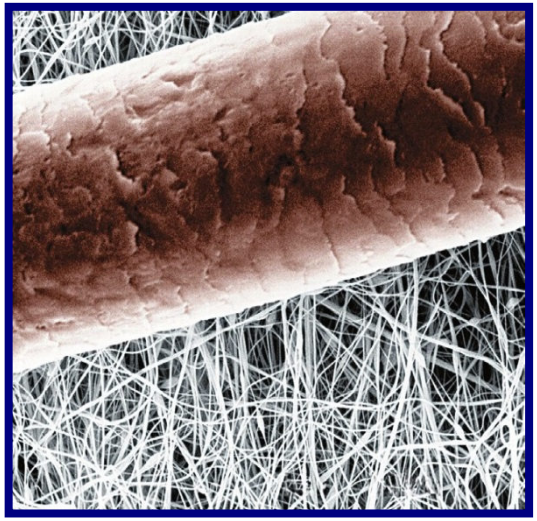
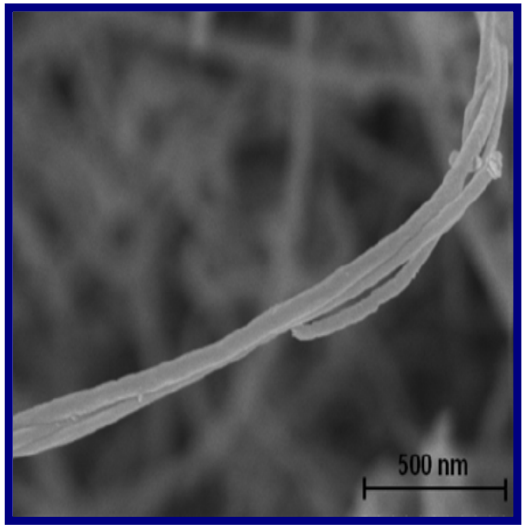
Prospective applications of nanomaterials in concrete

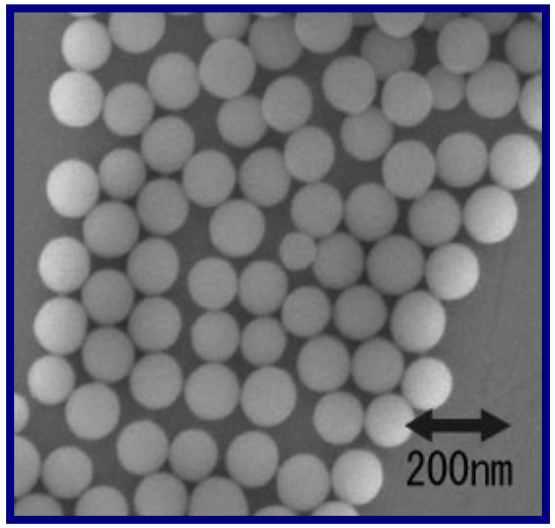
This presentation was created thanks to the support of FRVŠ project 915/2013 B1d „Tools for teaching design of concrete and masonry structures in English“

What is „nano-“?

- Nanometr = 10^{-9} m (*lat. nanos* = *dwarf*)
- The physics of nanoworld is different
  - High specific surface area of the material
  - Absence of crystal lattice failures







Source: eSpin Technologies, Inc., Chattanooga, Tennessee, USA

How could nanomaterials possibly improve concrete?

- New materials and technologies
- New utility properties
- Improving mechanical properties
- Better durability
- Preservation of historical monuments

Surface properties

Material properties

+

=

Improving mechanical properties and durability

- Higher strength
- Higher elastic modulus
- Better rate of hydration
- Decrease in porosity
- Preventing crack initiation

