Thermedia experience – From the vision to the industrial product

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Thermedia experience – From the vision to the industrial product

Outline
The Genesis – Why an insulating concrete?
Once upon a time in 2005... New Key Functions project

What are the typical "criticisms" about concrete?

- concrete structures are subject to cracking,
- concrete is a heavy material (density 2.35),
- concrete has poor insulation properties,
- concrete surfaces are often not aesthetic
- ... anything more?
End 2005, the roadmap of energy-efficient concretes

Lightweight concrete and thermal considerations

Classical Building Technology

Regular Concrete
Actual
External insulation
Multilayer panels
Higher insulation
Higher inertia

Innovative Building Technology

Innovative Concrete
Thermal bridges
Lightweight concrete
Higher insulation

External insulation
Multilayer panels
Higher insulation
Higher inertia

Precast elements
Construction optimisation
Higher insulation
Higher comfort
(with added functionalities)

Decision Year 2006: launch of a project on Lightweight Thermal Concrete to explore the identified potential area
The thermal issue of internally insulated buildings
(the reference insulation practice of French buildings)

Thermal bridges are heat losses due to the discontinuity of insulation at structural junctions

• Thermal bridge coefficient: $\psi$ in W/(m.K): heat power transmitted through a linear element due to a temperature difference
  • For example at wall/slab junction or at interior wall/peripheral wall junction

• According to ADEME thermal bridges account for 5-10% of heat losses of buildings

• Now thermal regulations (RT 2005 then RT 2012 in France) impose to limit thermal bridges

• Close to thermal bridges lower surface temperature $\rightarrow$ condensation risk $\rightarrow$ mold growth risk
2006 – The target specifications defined

KPI 2: Mix-design of lightweight concretes

- Lightweight structural concrete (contact with Bouygues, F/UK)
  - $R_c$ 28d 25/30 MPa, minimum density and thermal conductivity
  - Objectives for thermal bridge losses 0.6 and 0.4 W/m.K (0.99 for standard concrete), corresponding $\lambda$ value for concrete in ext. wall: 0.6 and 0.3 W/m.K
What are the other alternatives to treat thermal bridges?

External Insulation → no more discontinuity of insulation

- But: expensive, 10 year guarantee, not easy in case of balconies, fire propagation, acoustics
What are the other alternatives to treat thermal bridges?

Thermal breakers → skilled additional operation

- Modify jobsite sequence, limited use in seismic areas
From 2009 to now – several generations of

Improved thermal performances

<table>
<thead>
<tr>
<th>System</th>
<th>Improved Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate floor (20 cm)</td>
<td>$\Psi_9 \approx 0.99 \text{ W/m.K}$</td>
</tr>
<tr>
<td>External facade (16 cm)</td>
<td>$\Psi_9 \approx 0.60 \text{ W/m.K}$</td>
</tr>
<tr>
<td>Insulating product (EPS 100 mm)</td>
<td>$\Psi_9 \approx 0.55 \text{ W/m.K}$</td>
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Additional functionalities
- triggering
- white Thermedia
- pumpable Thermedia
Thermedia: design of an insulating concrete
Technical Specifications of a Structural Insulating Concrete for loadbearing facades

Objective: keep same construction methodology and design

- Similar reinforced concrete design
  - Compressive strength class = 25 MPa

- Allow to reduce significantly thermal bridges
  - $\lambda < 0.6 \text{ W/(m.K)}$

- The Thermedia wall system should comply all other performances required by an external wall
  - Fire resistance: 2 hours REI rating
  - Acoustical insulation: $D_{\text{nat}} > 30 \text{ dB}$ for external noise, $> 53$ or $58 \text{ dB}$ between rooms
  - Thermal insulation: the whole building should be thermal regulation compliant

Thermedia has to be seen not only as a concrete but also as a system
The concrete Thermedia is a compromise of two contradictory trends

Thermal conductivity decreases with density

Strength decreases with density

![Graph showing the relationship between density and thermal conductivity](image1)

![Graph showing the relationship between density and strength](image2)
Optimization of the thermal conductivity of a concrete

Concrete = aggregates + sand + cement paste + air

• Which best mix proportions can allow to meet all requirements?
  ➔ Homogenization methods in the service of thermal optimization of concretes
Multi-scale homogenization scheme

\[ \lambda_{\text{cement}} \rightarrow \lambda_{\text{air, } f_{\text{air}}} \rightarrow \lambda_{\text{paste}} \]

\[ \lambda_{\text{cement}} \rightarrow \lambda_{\text{paste}} \rightarrow \lambda_{\text{mortar}} \rightarrow \lambda_{\text{concrete}} \]
Mori-Tanaka and Self-Consistent homogenization schemes

