MCPinnov, phase change materials for energy transition in buildings

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Scientific Day of the Paris Seine Initiative – 05/06/2019
France engagement on reducing energy consumption and Greenhouse gases emissions (GHG):

- 1997 Kyoto Protocol
- 2015 Paris agreement on climate change

Global alliance for buildings and construction - 2018 Global Status report
11 % of GreenHouse gases emissions:

• Cement production:
  ➢ Extraction and use of resources
  ➢ Significant consumer of energy (600 – 900 °C)
  ➢ CO$_2$ emitted as by-product

  900 kg of CO$_2$ for every 1000 kg of produced cement *

• Energy used in construction, transport

French politics:
- Act on energy transition for green growth (2015)
- Objectives for upgrading the energy efficiency:
  - 500,000 housings/year
  - 100% of real estate for 2050
- Reinforcement of Thermal Regulations (2012)
- To Environmental Regulations (2020):
  - Reduction of primary energy needs/m²
- Financial support

Technologies:
- Isolation
- Equipments for heating/air conditioning
- Phase Change Materials
Phase Change Materials (PCM)

Polymers, oils, minerals

Potential uses:

- Isolation
- Electronics thermal protection
- Passive thermal control of indoor environment
PCM for passive thermal control

Cabeza et al. (2007): Measurement of thermal variation of walls including or not PCMs

- Thermal amplitude reduction
- Thermal variation shifting

- Increase of the thermal comfort zone
- Reduction of energetic needs involved in heating/cooling

$\Rightarrow$ Reduction of energy production

$\Rightarrow$ Reduction of GHG emissions
Solid/liquid PCMs

Paraffin:

- Phase change: Solid state ⇔ Liquid state
- Transition temperature between 20 and 27 °C
- Encapsulation required for incorporation in building materials
  - Extra cost
  - Mechanical properties
  - Leakage ⇒ Physical properties

⇒ Incompatible with processing

⇒ Innovation: solid/solid PCMs
Harlé et al. (2017): solid/solid PCMs (PUX1520)

Specified polymer property: crystalline solid $\leftrightarrow$ amorphous solid

Specifications:
- Permanent solid state
- Phase transition between 20 and 28 °C
- High Latent heat (> 90J/g)
- Possible to be grinded
Objectives

Producing of composites concrete /PCMs (PUX1520)

- Workability
- Thermal inertia efficiency
- Mechanical and physical properties
- Thermal and biological durability
Processing cement including PCMs

Composition of cement paste influence the flow properties:

**Viscosity:** Viscous dissipation of shear energy

**Yield stress:** Limit shear stress of the suspension

Viscosity increases with PCMs content

Yield stress drops to a steady state

Remains workable in regular conditions
Thermal Durability

- Pure Plaster
- Plaster + PCMs

In oven: $T^\circ$ from 5 to 50 °C (cycles)

1. Lower Temperature in composite + shifting
2. More than 600 thermal cycles
3. Same behavior after 100 cycles

No ageing after 600 thermal cycles, strong thermal durability

Harle, T. et al. (2019)
Biological Durability

Durability in indoor environments?

Microorganisms as fungi are known to be able to degrade polymers: via enzymatic means, via by-products release (acid), via mechanical loads.

*Penicillium* and *Aspergillus niger* are predominant genus in indoor environments. **Growth tests** of fungi on agar containing PUX1520 PCMs have been carried out in condition of nutritional stress.

**Sterilized mixture:**
- Water
- Agar (1.5 wt%)
- ± Malt Extract Agar (MEA) 0.5wt% (nutrient)
- ± PCM 5 wt% (powder)

Fungi Inoculum
*Penicillium* or *Aspergillus niger*
Biological Durability - *Penicillium*

**Graph:**
- **PEN1:** *Penicillium*
- **PEN2:** *Penicillium* + PCM 5wt%
- **PEN3:** *Penicillium* + MEA 0.5wt%
- **PEN4:** *Penicillium* + MEA 0.5wt% + PCM 5wt%

**Legend:**
- MEA: standard nutrient

**Description:**
- PCM presence: Accelerated growth of *Penicillium* biodegradation involved
- Temperature of growth: 24°C
- R: measured radius

**Observations:**
- **PEN2 (PCM):** PCM presence accelerates growth
- **PEN3 (MEA):** MEA addition slows growth
- **PEN4 (PCM + MEA):** Combination of PCM and MEA shows the most growth acceleration

**Graph Axes:**
- **Y-axis:** Radius of mycellium (cm)
- **X-axis:** Time (h)

**Images:**
- Images show fungal growth progression at different conditions.
Biological Durability – *Aspergillus niger*

**AN1**: *Aspergillus niger*  
**AN2**: *Aspergillus niger* + PCM 5wt%  
**AN3**: *Aspergillus niger* + MEA 0.5wt%  
**AN4**: *Aspergillus niger* + MEA 0.5wt% + PCM 5wt%

PCM presence: No impact on growth of *Aspergillus niger*  
Biodegradation not involved

Temperature of growth: 24°C  
R: measured radius
Conclusion

• Solid/solid PCMs (PUX1520) overcome Solid/Liquid encapsulated PCMs for processing into building materials
• PCMs affect viscosity and yield stress of cement paste but the flow properties remain processable
• Solid/solid PCMs does not undergo thermal ageing after 600 cycles
• In propice conditions: 6 genus tested → only 2 biodegrade PUX1520

On going

• Production of concrete composite samples
• Biodegradation tests on composites samples
• Physical, mechanical & thermal characterization of the composite properties
Acknowledgement

Thank you for your attention