Ordine degli Ingegneri della provincia di Napoli

ORDINE REGIONALE DEI CHIMICI E DEI FISICI DELLA CAMPANIA

Ordine degli Architetti della provincia di Napoli

CALCESTRUZZO: STATO DELL'ARTE E INNOVAZIONE

Workshop a cura della Commissione Materiali dell'Ordine dei Chimici e dei Fisici della Campania

Sabato 18 Maggio 2019 – Università Federico II di Napoli

RELAZIONE TRA MICROSTRUTTURA E PROPRIETA' MACROSCOPICHE. MATERIALI INNOVATIVI

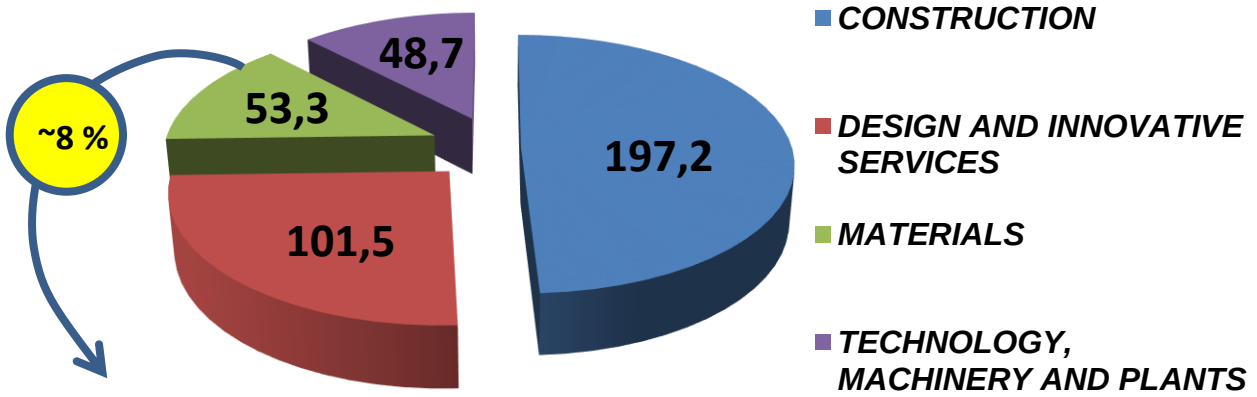
MAPEI

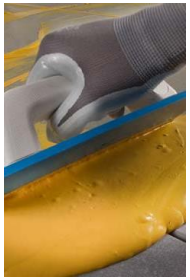
Day in **day out**, construction sites all around the **world** can count on **Mapei**

Giorgio Ferrari, Mapei S.p.A., R&D Laboratories, Milano (Italy)

The role of chemistry in construction

THE ROLE OF CHEMISTRY FOR CONSTRUCTION IN ITALY

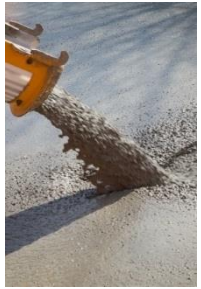




Adhesives

Paints & Pigments

Sealants



Cement & Concrete Additives

Restoration

Plastic & Fibers

Waterproofing

Source:

