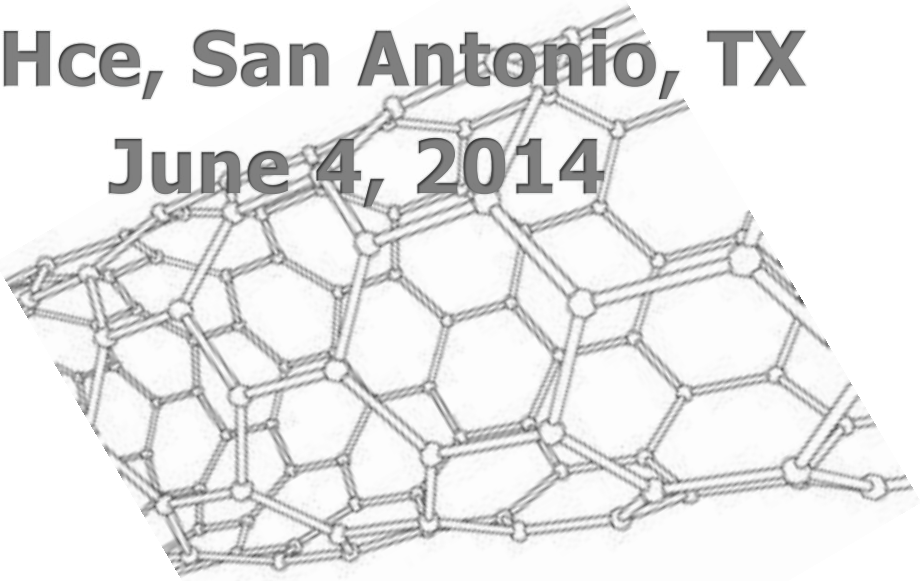
Exposure to Nanoparticles in Construction and Use of Existing Engineering Control Approaches

AIHce, San Antonio, TX

June 4, 2014



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What's New

CPSC, Ryobi Portable Table-Saws Recalled Due to Laceration Hazard

CPWR Technical Report: Risk of Isocyanate Exposure in the Construction Industry

Fatal and Nonfatal Injuries among Hispanic Construction Workers 1992-2008

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We are adding a construction nanomaterial inventory

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Sections to the Presentation

1. Improvements nano-enabled products will bring to construction
2. Why construction is of particular concern
3. Methods and Results for CPWR's Nanomaterials in Construction Project
4. Discussion and Future Plans
5. Resources