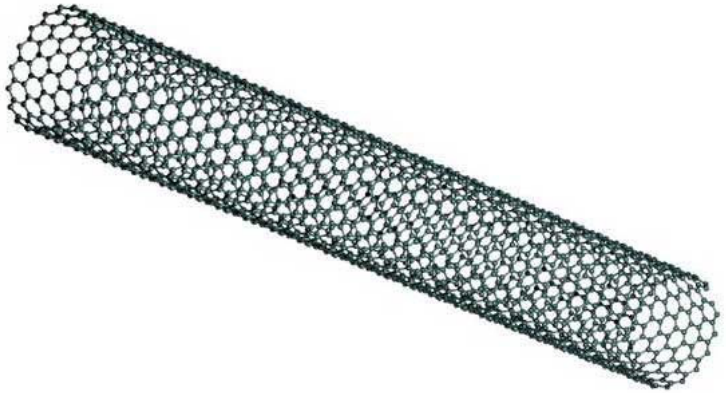
CNT+CNF

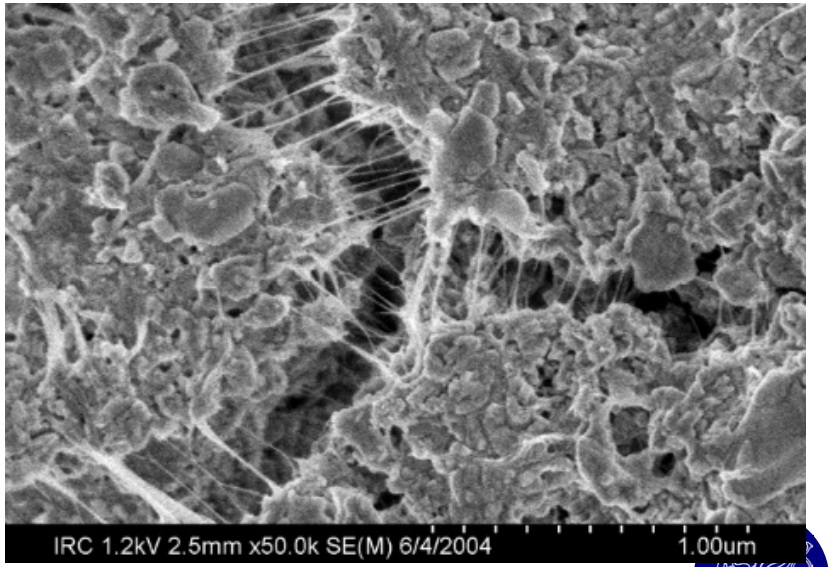
nano-SiO_2

Cr_2O_3

ZrO_2

TiO_2

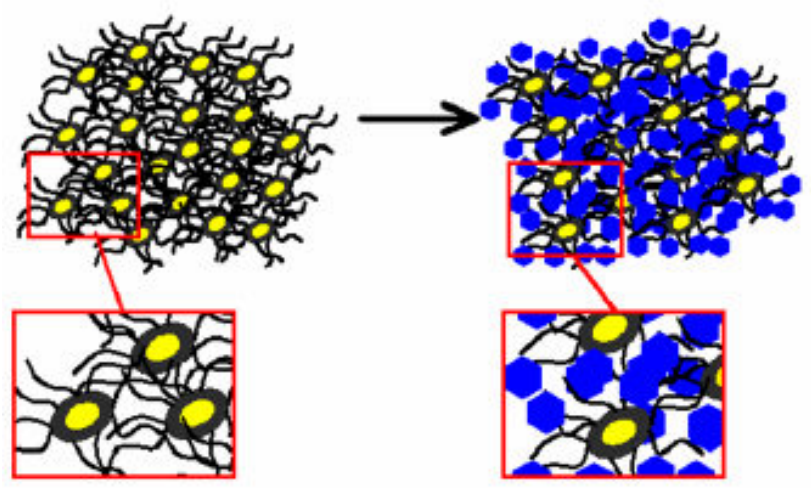


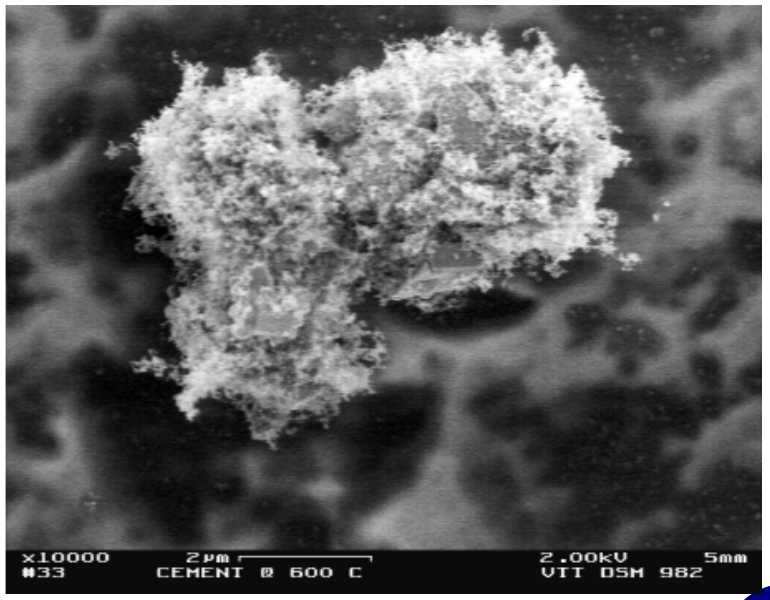


Source: Sanchez and Sobolev, 2010

New materials and technologies

- Carbon Hedgehog Cement (CHH)
- Low Energy Cement (LEC)
- Controlled release of admixtures
- Concrete curing





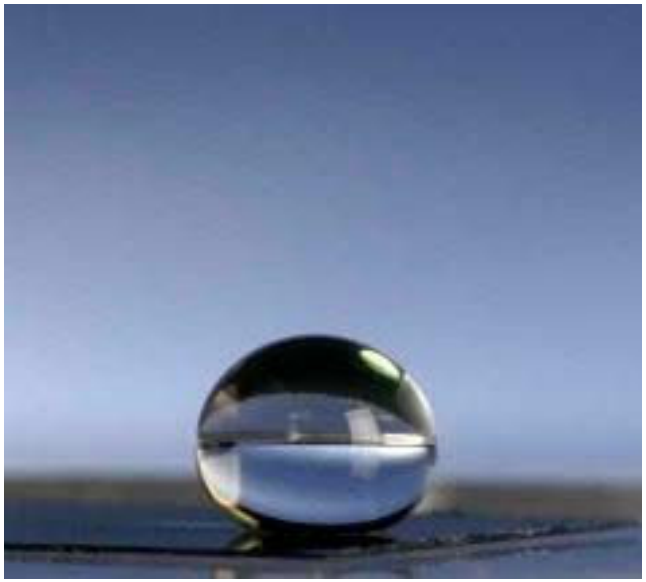
Source: Sanchez and Sobolev, 2010

New surface properties

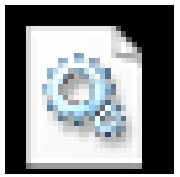
- Photocatalytic surfaces
- Self-cleaning surfaces
- Water-repellent surfaces
- Biocide surfaces