FEDERCHIMICA
Federazione Nazionale dell'Industria Chimica

The role of innovation in construction

1. PRODUCT INCREMENTAL INNOVATION
2. FROM PRODUCT TO SYSTEMS
3. RADICAL INNOVATION

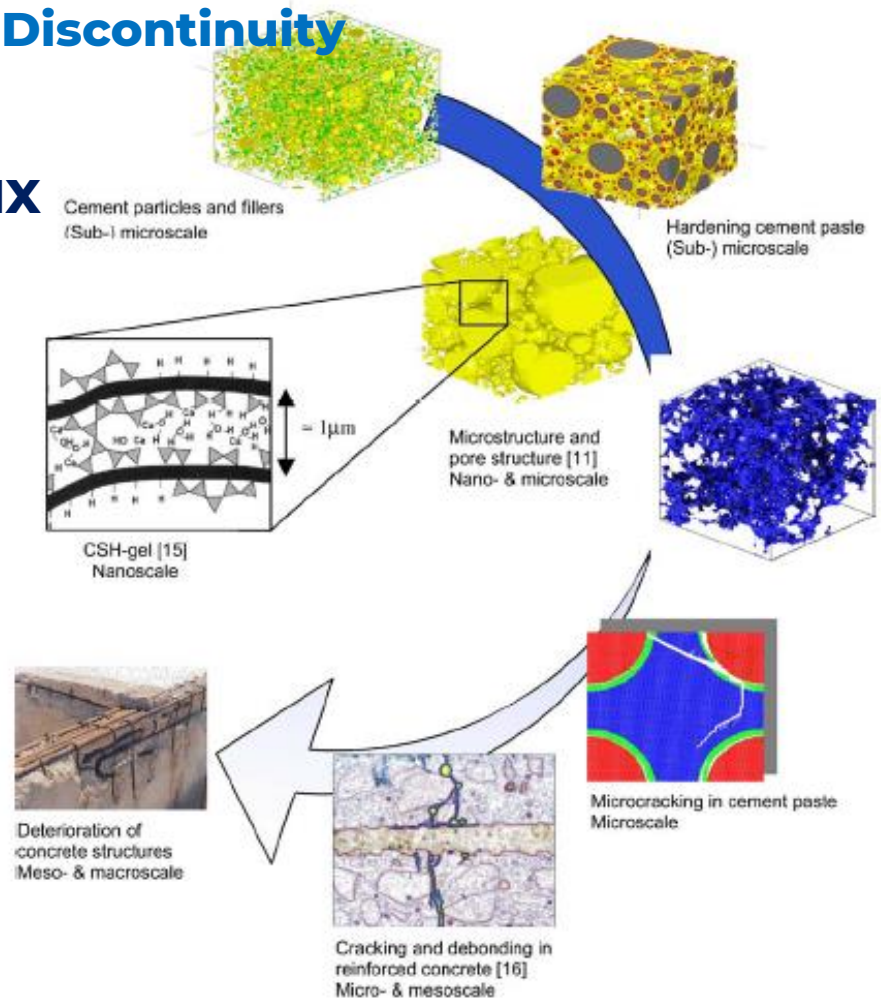
TECHNOLOGICAL DISCONTINUITY

«Process deriving from an emerging technology able to produce a value to performance ratio at least 10 times higher than existing technologies»

The strategy of Mapei in Techological Discontinuity

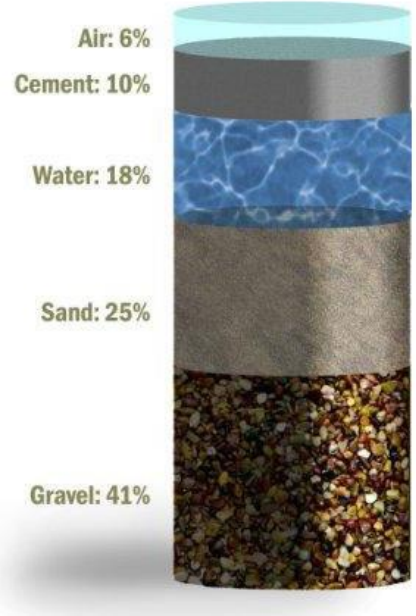
NANOTECHNOLOGY PROJECT

- **FOCUSED ON THE CEMENT MATRIX**
  - Mechanical performance
  - Durability
  - Rheology
- **MACRO & MICRO CHARACTERIZATION**
  - X-Ray Diffraction
  - Synchrotron light
  - Force Atomic Microscopy
  - Microtomography
- **MODELLING**
  - Molecular Dynamic
  - VCCTL Simulation (NIST)



Construction and Concrete

CONCRETE IS THE SECOND MOST USED MATERIAL IN THE WORLD, AFTER WATER



13 billion m^3/Y

Construction and Concrete

Burj Khalifa Tower, Dubai (UAE), open 2010
828 m, 163 floors, 330.000 m^3 concrete

Extension of Panama Canal, open 2016
4.300.000 m^3 concrete

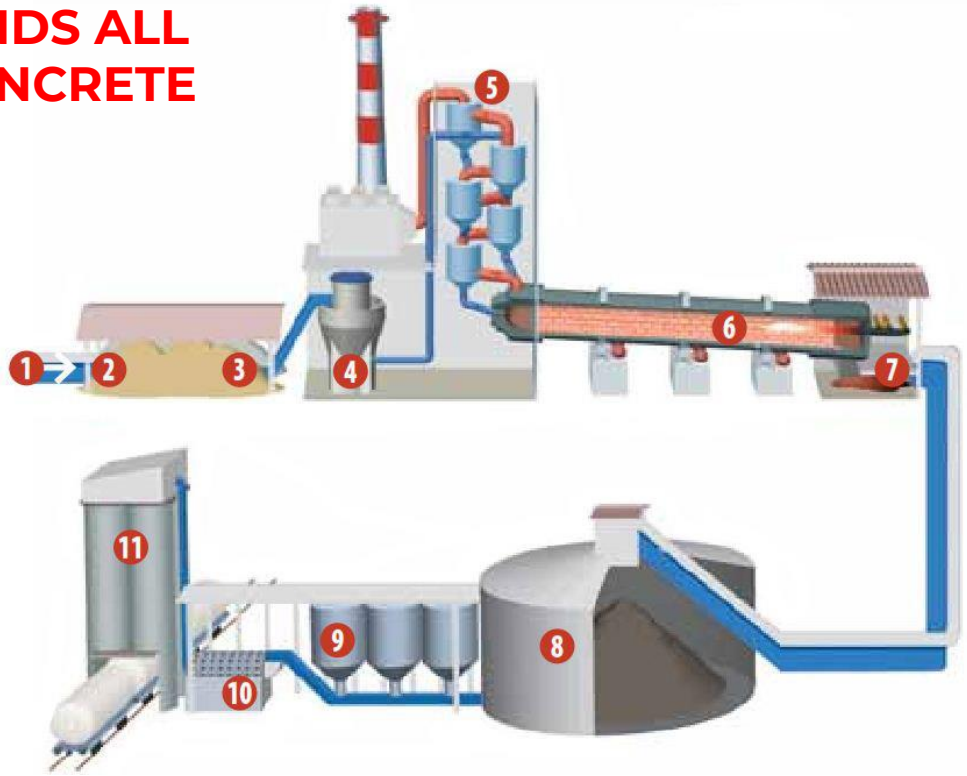
Three Gorges Dam (China), open 2012
28.000.000 m^3 concrete