Improvements nano-enabled products will bring to construction

Section 1

1

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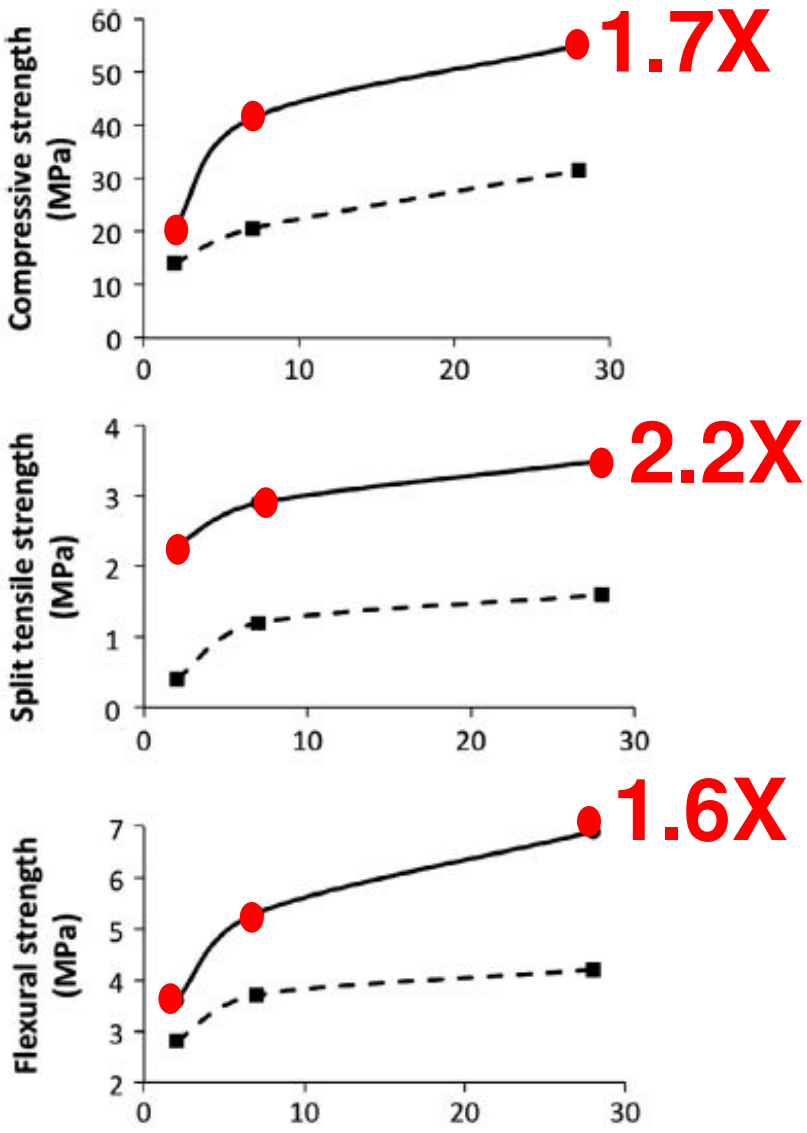
Changes to concrete can have a huge impact

- Manufacture of concrete releases 7% of CO_2 emissions globally.
- Structures life-span now 50-100 yrs. 500?
- Compressive strength increased in cement paste with 0.045% MWCNTs.

G. Constantinides, Nano in Eco-efficient Construction, 2013

Nanosilica strengthens cement composites



Narazir and Riahl in Hanus and Harris, 2013

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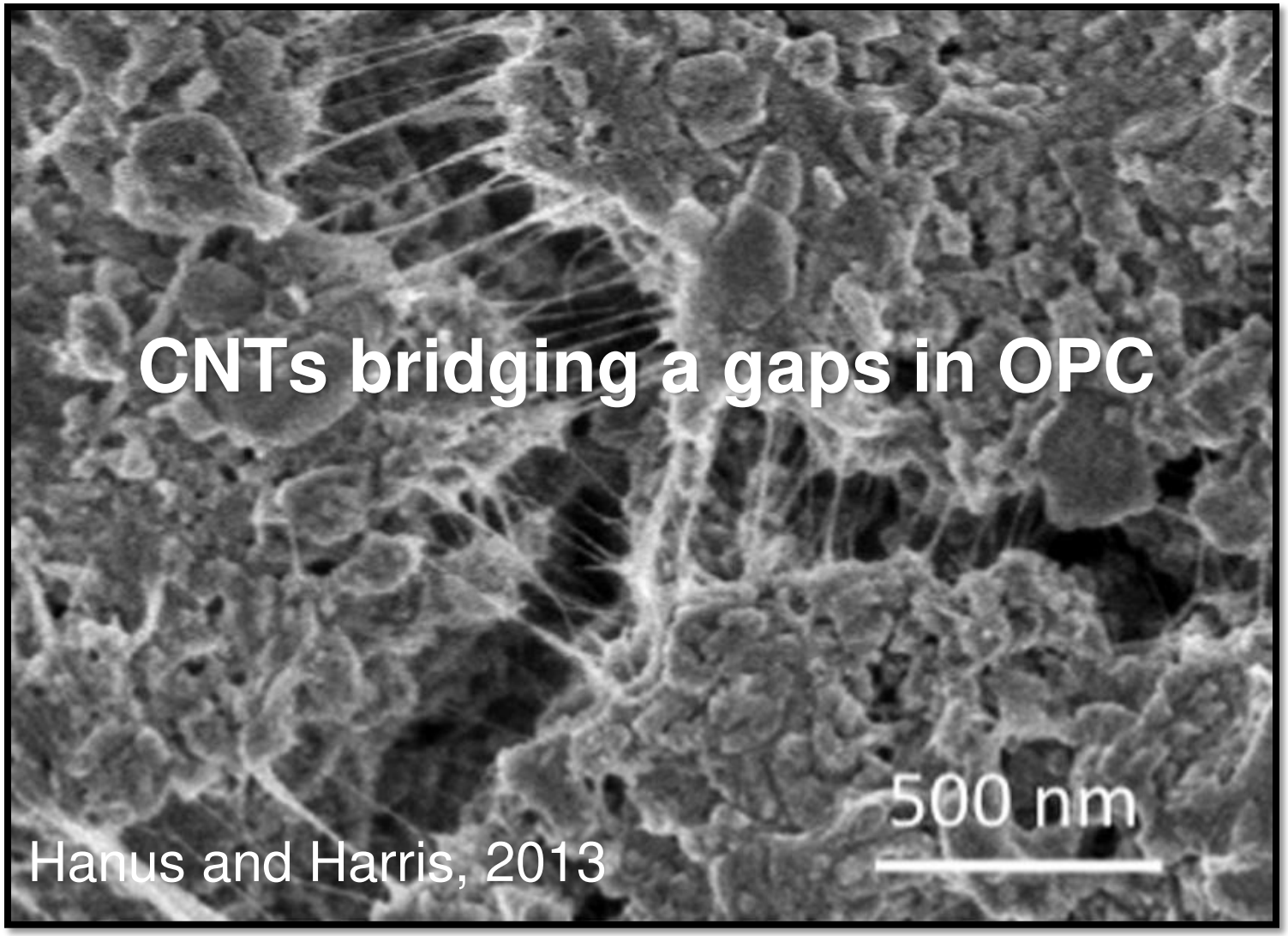
Carbon nanotubes reinforce cement at the nano scale



