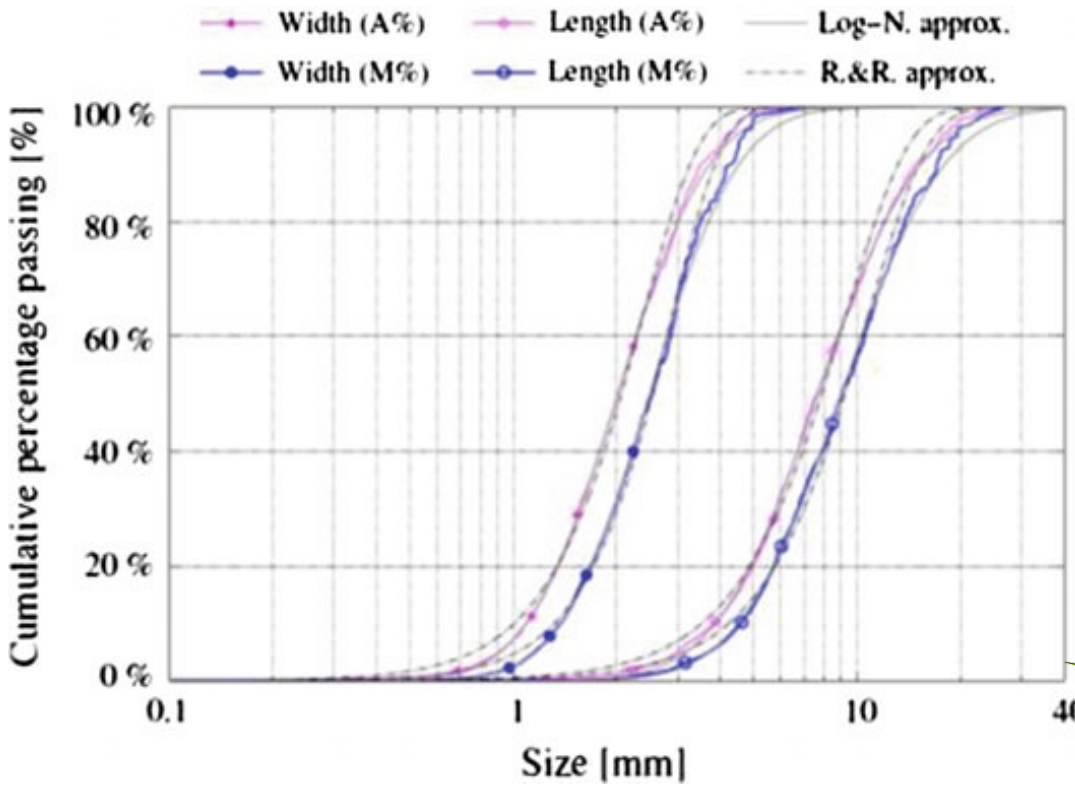
Hydrophilic Materials

distributions of width and length

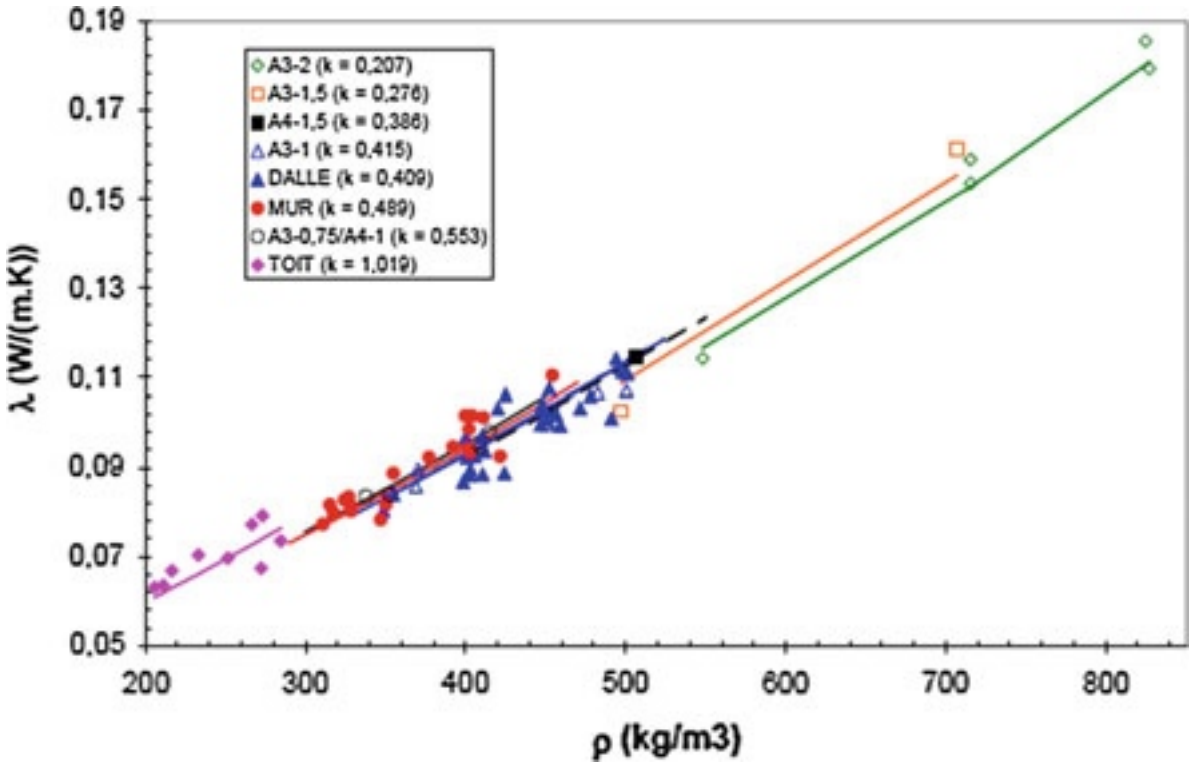


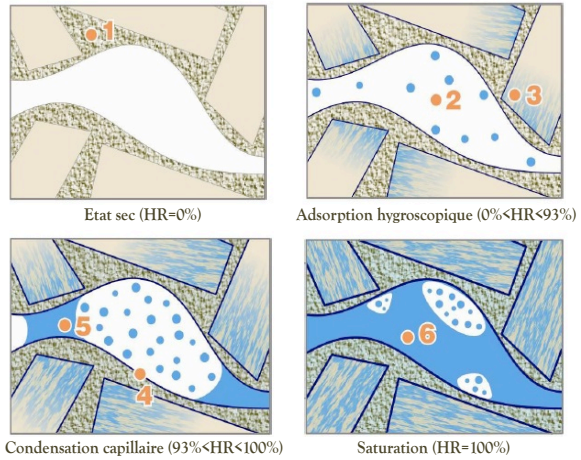






Thermal Conductivity of Bio-aggregate Based Building Materials





Desorption (Vaporisation) in the summer

Endothermic exchange

The wall is cooler

Sorption (Condensation) in the winter

Exothermic exchange

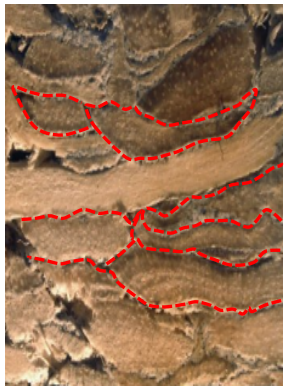
The wall is warmer

These materials are able to :

1. **improve summer and winter comfort**
2. **stabilize the indoor temperature between day and night**
3. **Prevent the phenomena of condensation and dampness on the walls**