The Chemistry of Portland Cement

CEMENT IS THE «GLUE» THAT BINDS ALL THE OTHER INGREDIENTS OF CONCRETE

THE MOST POPULAR CEMENT IS PORTLAND CEMENT

It is produced by heating carbonaceous and siliceous rocks and clays in kilns at high temperature (> 1400 °C) and then grinding the resulting clinker with 5% gypsum and other additions in ball mills to get the final cement powder



The Chemistry of Portland Cement

PORTLAND CEMENT IS A MULTIPHASE MIXTURE OF DIFFERENT CALCIUM OXIDES

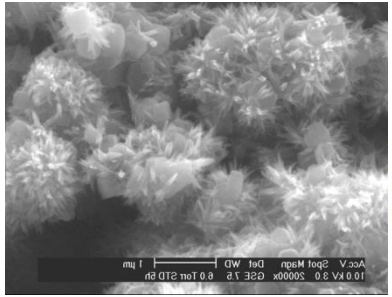
Formula	Notation	Composition	Property
$3CaO{\cdot}SiO_2$	C3S	45 - 75%	Hardened state
$2CaO{\cdot}SiO_2$	C2S	7 - 32%	Hardened state
$3CaO{\cdot}Al_2O_3$	C3A	0 - 13%	Fresh state
$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$	C4AF	0 - 18%	Fresh state
$CaSO_4{\cdot}2H_2O$	CS	2 - 5%	Fresh state

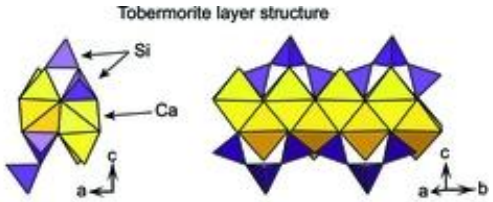
H_2O, (H)