CPWR has arguably the most complete inventory of construction nanomaterials in the world

What are our criteria?

1. Manufacturer's reference to nano
2. Use of term "nano" in product or company names
3. Product description suggests presence of nano (e.g. photocatalytic properties)

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elcosh NANO
Construction Nanomaterial Inventory

Coatings and paints dominate the product types

Product Types	Frequency	%
coatings & paints	101	64.3
insulation	13	8.3
concrete & cement	11	7.0
non-cementitious composites	6	3.8
solar power	5	3.2
additives	4	2.5
glass	3	1.9
lubricants	3	1.9
miscellaneou	11	7.0
Total	157	100.0

Now 250

TiO_2 was the nano-object found most often

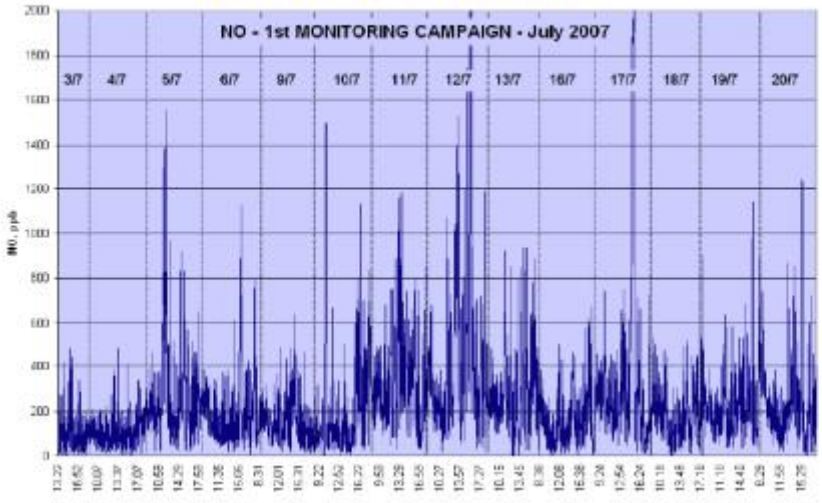
Nano-objects	Frequency	%
Titanium Dioxide (TiO2)	28	17.8
Nanoporous or Nanostructured	21	13.4
Hydro-NM-Oxide	10	6.4
Silver (Ag)	5	3.2
Carbon	4	2.5
Other (each < 2%)	28	17.8
To Be Determined	61	38.9
Total	157	100.0

