Thermedia experience – From the vision to the industrial product

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LafargeHolcim

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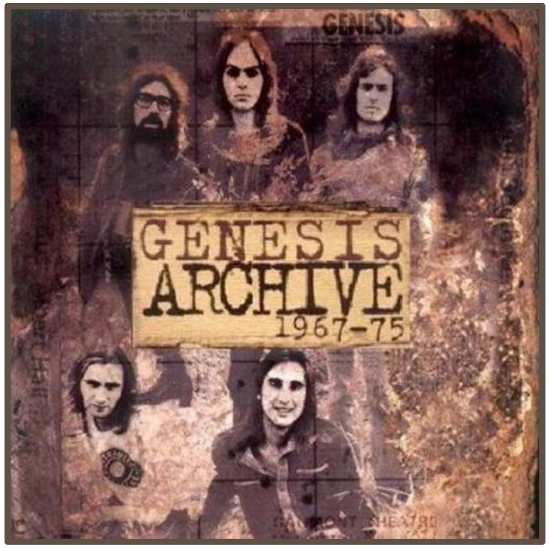
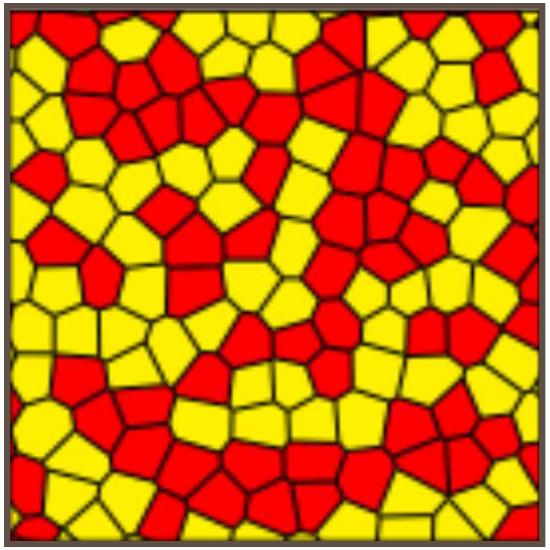
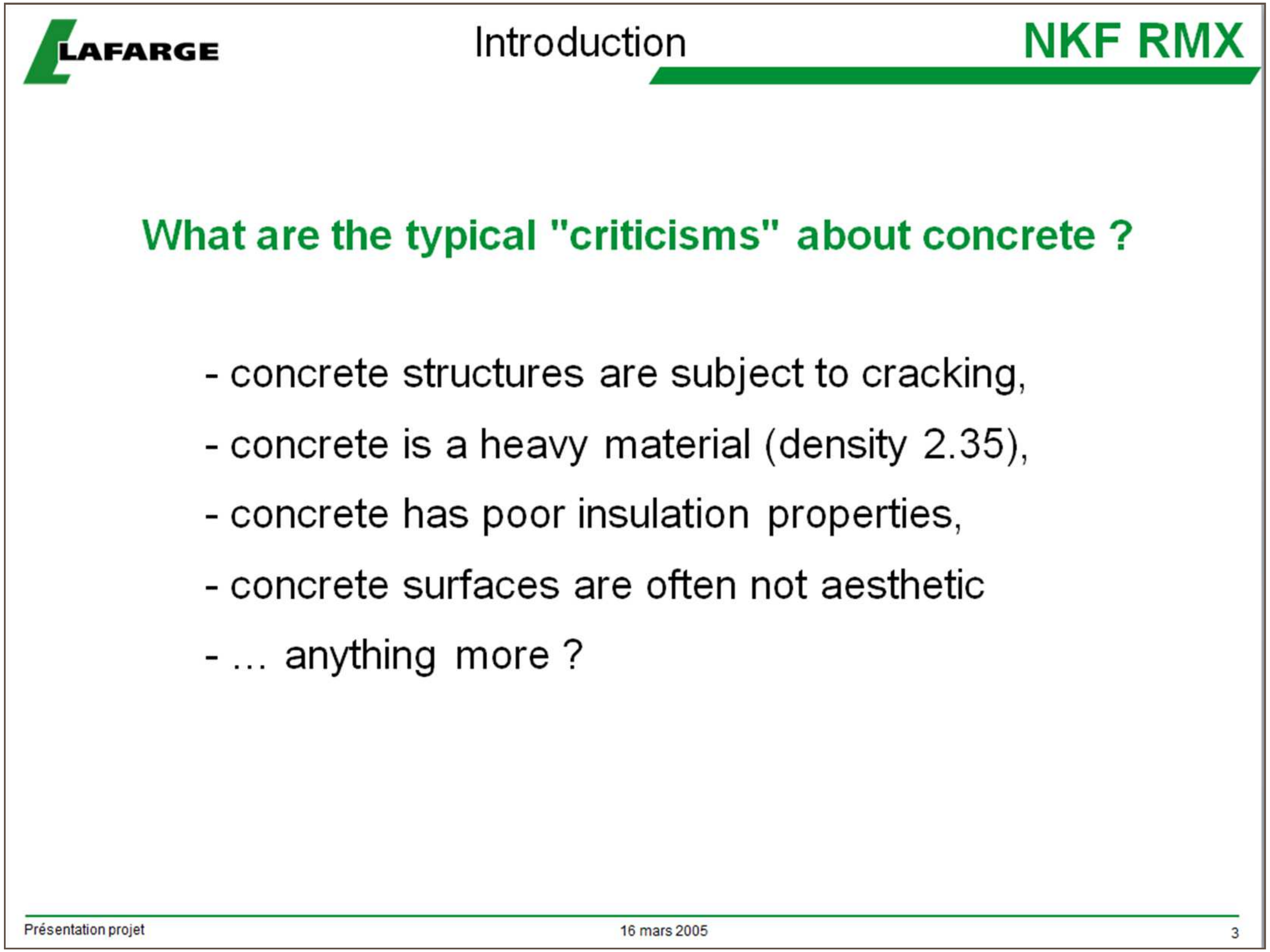
Outline