TiO_2

Ag



concrete.fsv.cvut.cz/~bily

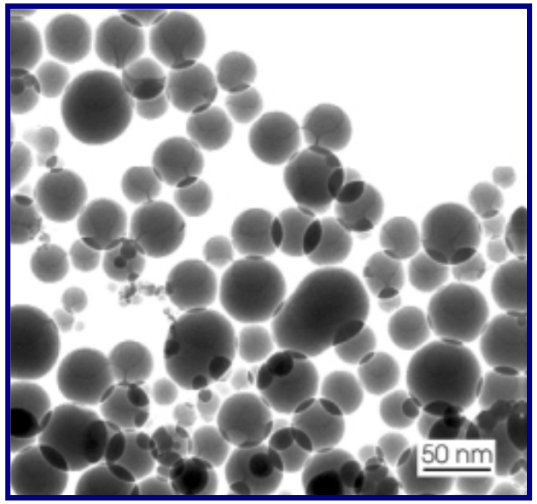


Film.wmv

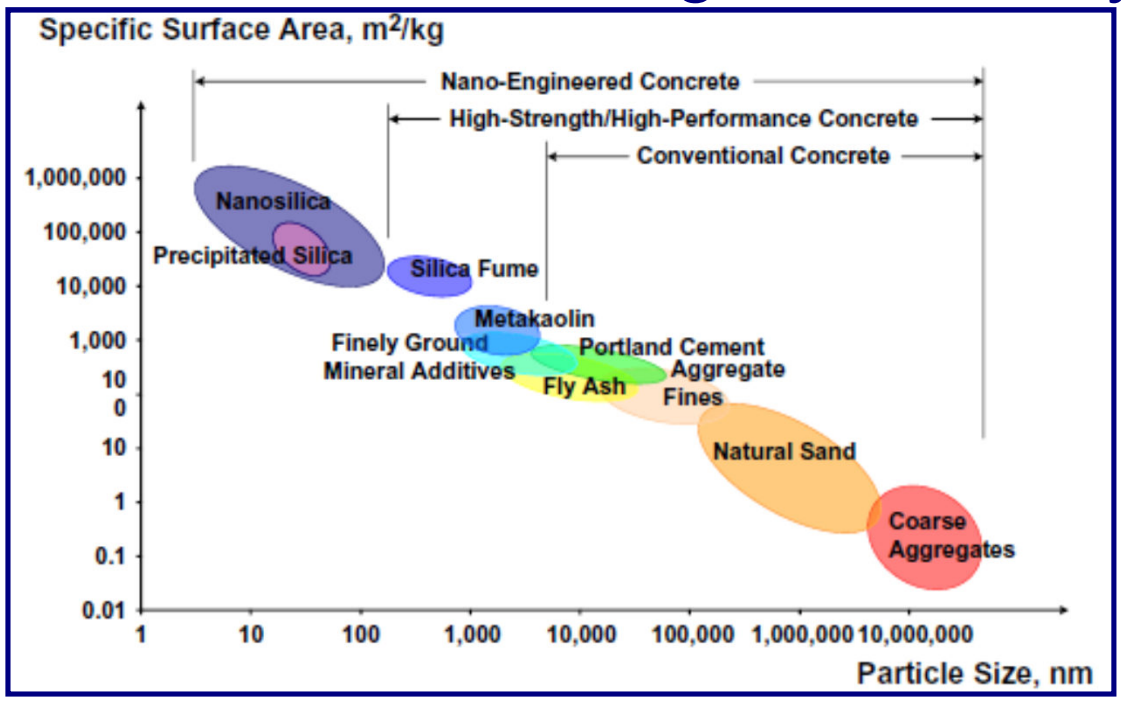
Influence of Nanosilica on Concrete Properties

Introduction

- Silica fume = cohesion ↑, segregation ↓, bleeding ↓, mechanical properties ↑, permeability ↓
- Nanosilica (nS) = SiO_2 particles ∅≤ 100 nm
- Higher specific surface area => Higher reactivity

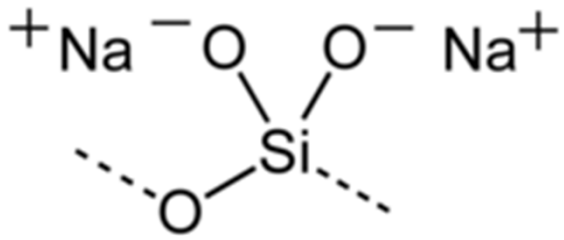


Source: Sobolev and Gutiérrez, 2005



Nanosilica Production

- Precipitation of Na_2SiO_3 solution
- Quartz vaporization at 1500 – 2000°C
- Feeding worms with rice husk