In the way to improve the mechanical behaviour

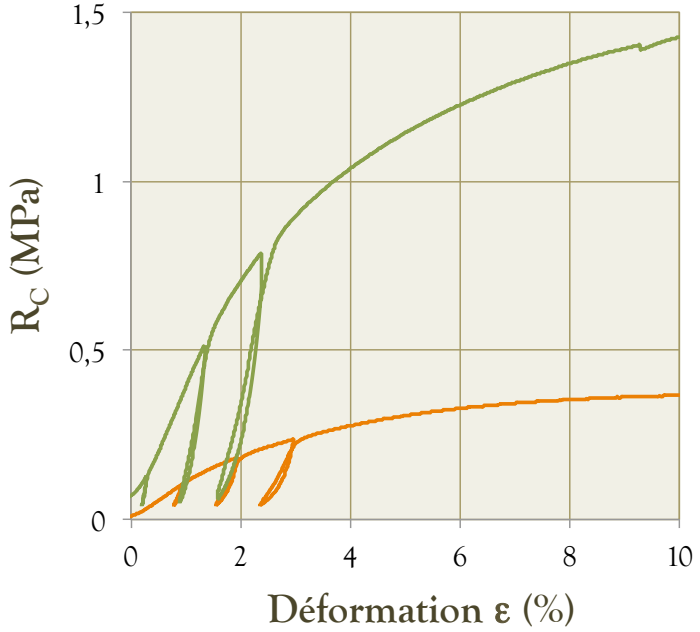
PLANT CONCRETE DESIGN

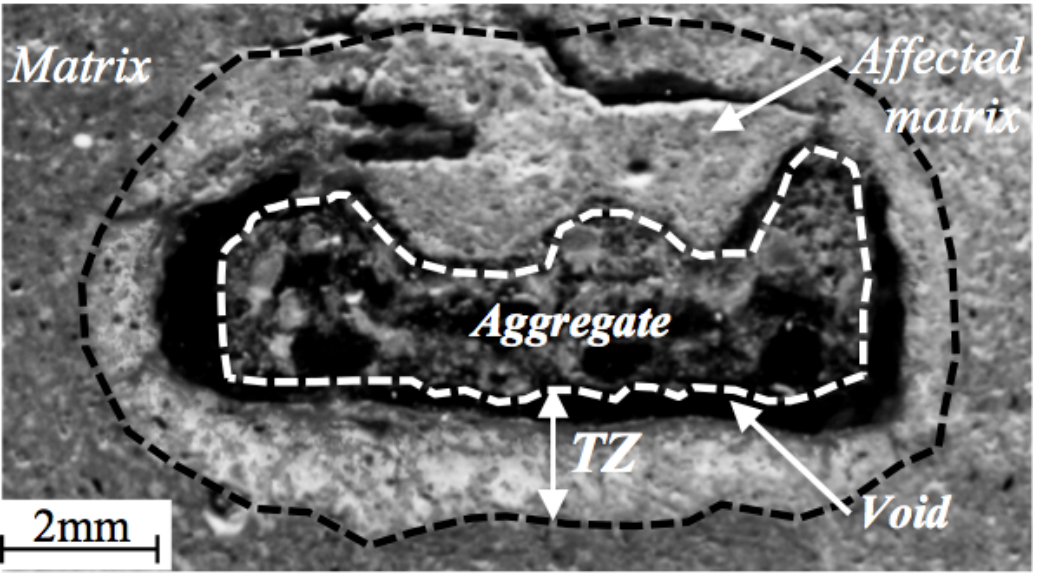


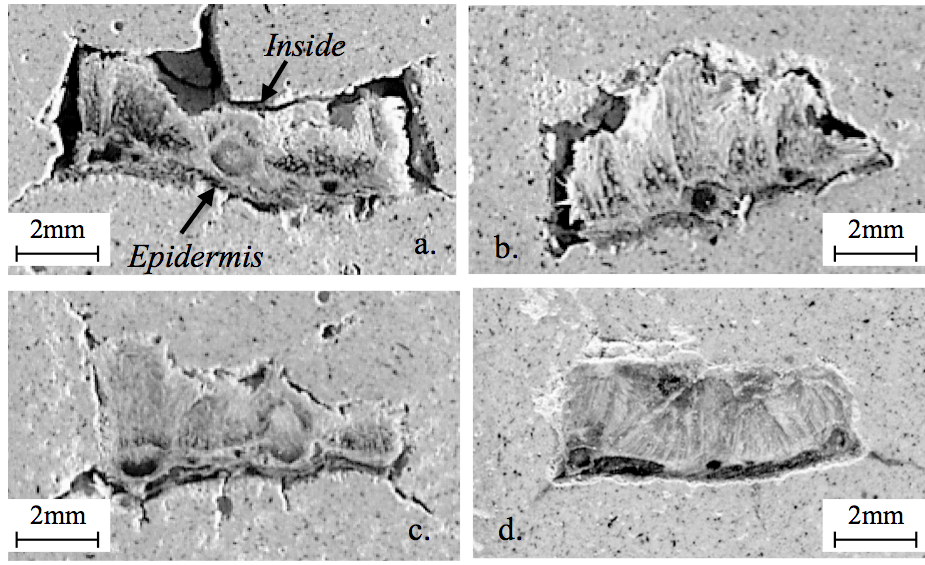
Binder bonds

Nguyen, 2009 (phD thesis)

GENERALISED INTERFACIAL PROBLEM!!!