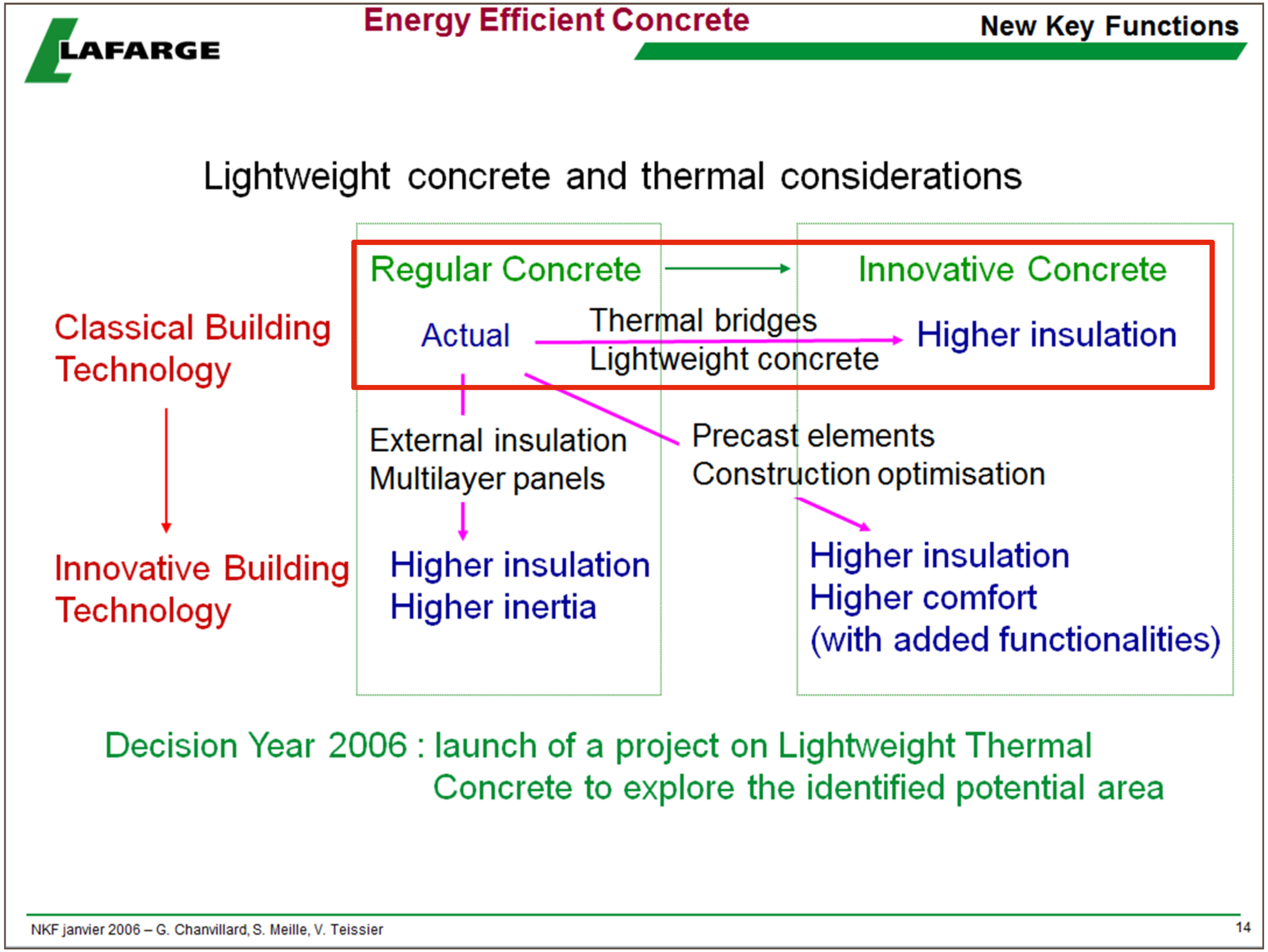


The Genesis – Why an insulating concrete?

Once upon a time in 2005… New Key Functions project

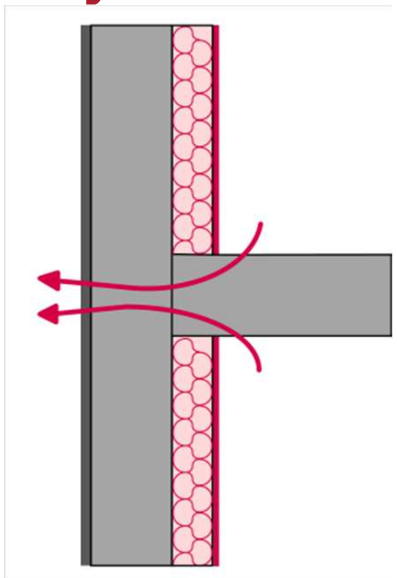


End 2005, the roadmap of energy-efficient concretes



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



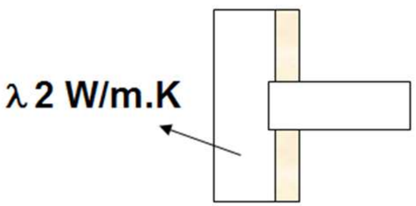
- Thermal bridge coefficient: ψ in W/(m.K): heat power transmitted through a linear element due to a temperature difference
  - For example at wall/slab junction or at interior wall/peripheral wall junction
- According to ADEME thermal bridges account for 5-10% of heat losses of buildings
  - Now thermal regulations (RT 2005 then RT 2012 in France) impose to limit thermal bridges
- Close to thermal bridges lower surface temperature → condensation risk → mold growth risk

2006 – The target specifications defined

LAFARGE

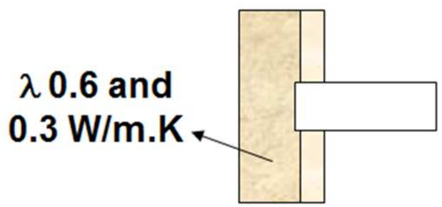
KPI 2: Mix-design of lightweight concretes

- Lightweight structural concrete (contact with Bouygues, F/UK)
  - Rc 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 λ value for concrete in ext. wall: 0.6 and 0.3 W/m.K



Concrete

ψ 0.99 W/m.K



LW structural concrete

ψ 0.6 and 0.4 W/m.K

EEC – S. Meille   October 2nd 2006   10

What are the other alternatives to treat thermal bridges?

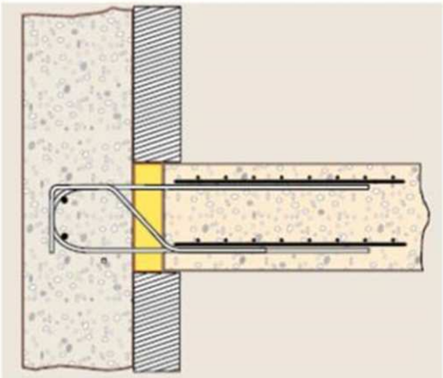
External Insulation → no more discontinuity of insulation

- 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

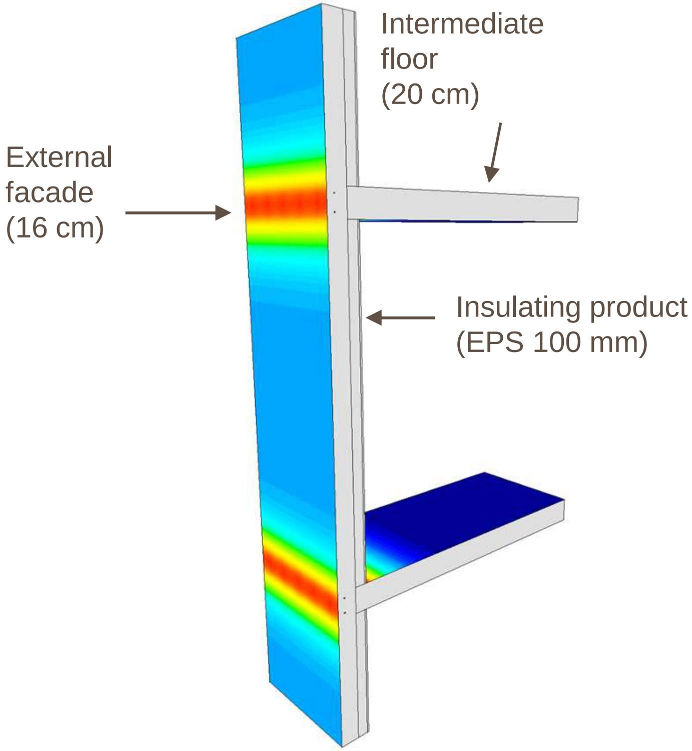
- Modify jobsite sequence, limited use in seismic areas