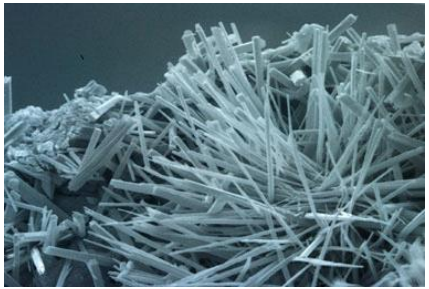
C3S, C2S + H → C-S-H *(C/S 1.7)* + CH

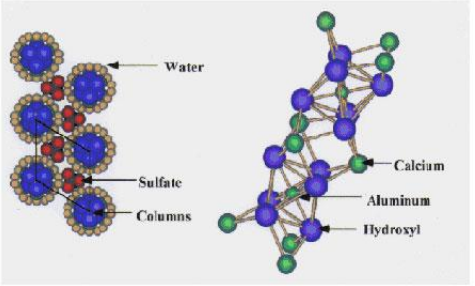
C3A +H+CS → ETTRINGITE AFt

$[Ca_3(Al,Fe)(OH)_6{\cdot}12\ H_2O]_2{\cdot}X_3{\cdot}nH_2O$





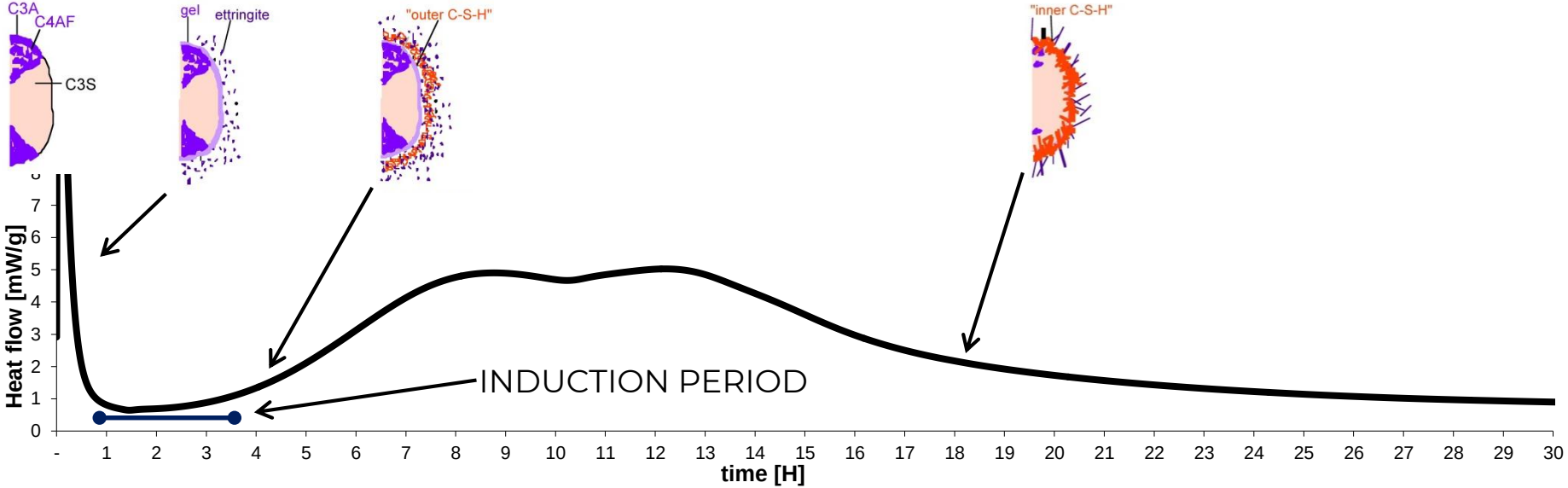




The Chemistry of Portland Cement

PRODUCTION **TRANSPORTATION** **PLACING** **HARDENING**

0 – 2/3 hrs **2/3 hrs**



The Chemistry of Portland Cement

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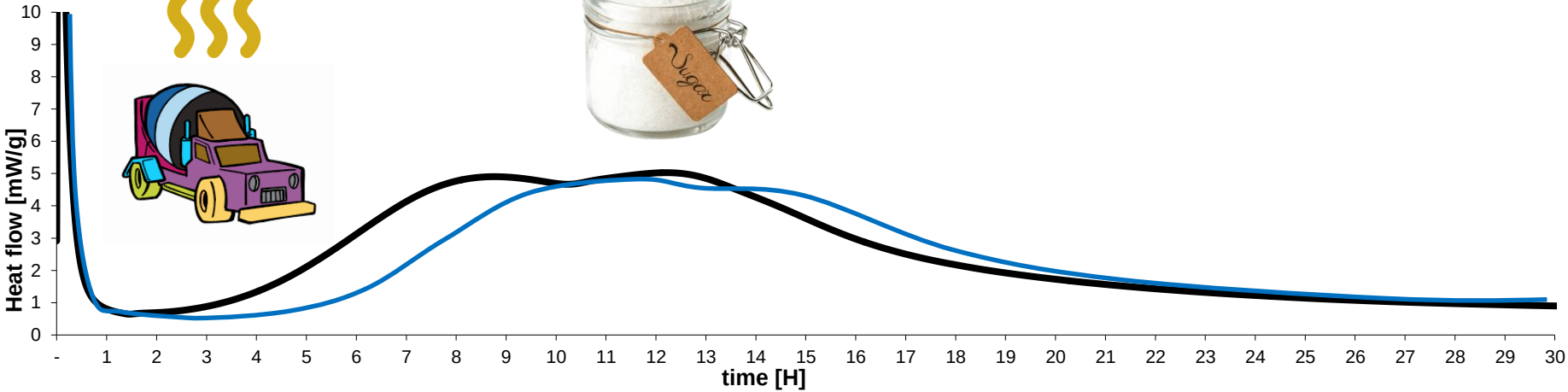