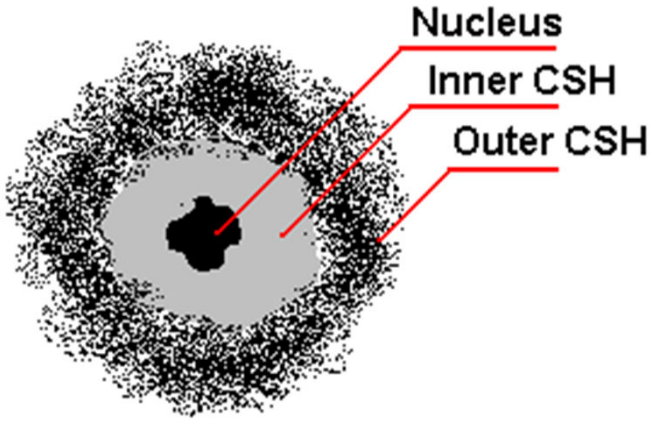
Source: Liou and Yang, 2011

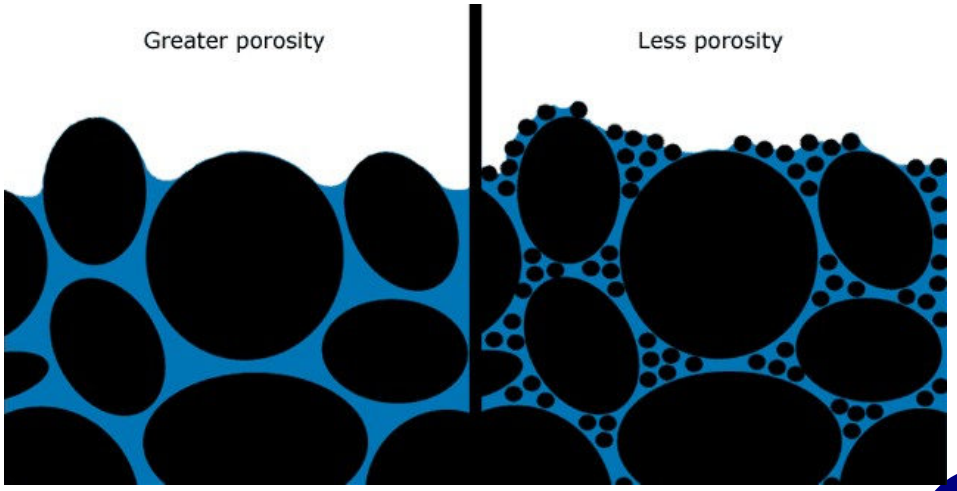
Nanosilica in Concrete – Principles

- Pozzolanic activity

$$„nS + Ca(OH)_2 \rightarrow CSH“$$

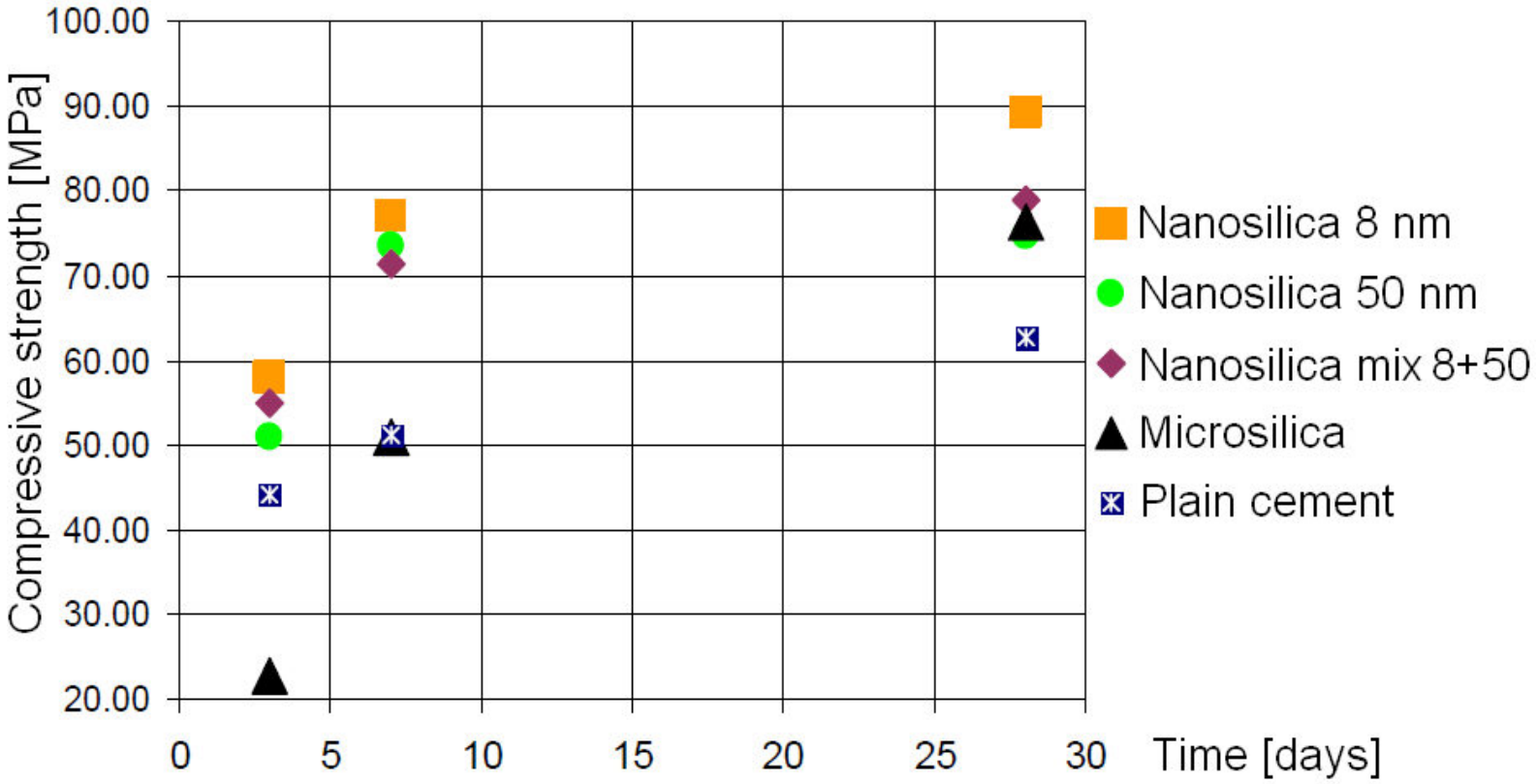
- Nucleation centers for cement hydration
- Filling material => lower porosity