From 2009 to now – several generations of Thermedia

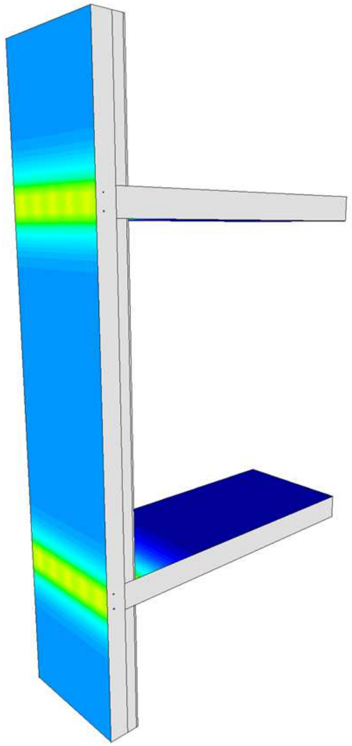
DES SOLUTIONS BÉTON POUR L'ISOLATION

Improved thermal performances →



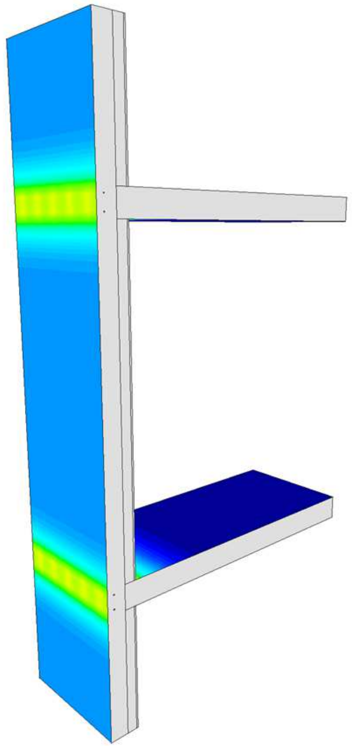
STD C25 concrete

$\Psi_9 \approx 0.99$ W/m.K



Thermedia 0,6

$\Psi_9 \approx 0{,}60$ W/m.K

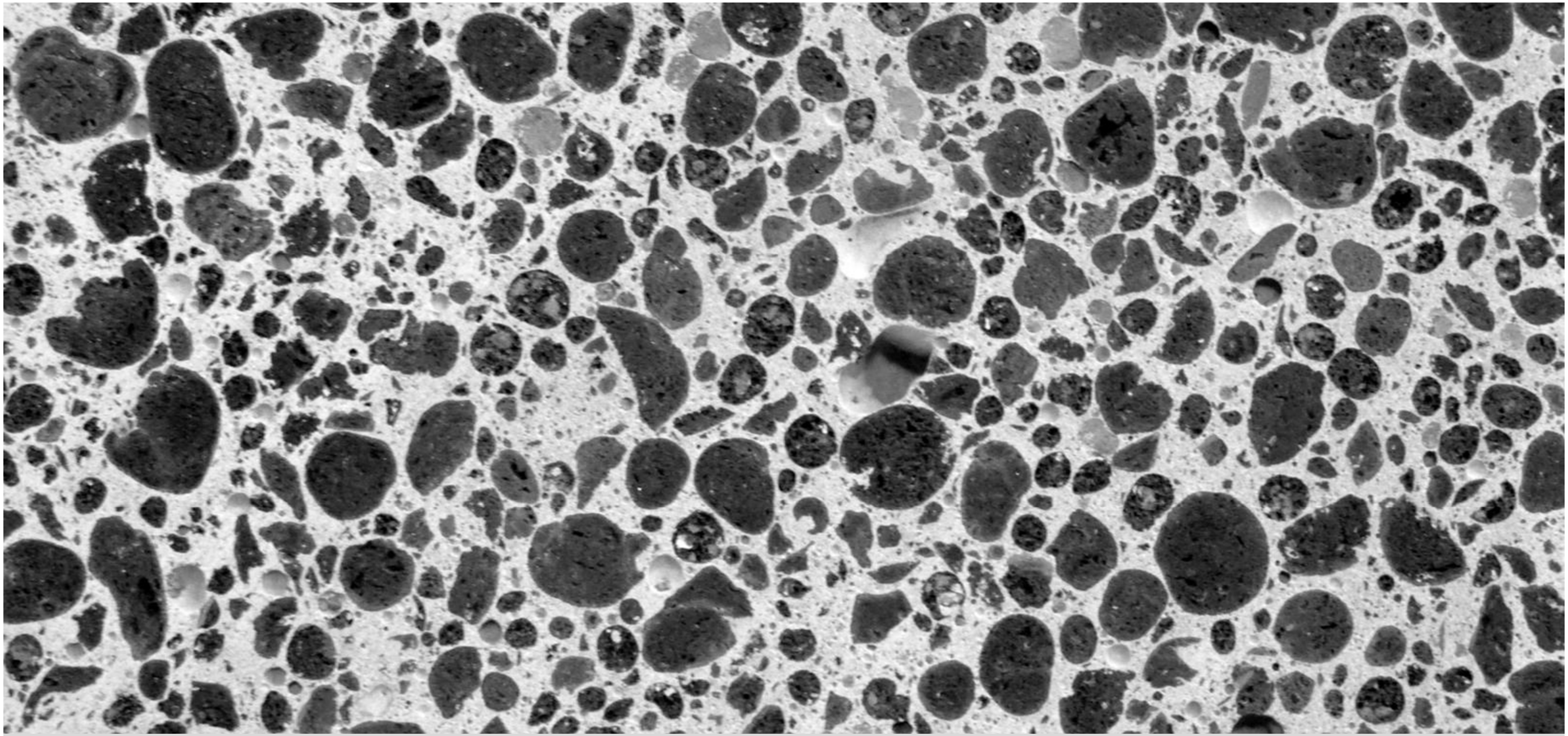


Thermedia 0,45

$\Psi_9 \approx 0.55$ W/m.K

Additional functionalities ↓

- triggering
- white Thermedia
- pumpable Thermedia



Thermedia: design of an insulating concrete

Technical Specifications of a Structural Insulating Concrete for loadbearing facades

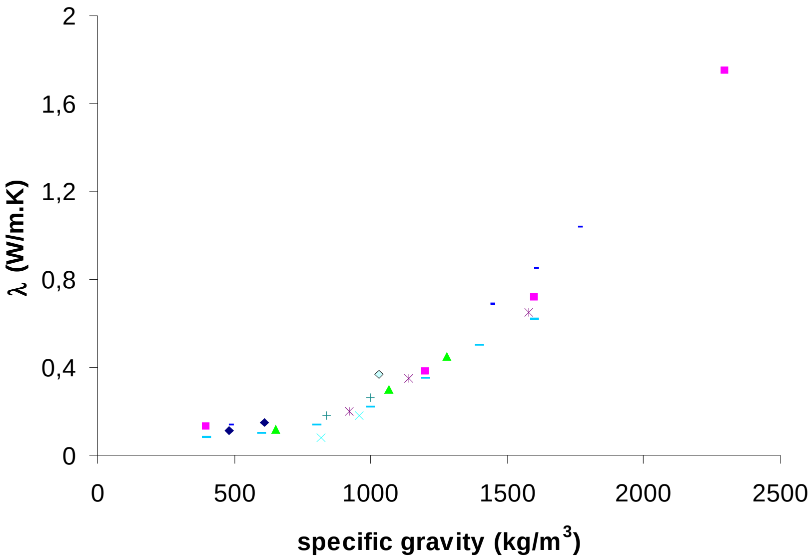
Objective: keep same construction methodology and design