The Chemistry of Portland Cement

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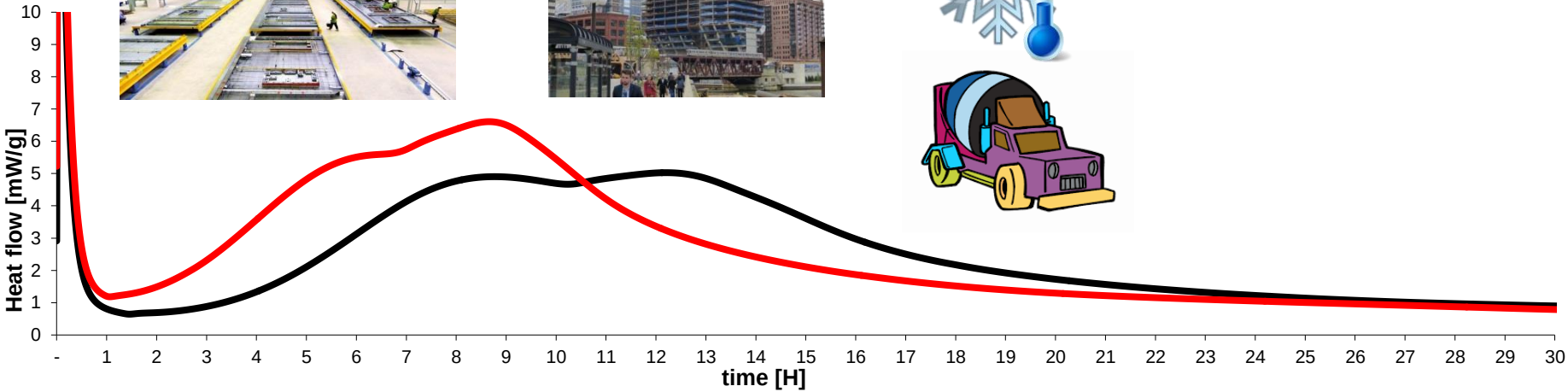
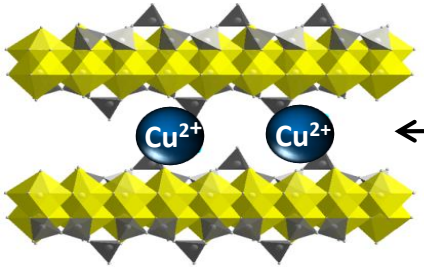


New Accelerator for Cement Hydration

Aqueous suspension of nano-sized polymeric silicate hydrate

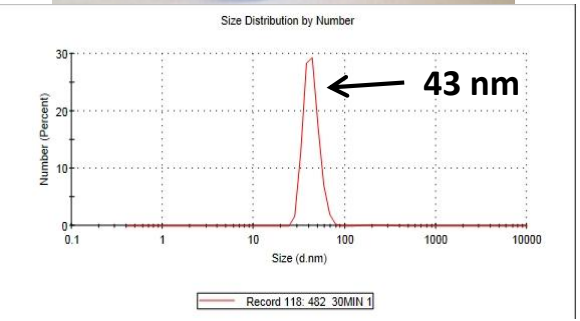
Synthesized by "bottom-up" sol-gel reaction of calcium and transition metals ions with sodium silicate in the presence of surfactants



Polysilicate chain

Ca^{2+} counterions

Cu^{2+} intercalating ions

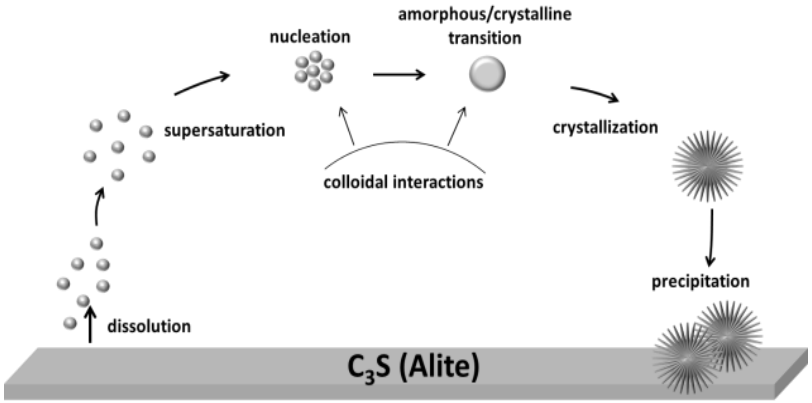


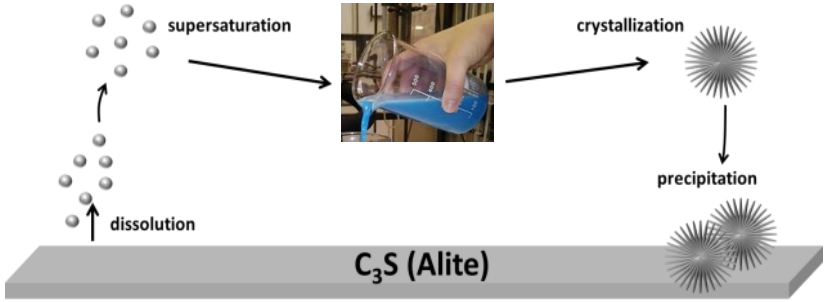
DEFINITION OF NANOMATERIAL (2011/696/EU)