Nanosilica in Concrete – Examples

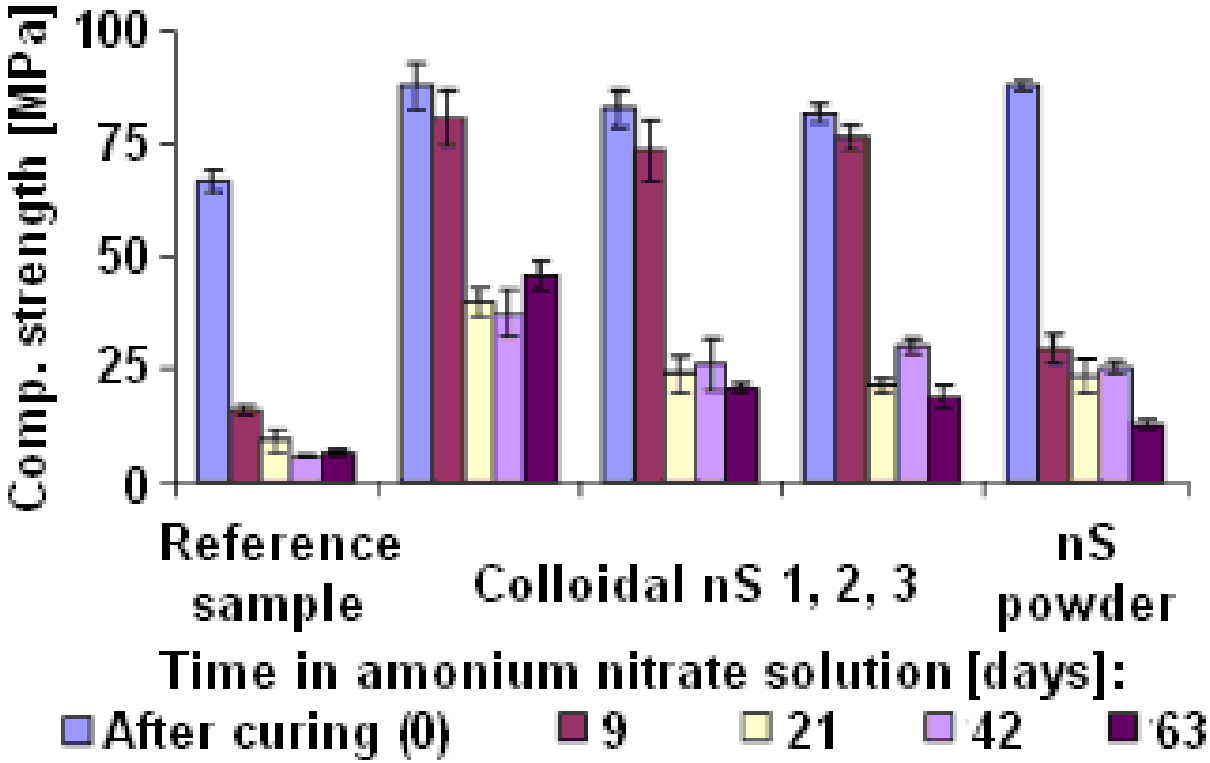
- Cement 425 kg/m^3, w/c = 0,32, SPF 1,9 l/m^3
- Microsilica/nanosilica 21 kg/m^3