Photocatalytic cement containing TiO_2 is being used in Europe

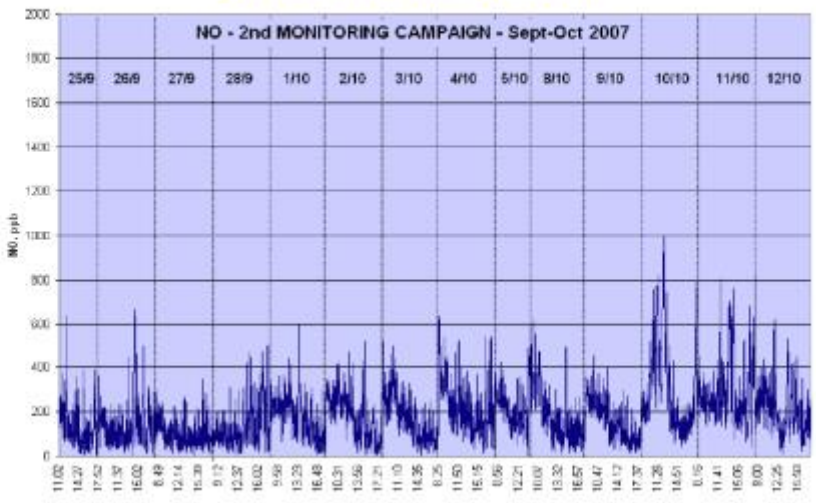
Gian Luca Guerrini, "Photocatalytic performances in a city tunnel in Rome. NOx monitoring results" *Construction and Building Materials* 27 (2012) 165–175

There was a clear reduction of peaks in nitric oxide in the tunnel

before the renovation



after the renovation



Reductions of 20 to 60%

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Emaco NanoCrete patching compounds illustrate a difficulty with nano

"Nanotechnology does NOT mean nano-sized particles: We do not use any nano-particles in our cement formulations."