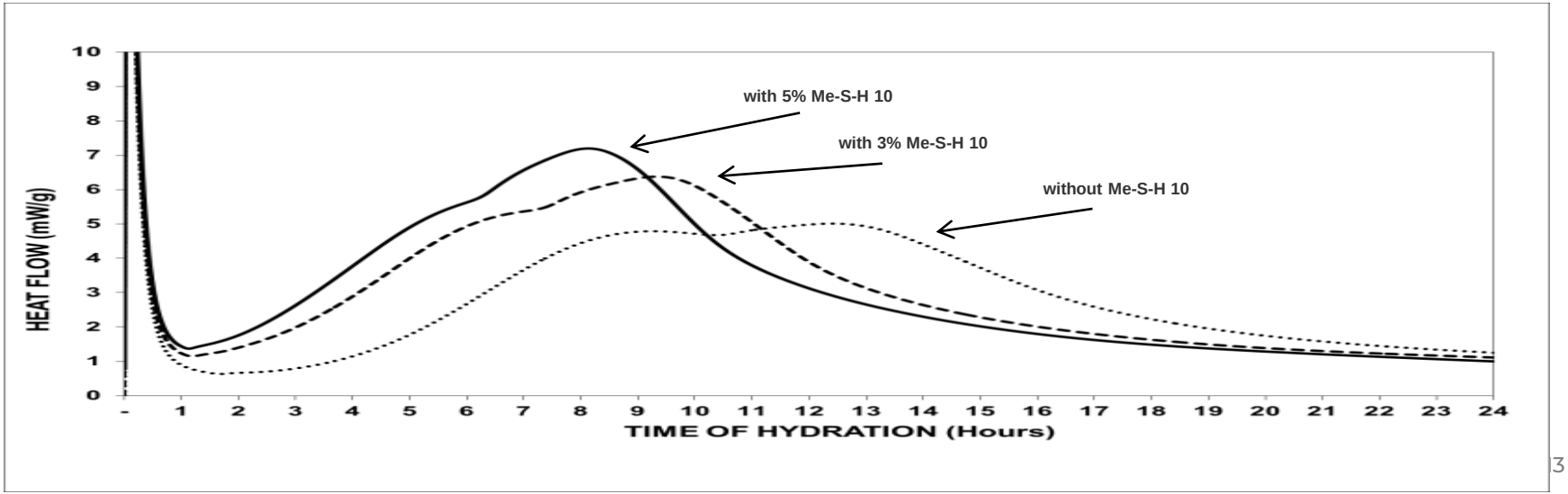
"A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm."

Nano-sized metal silicate hydrates Me-S-H represent the first application of NANOTECHNOLOGY which gained commercial application in CONSTRUCTION INDUSTRY

Acceleration by «Seeding Effect»