- Similar reinforced concrete design
  - ➔ Compressive strength class = 25 MPa
- Allow to reduce significantly thermal bridges
  - ➔ λ< 0.6 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_{naT}> 30 dB for external noise, > 53 or 58 dB between rooms
  - Thermal insulation: the whole building should be thermal regulationcompliant

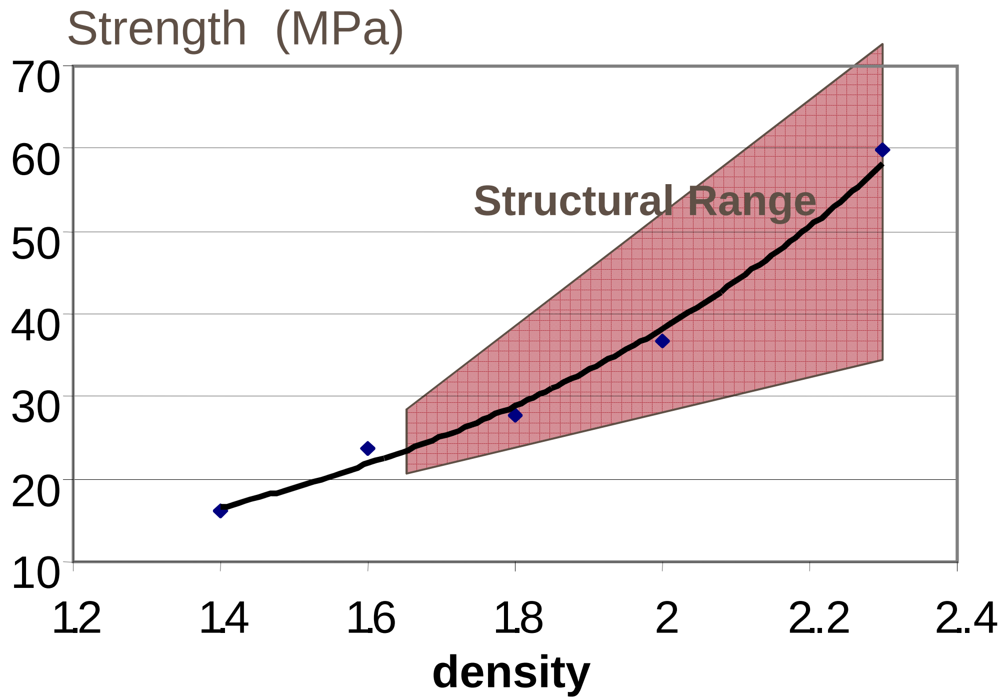
Thermedia has to be seen not only as a concrete but also as a system

The concrete Thermedia is a compromise of two contradictory trends

Thermal conductivity decreases with density



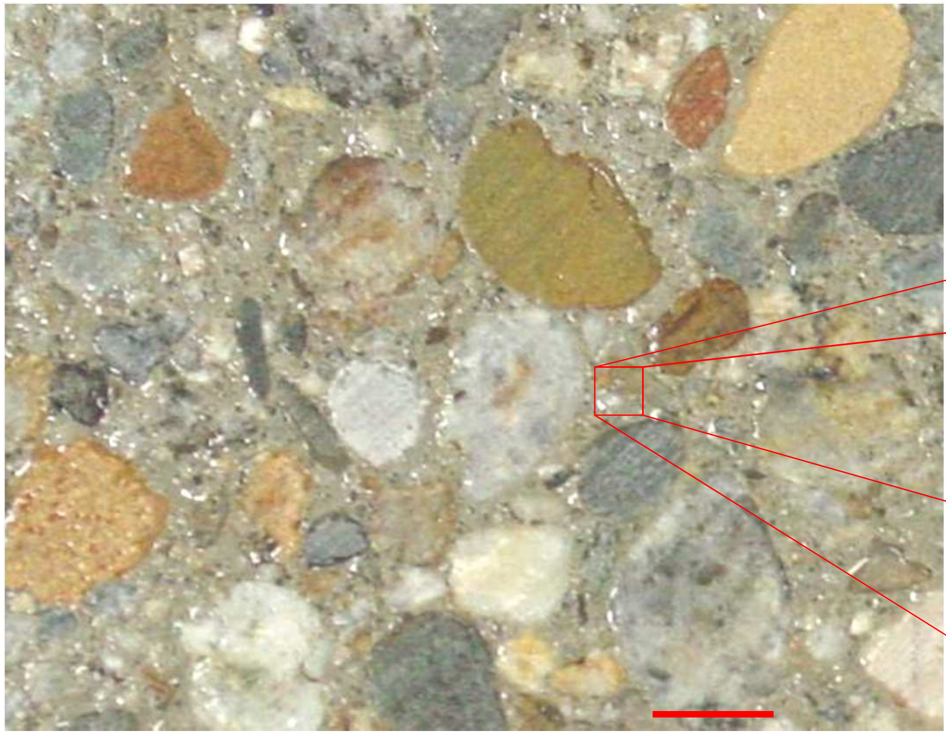
Strength decreases with density



Optimization of the thermal conductivity of a concrete

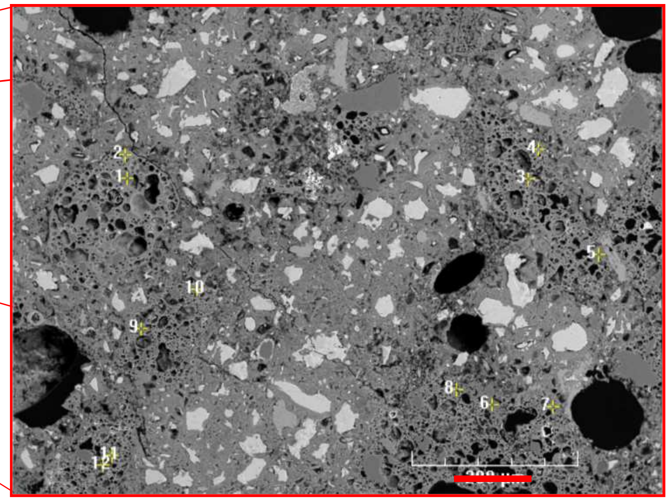
Concrete = aggregates + sand + cement paste + air