(Belkowitz and Armentrout, 2010)

Nanosilica in Concrete – Examples

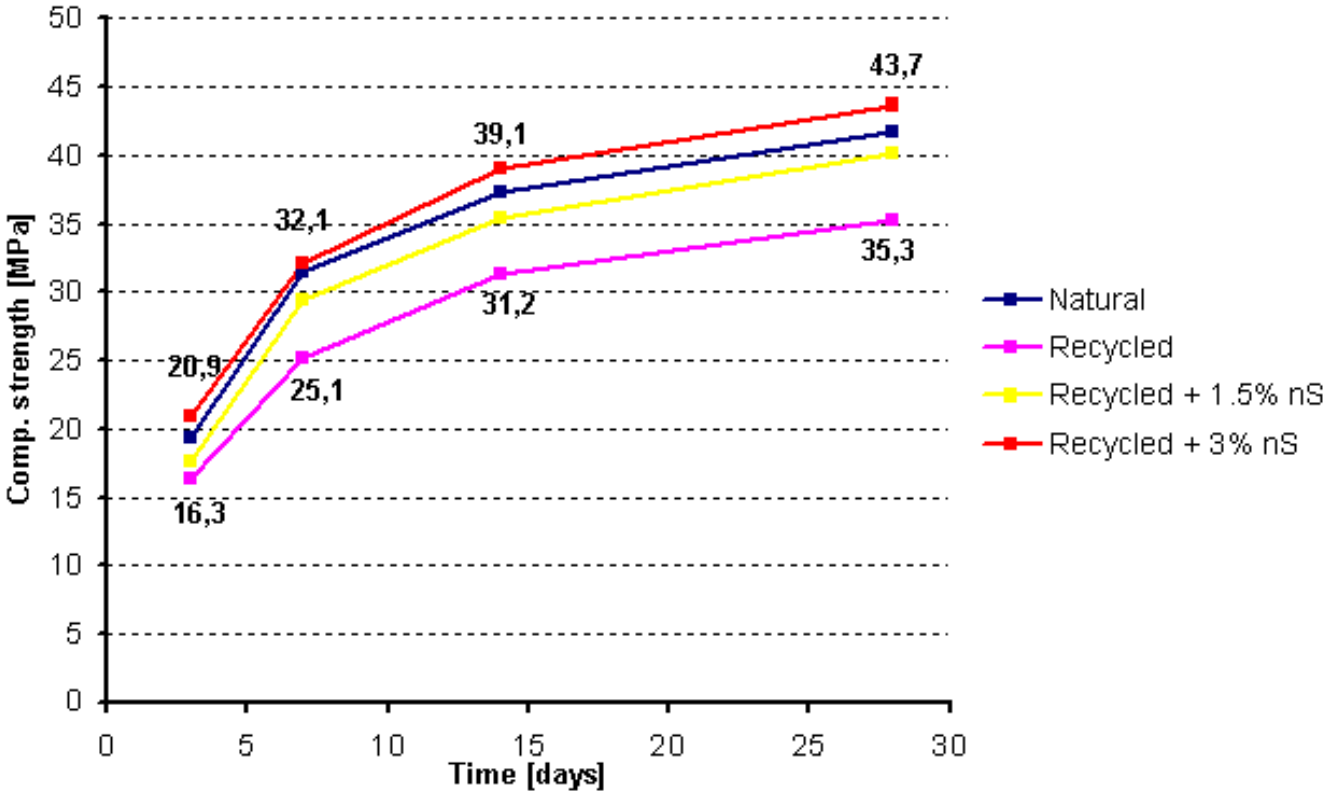
- Nanosilica 6% wt. of cement dose
- Calcium leaching in ammonium nitrate solution



(Gaitero et al., 2009)