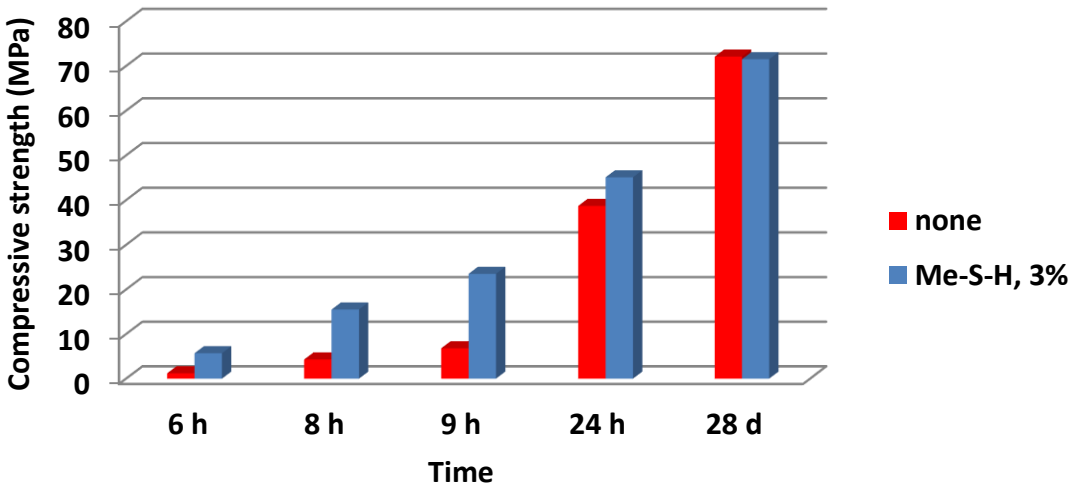


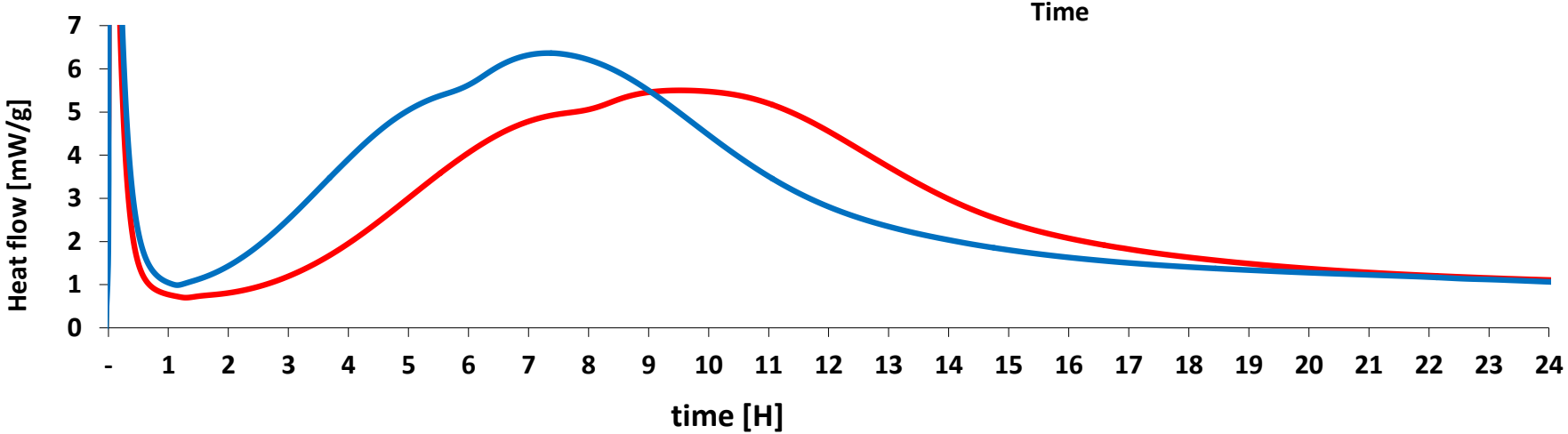




Early High Strength Development

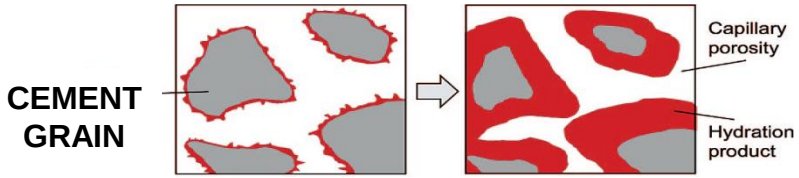
MIX DESIGN OF CONCRETE	
Type of cement	CEMI 52.5R
Dosage of cement	400 kg/m³
W/C	0.40
Dynamon NRG 1010, Mapei S.p.A.	0.9 % (blank, 0.8%)
Accelerator	3 %
Consistency class	S4 (160 - 210 mm)
Aggr. max diam.	25 mm