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



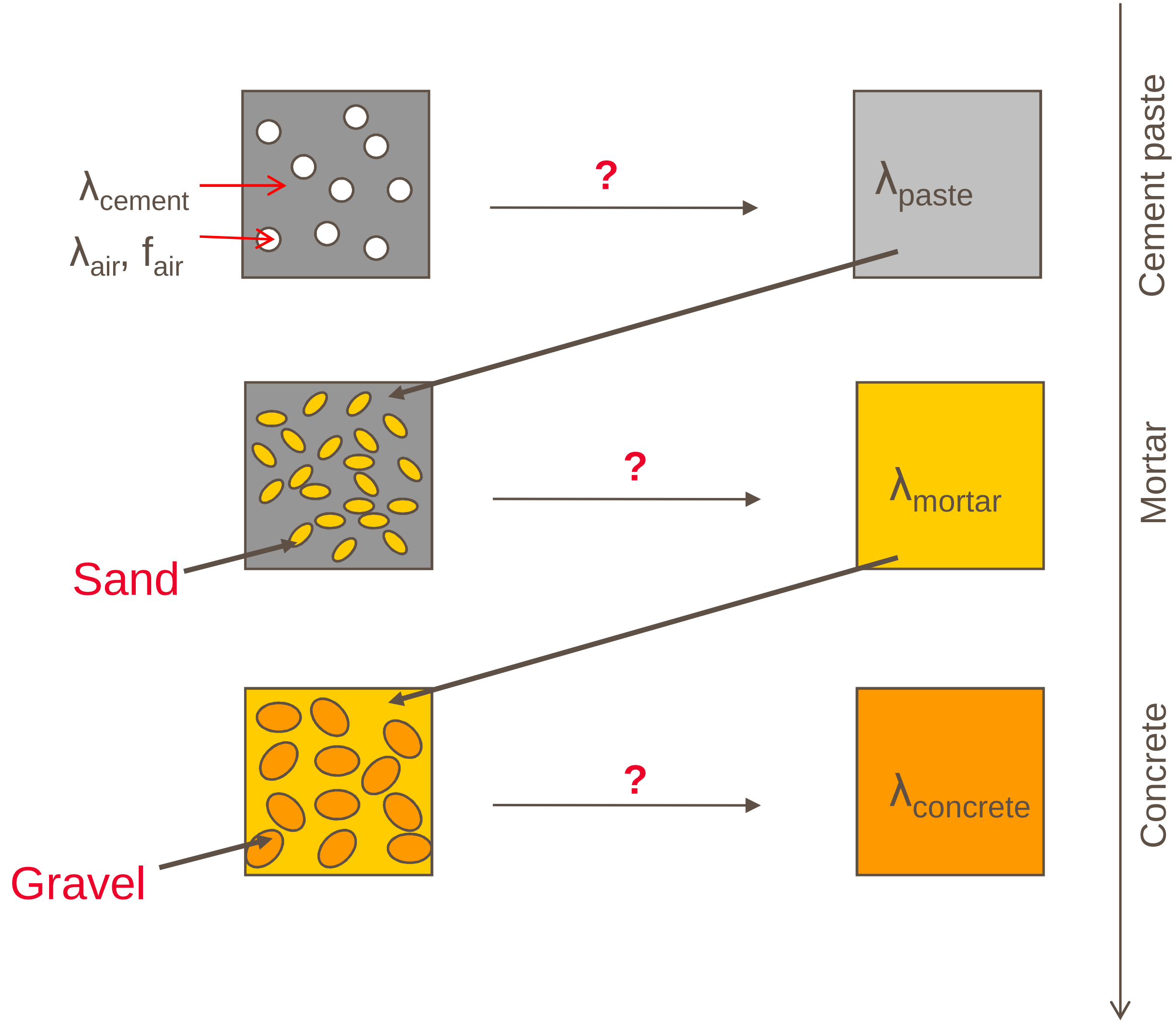
1cm

Cement paste



100µm

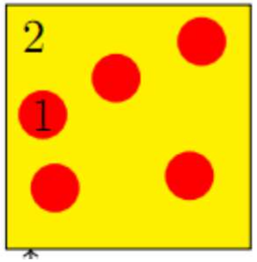
Multi-scale homogenization scheme



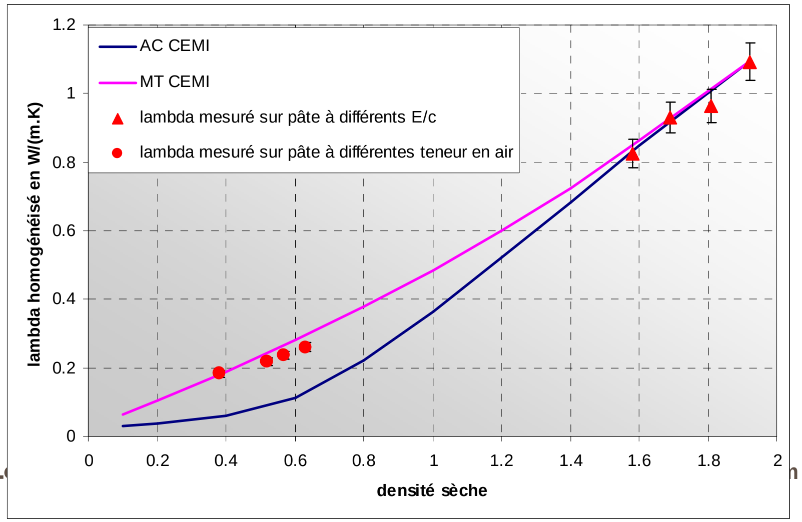
Mori-Tanaka and Self-Consistent homogenization schemes

Mori-Tanaka: Matrix-Inclusion Scheme

Tested and validated for cement paste homogenization

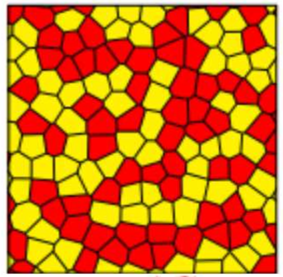


$$\lambda^{MT} = \lambda_2 \frac{\lambda_1 + 2\lambda_2 + 2f_1(\lambda_1 - \lambda_2)}{\lambda_1 + 2\lambda_2 - f_1(\lambda_1 - \lambda_2)}$$