Mori-Tanaka: Matrix-Inclusion Scheme
Tested and validated for cement paste homogenization

\[ \lambda_{MT} = \lambda_2 \frac{\lambda_1 + 2\lambda_2 + 2f_1(\lambda_1 - \lambda_2)}{\lambda_1 + 2\lambda_2 - f_1(\lambda_1 - \lambda_2)} \]

Self-Consistent: randomly arranged
Tested and validated for mortar and concrete homogenization

\[ \lambda_{AC} = \frac{\lambda_1 \lambda_2 + 2\lambda_{AC} [\lambda_2 + f_1(\lambda_1 - \lambda_2)]}{\lambda_1 + 2\lambda_{AC} - f_1(\lambda_1 - \lambda_2)} \]
Multi-scale homogenization scheme

\[ \lambda_{\text{cement}} \rightarrow \lambda_{\text{paste}} \]
\[ \lambda_{\text{air}}, f_{\text{air}} \rightarrow \lambda_{\text{paste}} \]

Self-Consistent

\[ \lambda_{\text{mortar}} \rightarrow \lambda_{\text{concrete}} \]

Mori Tanaka

\[ \lambda_{\text{rock}} \rightarrow \lambda_{\text{agg}} \]
\[ \lambda_{\text{air}}, f_{\text{air}} \rightarrow \lambda_{\text{agg}} \]

Sand

\[ \lambda_{\text{rock}} \rightarrow \lambda_{\text{agg}} \]
\[ \lambda_{\text{air}}, f_{\text{air}} \rightarrow \lambda_{\text{agg}} \]

Gravel
Comparison of modeling with experiments

Good correlation \( \Rightarrow \) we can use model to define target mix proportions as function of possible lightweight aggregates
From the insulating concrete to the structural insulating concrete
What differentiates Thermedia from a STD concrete?

Thermedia is a LC 25/28 concrete according to EN 206 but…

• From the concrete producer point of view…
  • A concrete with lightweight aggregates ➔ another sourcing
  • A concrete with water-absorbing aggregates ➔ robustness, quality management
  • Several mixes available as function of local cements, available aggregates,…

• From the structural designer point of view…
  • A concrete with lower density than STD concrete
    • Design values of other material properties (Young modulus, shear strength, …) are decreased ➔ structural design slightly differs
  • A lighter concrete so with higher drying shrinkage
One of Gilles’s contribution against a recurrent misconception: “more shrinkage = more cracks”

Thermedia compared to a STD C25/30 concrete…

- Drying shrinkage is higher because of the use of lightweight aggregates
- But Thermedia has a lower Young modulus
  - in case of restraint, lower internal stresses
- And tensile strength is equivalent
  - cracking occurs only if stress > strength

- Using Cracking Index: same or lower cracking ‘risk’ induced by drying

<table>
<thead>
<tr>
<th></th>
<th>C20/25</th>
<th>C25/30</th>
<th>LC20/22</th>
<th>LC25/28</th>
<th>Thermedia</th>
</tr>
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<tbody>
<tr>
<td>Cracking Index</td>
<td>7.4</td>
<td>6.1</td>
<td>5.3</td>
<td>4.4</td>
<td>4.6</td>
</tr>
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As evaluated using STD design values (Eurocodes)

Using characteristic exp. data
But sometimes it does not prevent from cracks to appear...
The importance of pilot tests and key learnings

After 3-4 days, regularly spaced cracks appearing on all lintels
Then Gilles asked to get a sample from the bottom side of the lintel...

And its intuition was confirmed: concrete segregation
Confirmation in lab of cracking origin and cause tree

- Cracking of lintels
- Differential Shrinkage
- Segregation of concrete
- Concrete over vibrated
- Oversized vibrating needle
- Vibration to accelerate placing
- Concrete pouring above lintel
- Inadapted rebar support

600µm differential shrinkage, 400µm in only 4 days
Reproduction of jobsite observations in LCR

The original concrete mix and a revised formulation, with the same placing methodology as for pilot test
Thermedia was one perfect example that concrete offers more than a compressive strength at 28 days

- A material that solves a building system issue
  - Thermal bridge treatment

- A material that educated LCR and Lafarge to structural design
  - Cracking risk, reinforced concrete design with lightweight concretes

- An experience that showed that lab-crete and real-crete can be different
  - Importance of understanding customer’s needs.
  - Importance of testing on real conditions

- Scientific expertise in the service of accelerating innovation