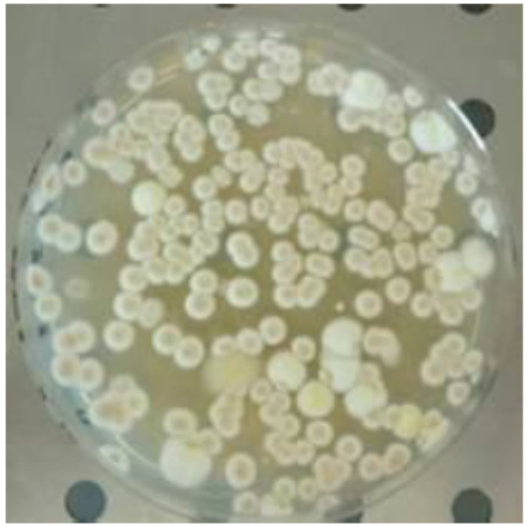
Durability of vegetal concretes

RILEM TC-275

Chair : Sofiane AMZIANE

[Marceau 2017]

- Natural fungal growth
  - After 3 months of exposure at 30°C and 98% RH



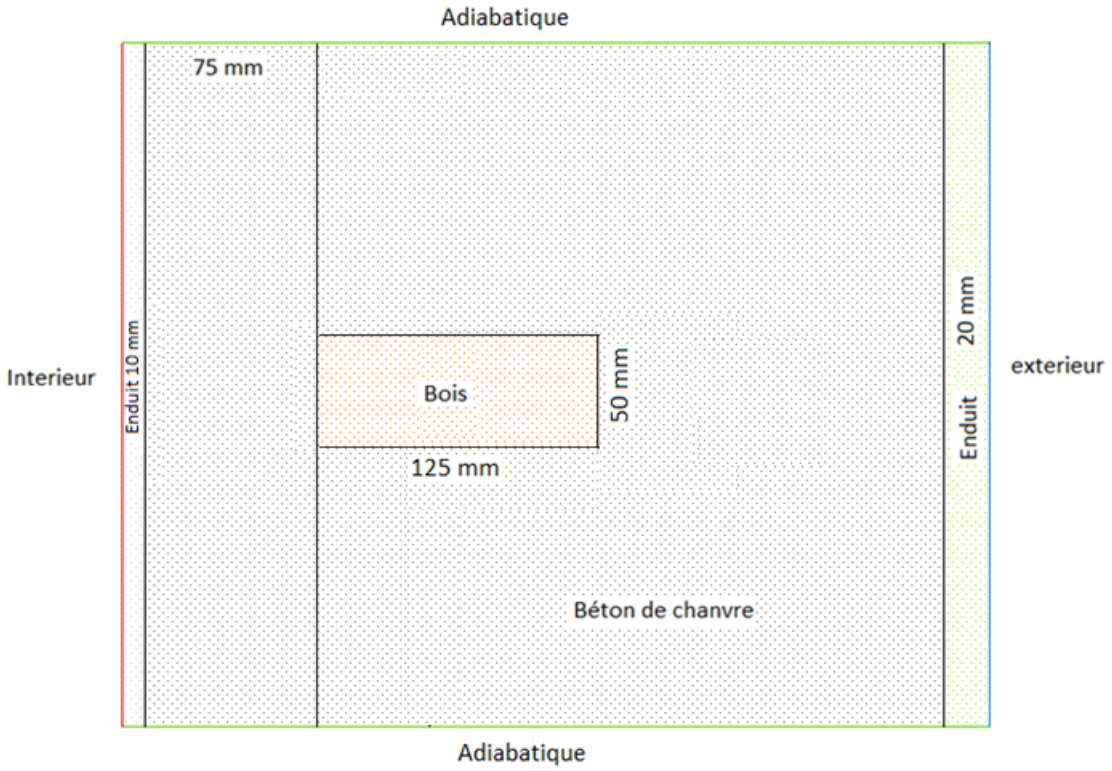
- Influence of the pH of the binder

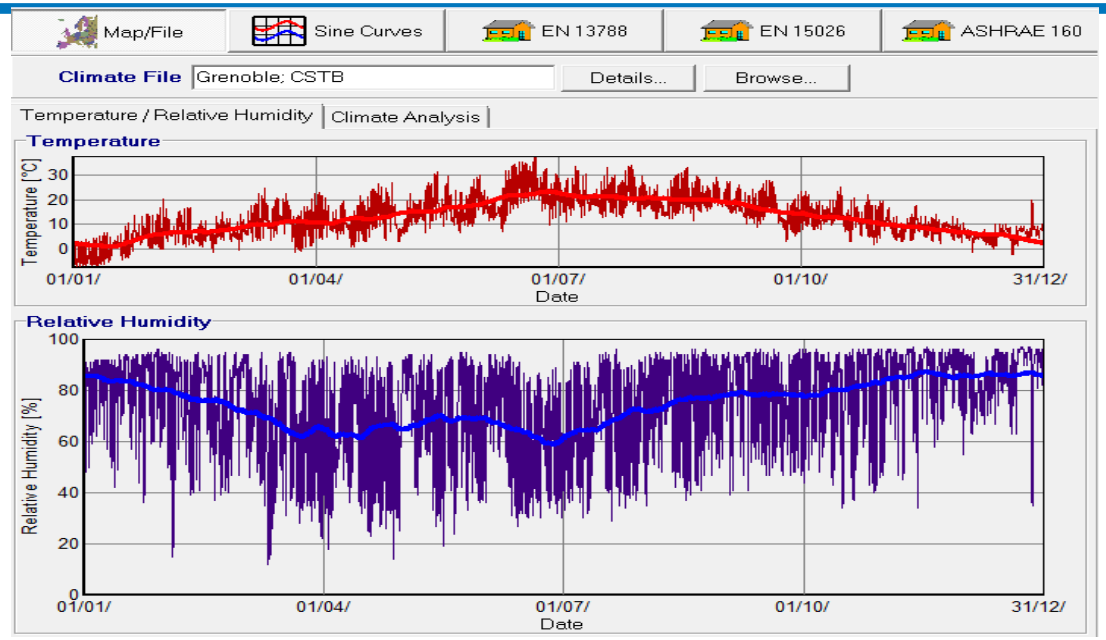
Age of the concrete	14 days		120 days	
Type of shiv	A	B	A	B
Surface pH	10.5	10.4	8.7	9.2
Presence of moulds?	No	No	Yes	Yes

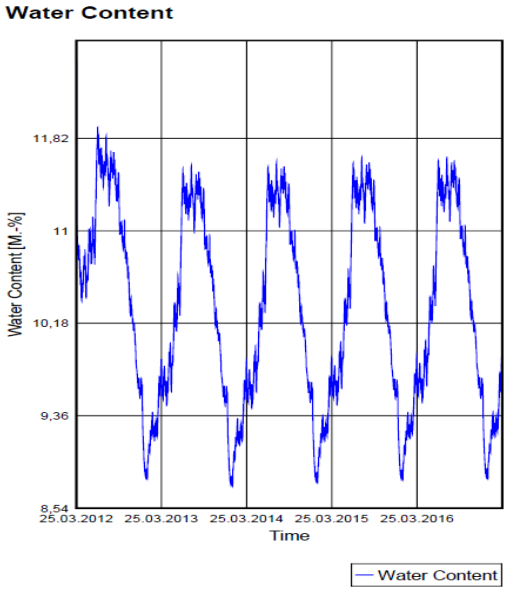
Mold Growth in BBM STRUCTURE

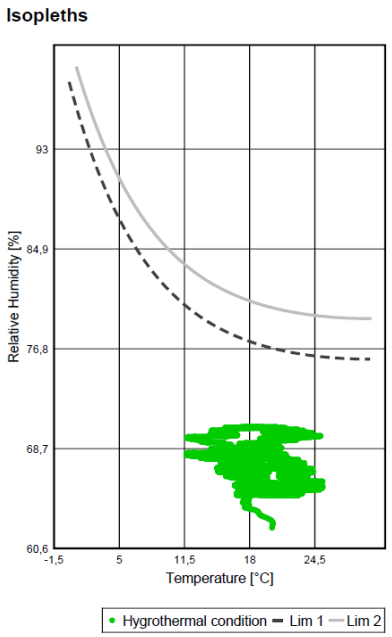
At PH > 10 No Mold Growth

For European climate with an adapted design, there is no risk of mold growth









- New standard based on multiphysics performances vs CO_2 (MPa/ Kg of CO_2)
- This leads to a deviation from the usual description of norms (lambda, u-values…..etc) which no-one really understand
- We have to set new standards where we combine a natural solution for energy reduction, humidity regulation, healthy in-door climate
- EDUCATION
- New Master Eng. on BBM At Clermont

Thank you !