Photos courtesy Emaco

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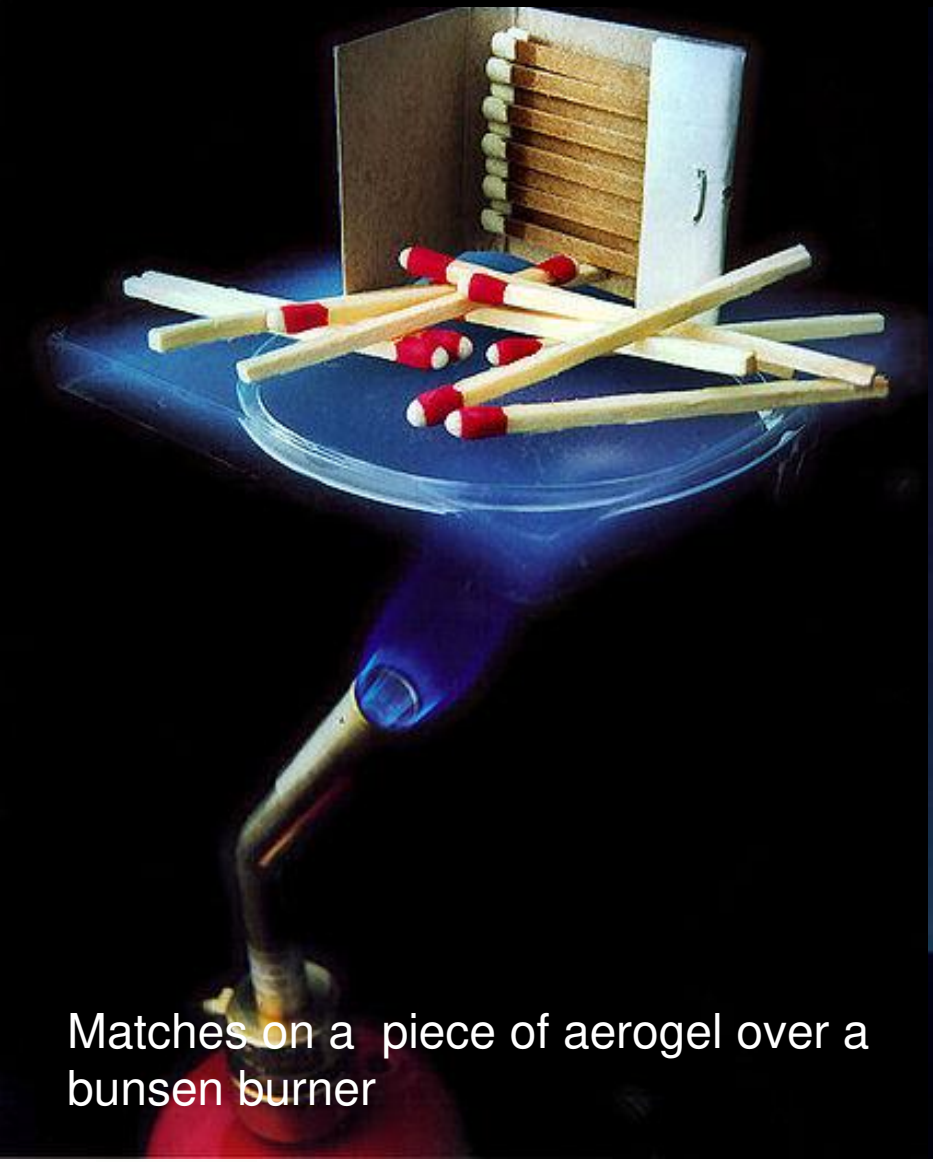
These hydrated silicates are *nano-structured*

Aerogels are incredible insulators



Matches on a piece of aerogel over a bunsen burner

A 2.5 kg brick supported by a piece of aerogel with a mass of 2 grams

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Photos courtesy Wikimedia and NASA

Aerogels insulate thermal systems and reduce noise

Average attenuations of -60 dB for a thickness of 70mm.

"Aerogel insulation sheets suffer from dust production."

R. Baetens, in Nanotechnology in eco-efficient construction, edited by Pacheco-Torgal et al, 2013

NIOSH conducted an HHE of Aspen Aerogel working with insulators union in Chicago in January, 2014

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Water repellent surfaces for masonry are impressive

Concentrate

3001

3001 Concentrate | 2

3001 is a new surface protection product to reduce water absorption, efflorescence, moss and algae buildup on mineral substrates. 3001 is a concentrate, that will be diluted prior the application with 9 parts of tap water. Therefore, each litre of 3001 concentrate will give you 10 litre of ready to use, penetrating sealer.
Traditional solvent based products have high water repellent values, but fail to meet modern environmental standards. 3001 is the most sustainable penetrating sealer on the market.

The product has deep penetrating properties, without the use of any hazardous hydrocarbon solvents, or substances. 3001 is nearly odour free and still matches and even outperforms conventional sealer solutions. The extreme reduction of the water absorption results in fast drying surfaces were moss and algae will not find the appropriate growing ground. Slippery surfaces and unsightly discolourations can be avoided and the risk of falls can be significant reduced.

Suppling such a usual voluminous building product as a concentrate is truly ground breaking, and has significant financial benefits.

High penetration
3001 shows very high penetration.

Moos and Algae reduction
Fast drying surface , less microbial growth and less slippery surfaces.