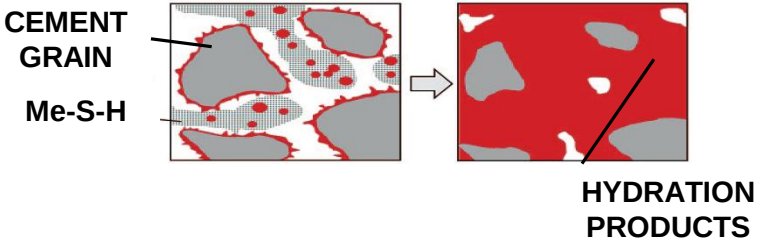


The Improvement of the Microstructure

THE EFFECT OF Me-S-H ON THE MICROSTRUCTURE OF CEMENT PASTE



Adapted from J.J. Thomas et al., J. Phys. Chem, 2009



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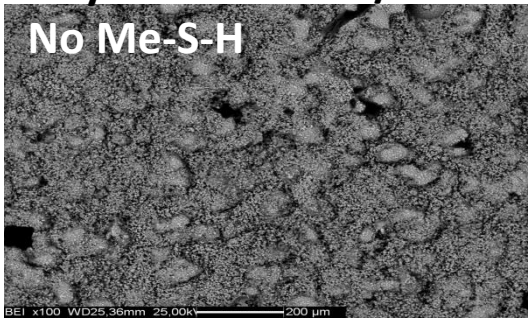
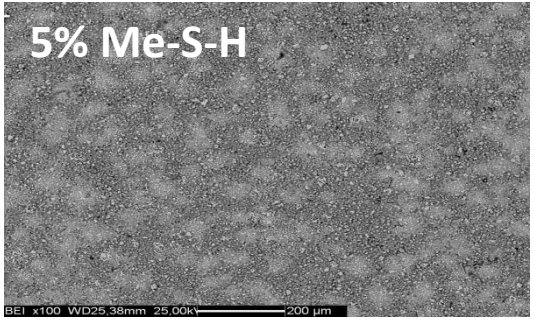
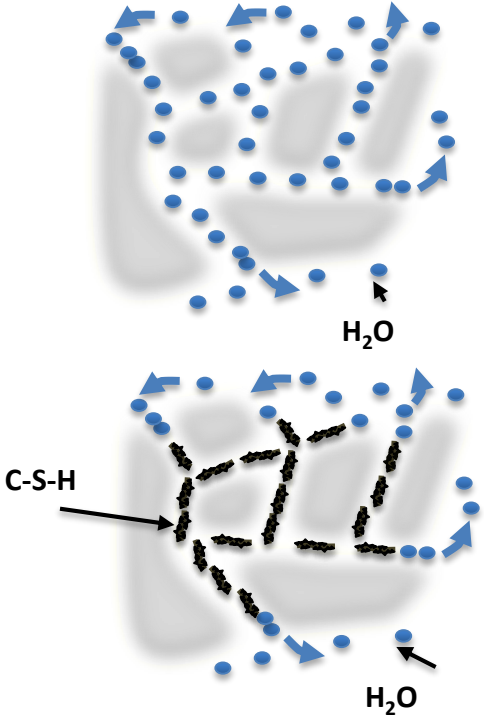
C3S hydrated 24h W/S = 0.5



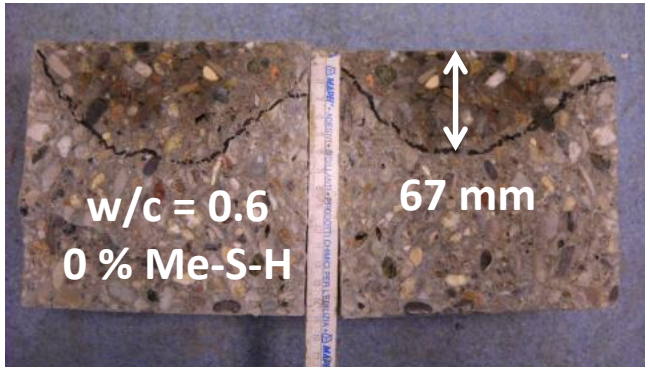


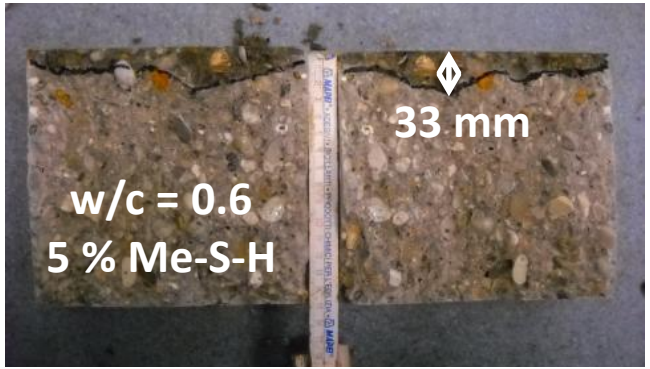


The Improvement of the Microstructure

THE EFFECT OF Me-S-H ON THE WATER PERMEABILITY OF CONCRETE

Concrete cubes were cured for 28 days at standard conditions tested for water permeability according to EN 12390-8





A DENSER MICROSTRUCTURE RESULTS IN A LOWER WATER PERMEABILITY AND HIGHER DURABILITY OF CONCRETE

Mutagenicy test according Bacterial reverse mutation assay (AMES Test)

↓

NOT MUTAGENIC

In vitro skin corrosion test on three dimensional RHE tissues

↓

NOT CORROSIVE, NOT IRRITANT TO SKIN

Leaching test for Cu from grinded concrete (EN 12457 2:2002)

↓

< 0.01 mg/L (Regulatory limit 0.05 mg/L)

Acute toxicity test on aquatic organism (freshwater algae) EC_{50} 72h

↓

20 mg/L

Application in Precast Industry

THE USE OF STEAM CURING CAN BE COMPLETELY ELIMINATE WITH Me-S-H

- ***Energy Saving***
- ***Improved Microstructure***
- ***Lower CO_2 emissions***

Concrete test	Compressive strength (N/mm^2)		GWP_{100}
	15 hours	80 days	$kgCO_2eq/m^3$
Steam cured	35.6	56.8	358
2 % Me-S-H	32.6	72.6	315

Thank you

for your attention

www.mapei.com