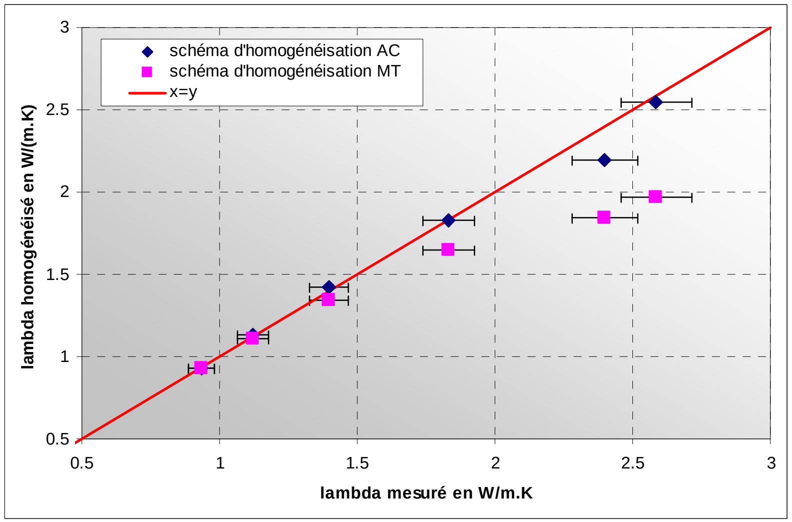


Self-Consistent: randomly arranged

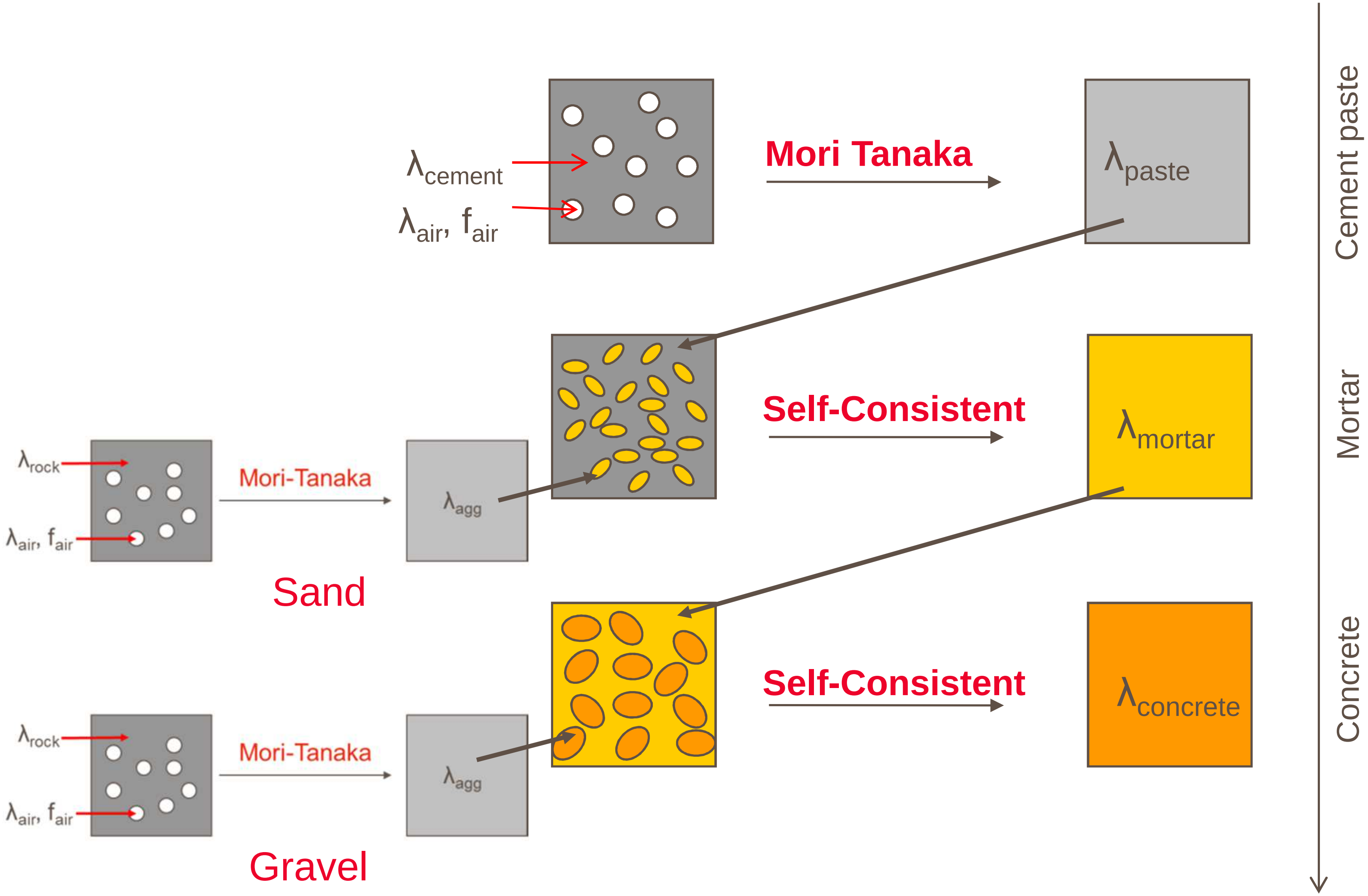
Tested and validated for mortar and concrete homogenization



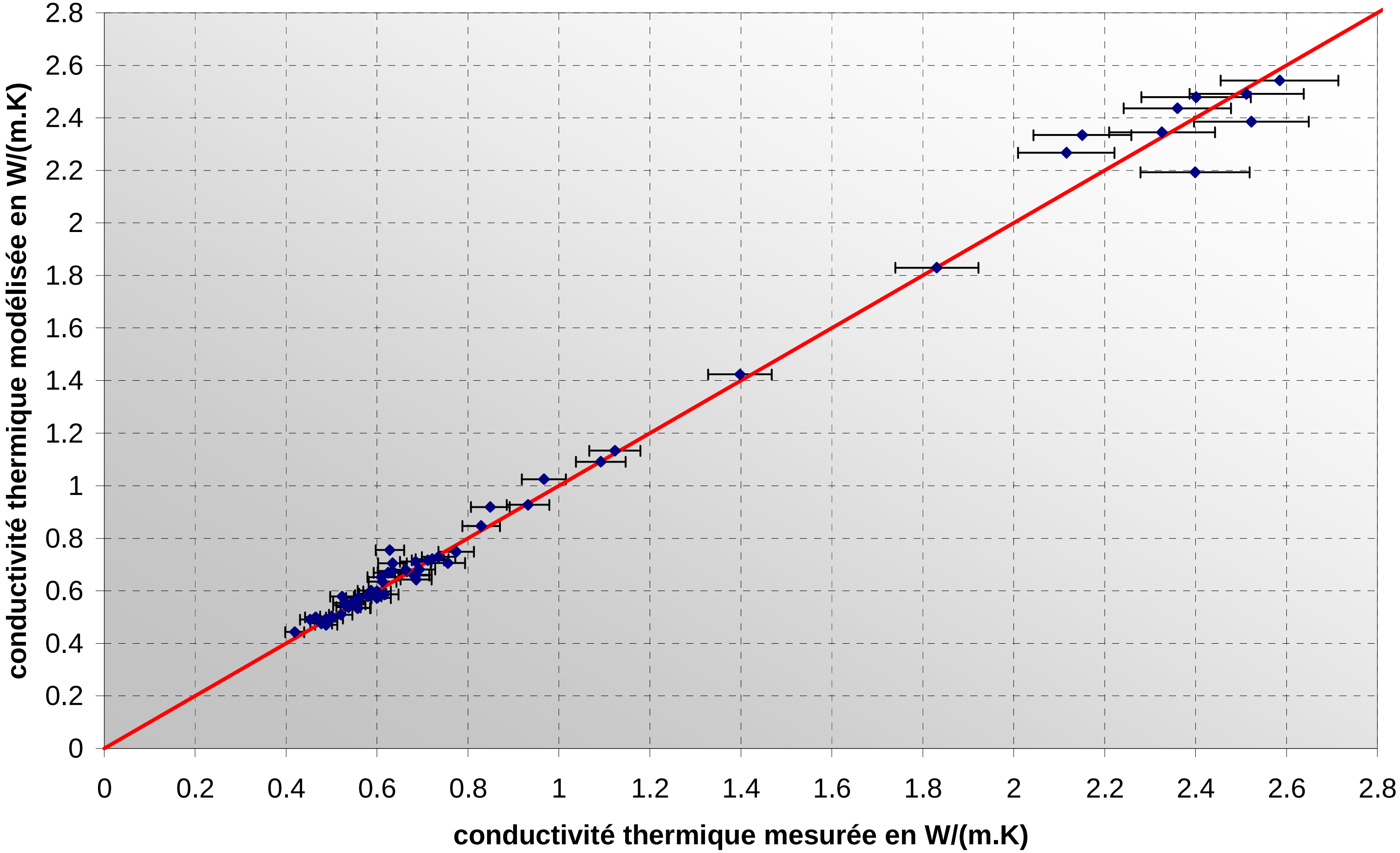
$$\lambda^{AC} = \frac{\lambda_1\lambda_2 + 2\lambda^{AC}\left[\lambda_2 + f_1(\lambda_1 - \lambda_2)\right]}{\lambda_1 + 2\lambda^{AC} - f_1(\lambda_1 - \lambda_2)}$$