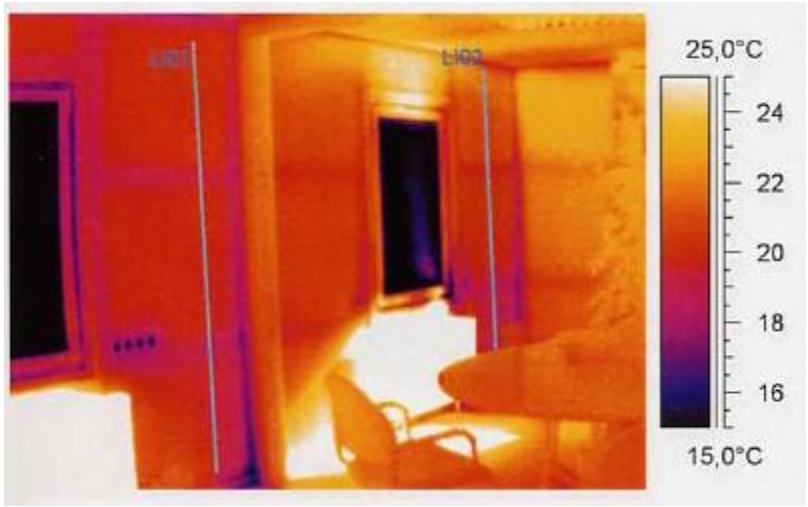
Durable
Last up to 10 years on horizontal surfaces and up to 15 years on vertical surfaces

Reduced Costs
up to 90 % cheaper to transport
90 % reduced packaging material

What is the nano part?

http://www.nanovations.com.au/Concrete.htm

Paint with glass spheres distributes heat more evenly



Non-flammable, zero-VOC, Bioni Comfort can be applied over normal paint

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NANOVATIONS
engineering a sustainable future

Paint containing silver and titanium dioxide acts as a biocide

BIONI MEDICAL
Clinical Coating System

The first clinical interior coating system

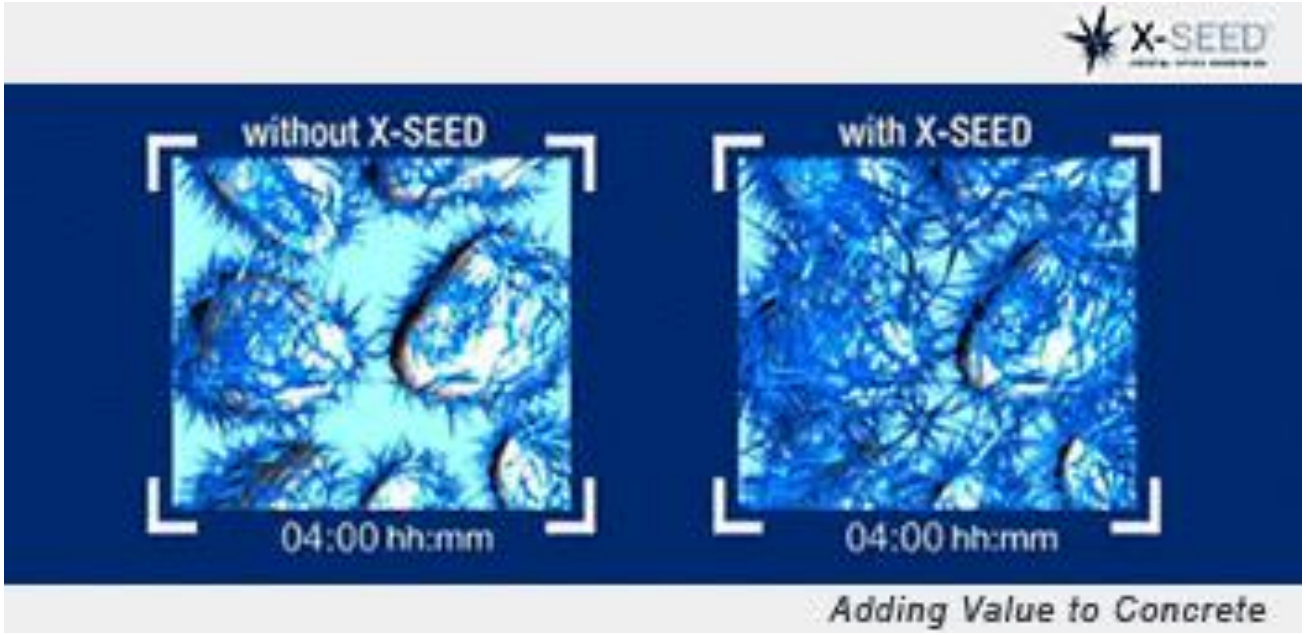
Nature Interior Paint
New multi-functional interior paint based on green nanotechnology