Nanosilica in Concrete – Examples

- Nanosilica 0 – 3 % wt. of cement dose
- Recycled aggregate used

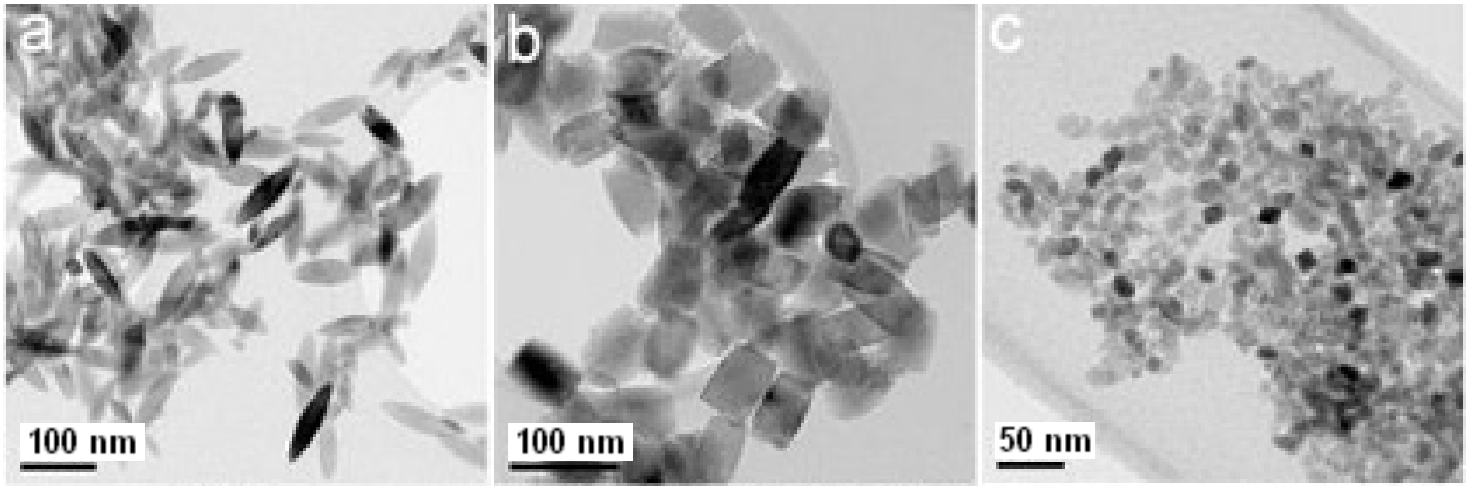


(Hosseini et al., 2009)

Influence of Titanium Dioxide Nanoparticles on on Concrete Surfaces

TiO_2 Nanoparticles in Concrete

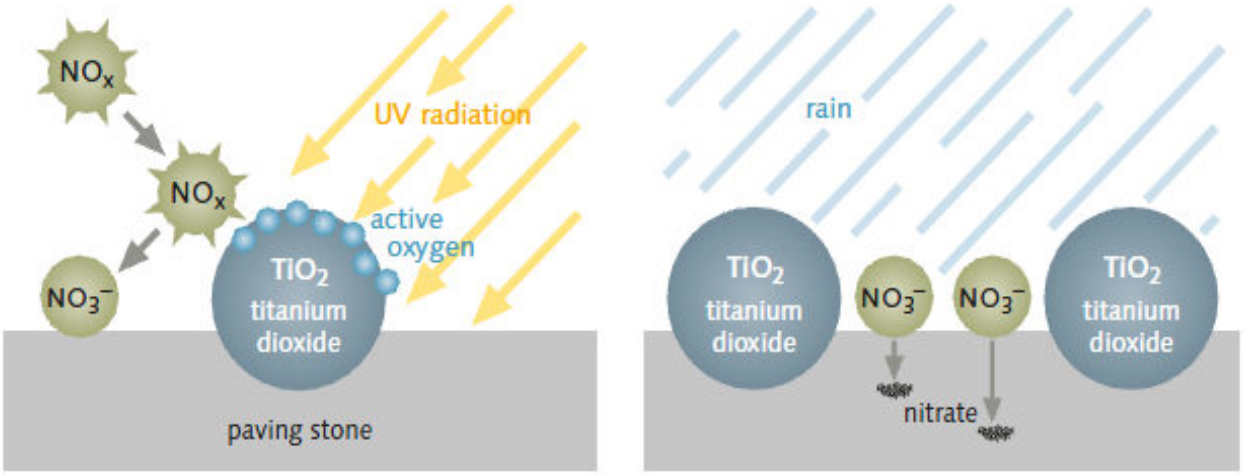
- Used as a part of cement or as an additive
- Photocatalytic effect
- Self-cleaning effect
- Influence on mechanical properties



Source: Ústav anorganické chemie AV ČR

Photocatalytic Effect

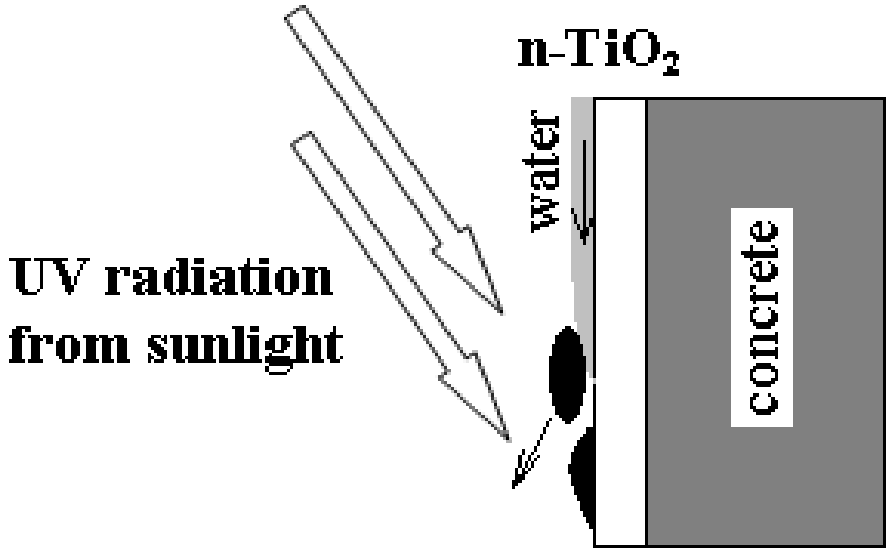
- Decomposition of pollutants by UV radiation = photolysis
- n-TiO_2 = catalyst => acceleration => photocatalysis
- Active oxygen or hydroxyl radicals are created => oxidation of pollutants, e.g. NO_x to NO_3^-