Multi-scale homogenization scheme



Comparison of modeling with experiments



Good correlation ➔ 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

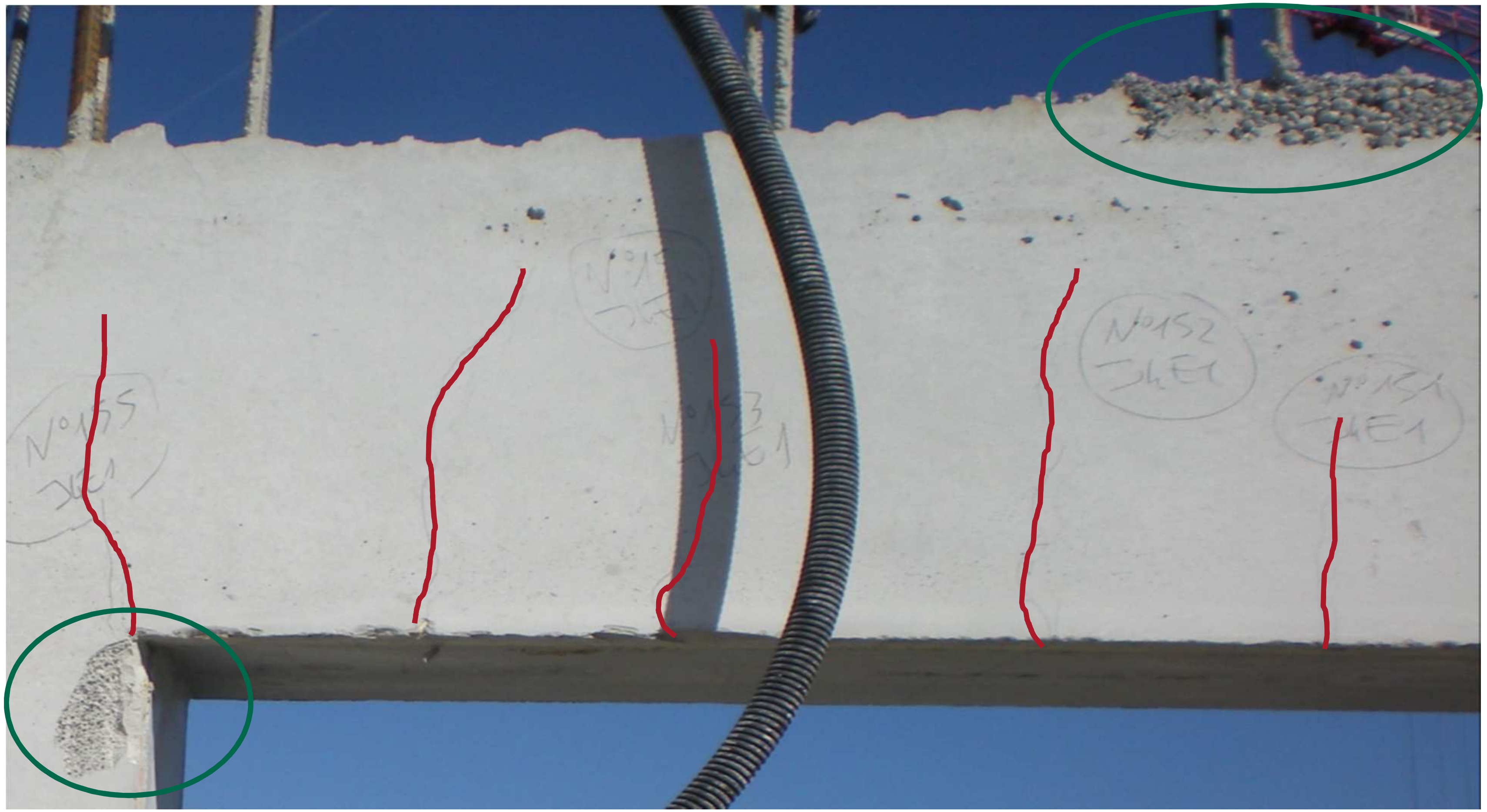
	C20/25	C25/30	LC20/22	LC25/28	Thermedia
Cracking Index	7.4	6.1	5.3	4.4	4.6

C20/25 to LC25/28: As evaluated using STD design values (Eurocodes)

Thermedia: Using characteristic exp. data

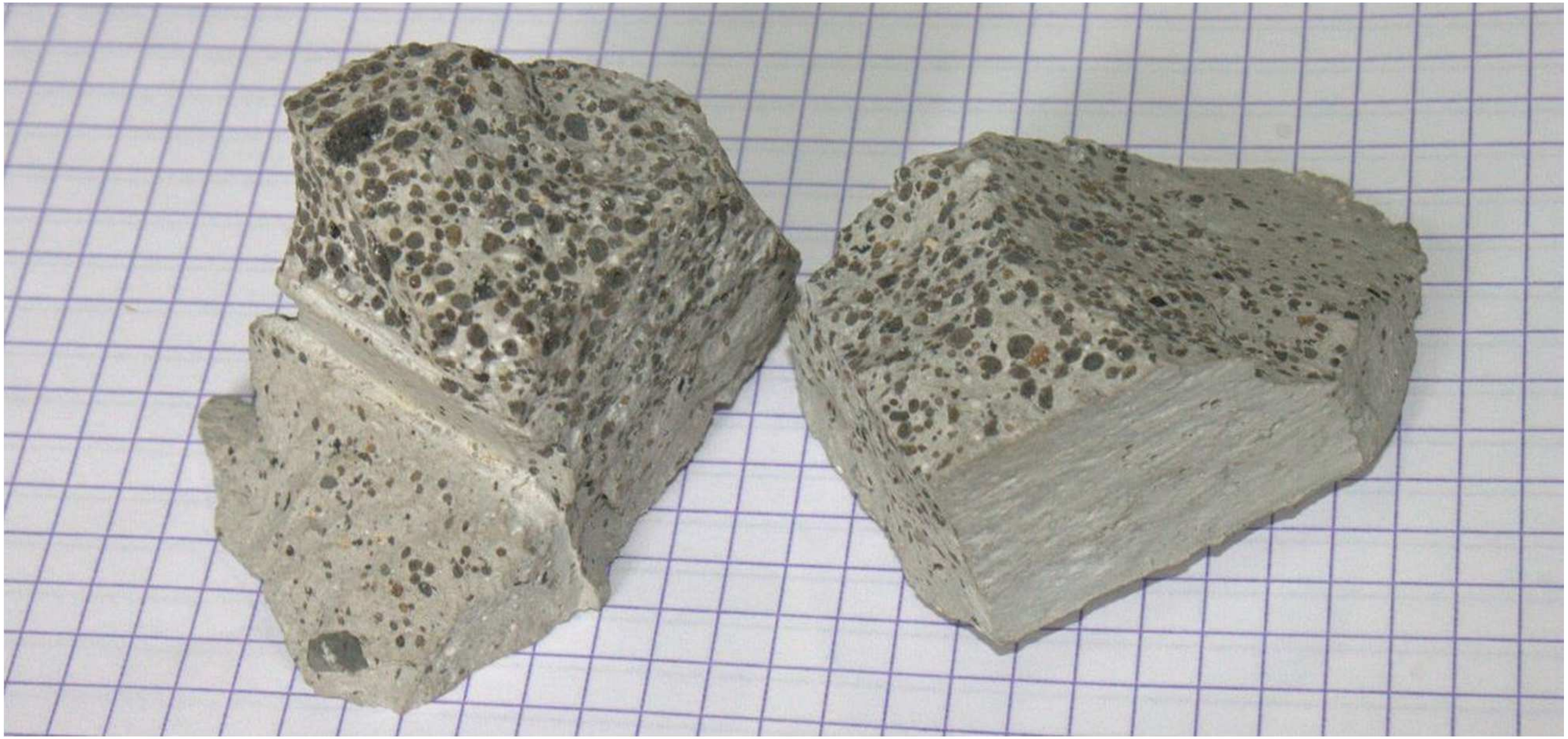
But sometimes it does not prevent from cracks to appear… The importance of pilot tests and key learnings