BIONI Perform - Exterior
New multi-functional energy saving paint for exteriors based on green nanotechnology

BIONI Roof
New multi-functional energy saving roof coating based on green nanotechnology

BIONI Grip
Special Primer for interior and exterior use, free of solvents

BASF product speeds up concrete hardening at low temperatures and double strength

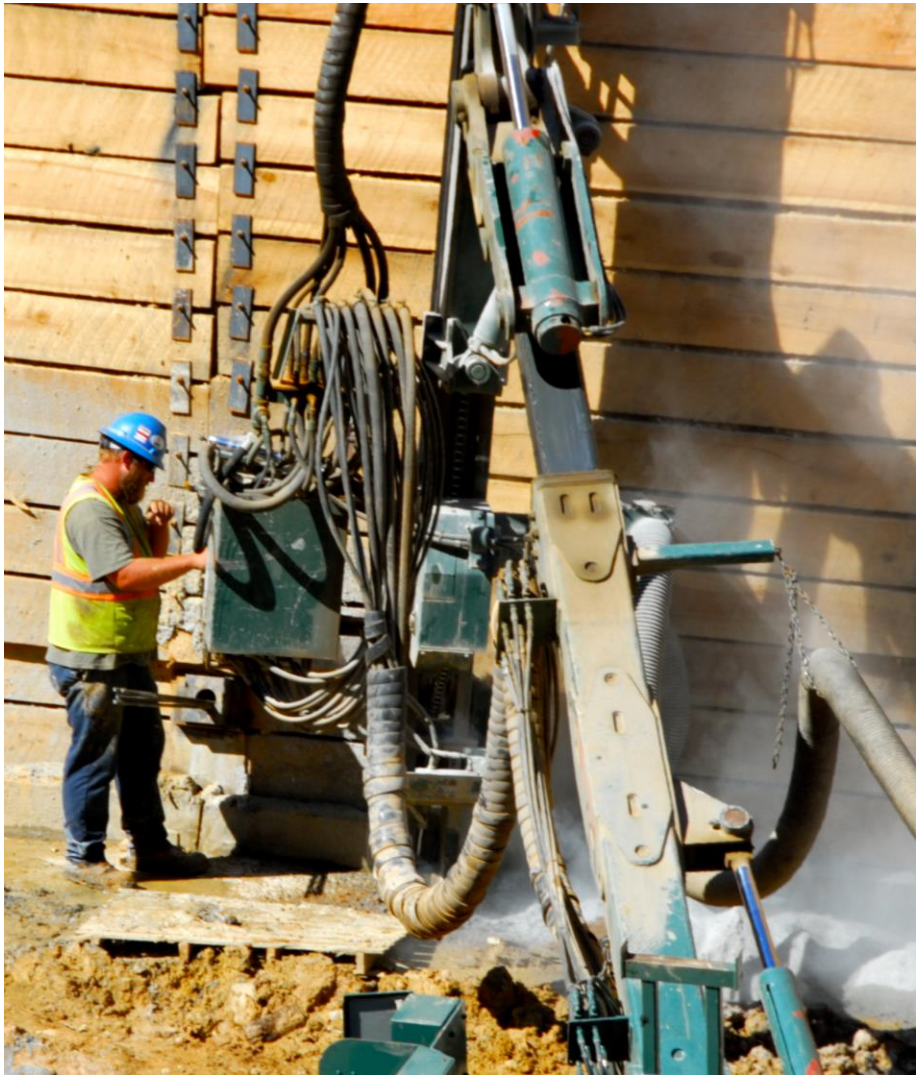


Calcium silicate hydrate crystals

Why construction is of particular concern

Section 2

In 2010, more than half of construction workers reported exposure to vapors, gas, dust or fumes twice a week or more



Liss GM, Petsonk EL, Linch KD [2010, Nov]. The construction industry. In: Occupational and Environmental Lung Diseases

Construction workers are 5-6% of non-farm labor force, but account for half of all occupational cancers

(Construction Chart Book, 2013)

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Exposures must be considered over the life cycle of nanoproducts

Production

Installation

Maintenance

Demolition

What happens with Hazcom?