Source: Heidelberg Cement AG

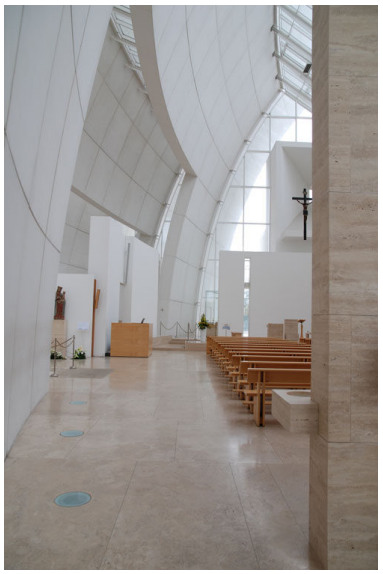
Self-cleaning Effect

- Result of photocatalysis
- Hydrophilic and hydrophobic areas exist side by side on the surface (hundreds nm^2)
- Water droplets form a uniform thin film
- As the water flows off the surface, it removes pollutants effectively



Pioneering Applications

- Chiesa di Dio Padre Misericordioso, Rome



Source:
www.bezsmogu.cz

Pioneering Applications

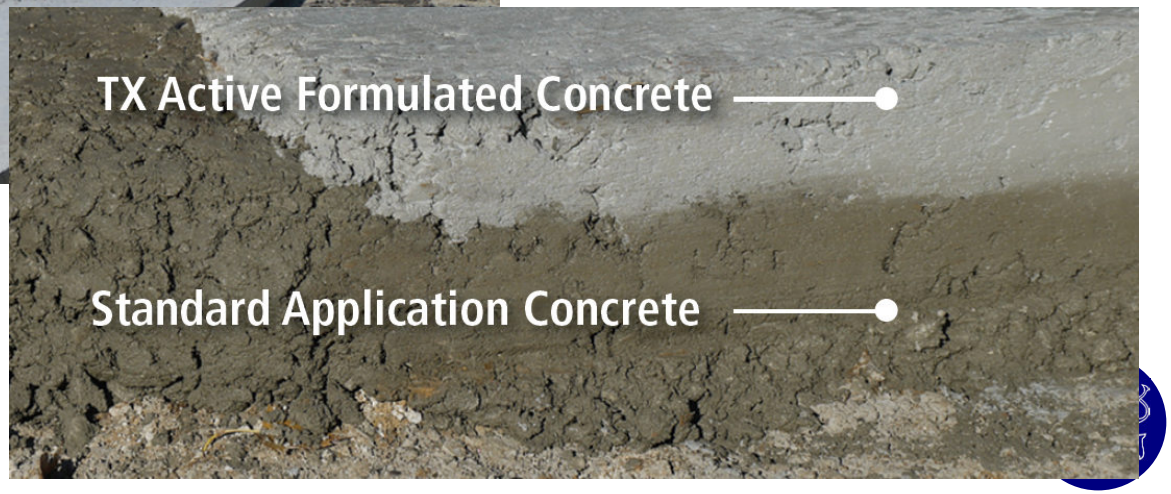
- Tunnel Umberto I., Rome

Source:
Italcementi SA

Pioneering Applications

- Photocatalytic road in St.Louis

Source: University of Missouri at Kansas City



Pioneering Applications

- 12LOFTS, Praha-Bubeneč

Source: Hochtief CZ

Where is the catch?

- Price
- Production technology
- Health and environmental risks
- The research is in it´s early stage yet

+

=

Interesting free articles

- How Nanotechnology Can Change the Concrete World
  http://www.cognoscibletechnologies.com/en/files/How-Nanotechnology-Can-Change-the-concrete-world-I.pdf
  http://www.cognoscibletechnologies.com/en/files/How-Nanotechnology-Can-Change-the-concrete-world-II.pdf
- Cement and Concrete Nanoscience and Nanotechnology
  http://www.mdpi.com/1996-1944/3/2/918/pdf
- Crack Free Concrete Made With Nanofiber Reinforcement
  http://onlinepubs.trb.org/onlinepubs/conferences/2009/Infrastructure/Metaxa.pdf
- An Investigation of Nano Silica in the Cement Hydration Process
  http://www.concretetechnologyforum.org/2010CSCProceedings/documents/Belkowitz%20Paper%204-13-10.pdf
- TioCem – comercially produced cement with TiO2
  http://www.heidelbergcement.com/NR/rdonlyres/28528B72-3125-4370-B657-616609415500/0/6TioCem_Broschuere_englisch.pdf
- Influence of Nano-Anatase Titanium Dioxide on Cement Hydration
  http://blogs.cae.tntech.edu/hydration-kinetics/files/2009/07/jayapalan_poster.pdf
- Video – water droplet on water-repellent surface
  http://vtm.zive.cz/aktuality/kapka-vody-na-hydrofobni-plose-neuveritelne-video