After 3-4 days, regularly spaced cracks appearing on all lintels

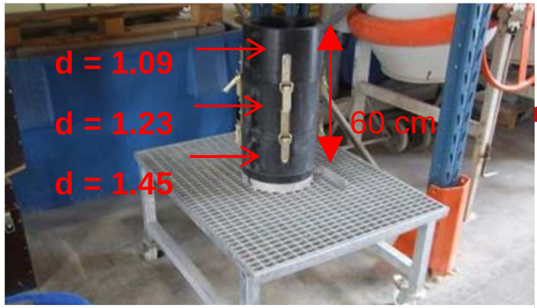


Then Gilles asked to get a sample from the bottom side of the lintel…

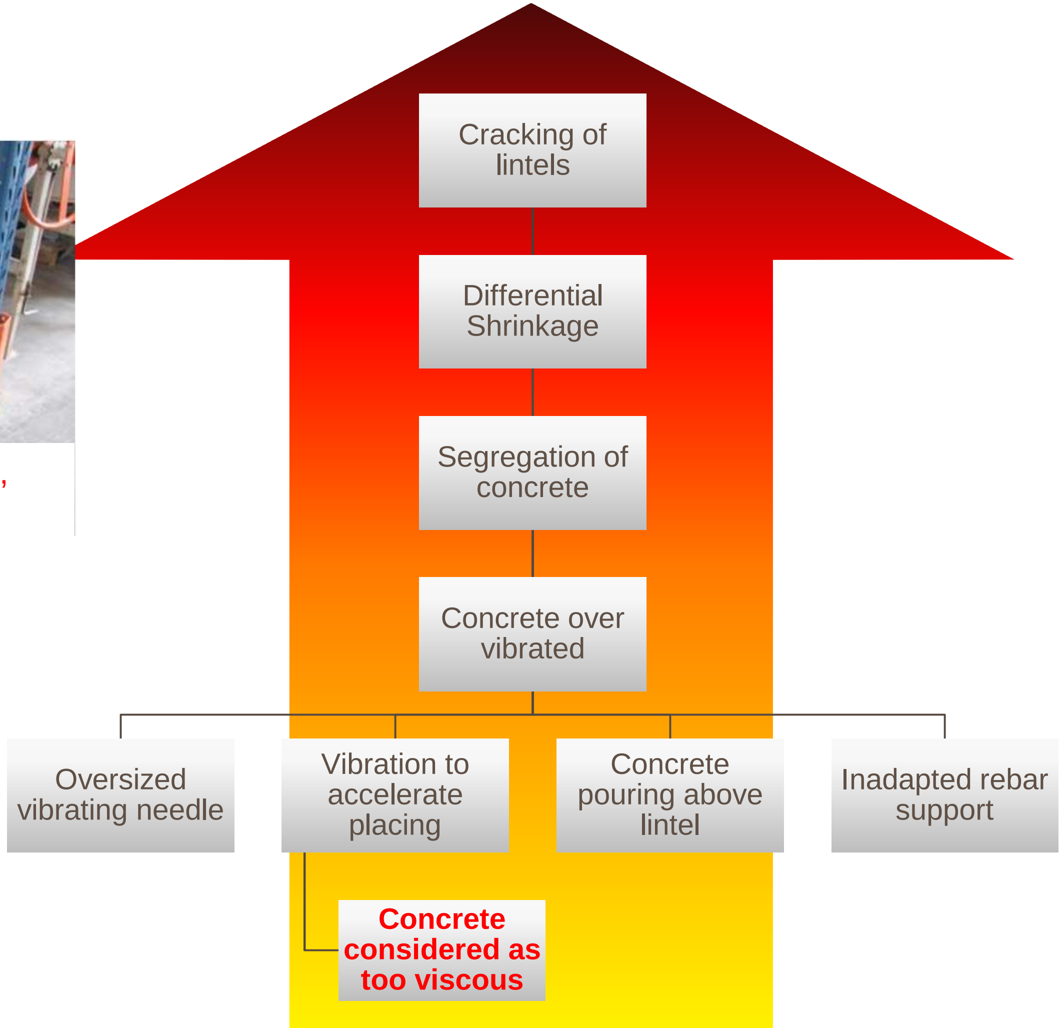
And its intuition was confirmed: concrete segregation

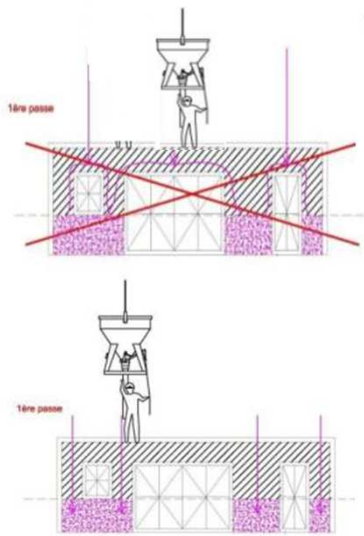


Confirmation in lab of cracking origin and cause tree



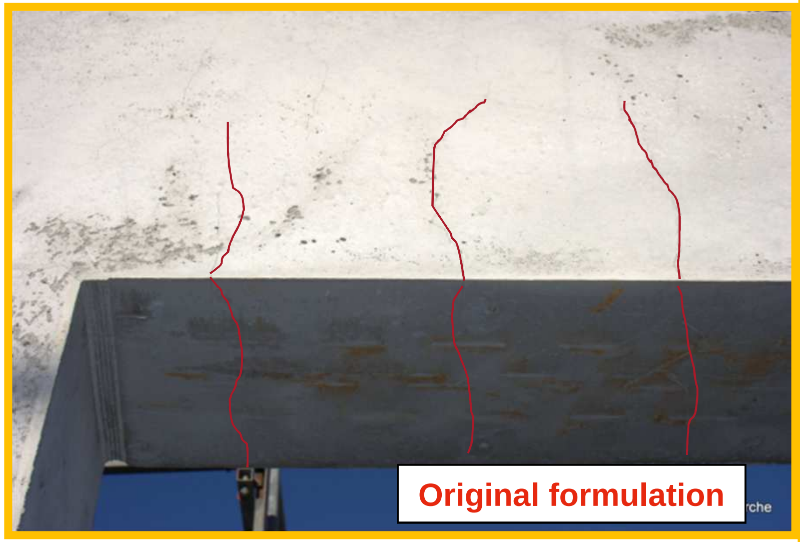
600µm differential shrinkage,
400µm in only 4 days





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

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