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Bystander exposures are much more prominent in construction

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Metal nanoparticles have been shown to penetrate flexed, damaged or diseased skin

Int Arch Occup Environ Health (2009) 82:1043-1055

Methods and Results for CPWR's Nanomaterials in Construction Project

Section 3

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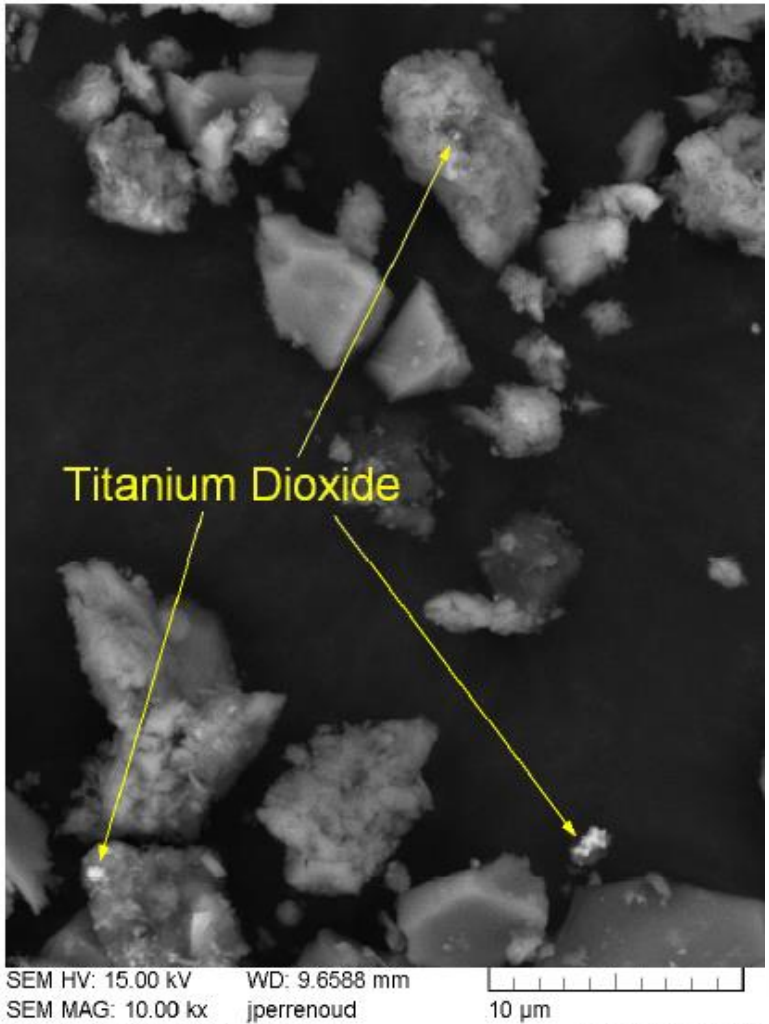
We first tested these smog-eating concrete tiles that contain a coating of TiO_2



The Boral roofing system requires significant tile cutting

CPWR conducted sampling during the grinding, drilling and nailing of tiles outdoors, July, 2013

We collected total and respirable dust, TiO_2 and particle counts with CPC and OPC

We conducted sampling with LEV on and off

RIDGID 15-Amp 7 in. Angle Grinder

Cut Buddy

Ermator S26 HEPA Dust Extractor

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Sampling strategy

1. Used union apprenticeship trainers to provide tools and techniques
2. Chose control technologies from CPWR's Construction Solutions website to test
3. Used same tradesperson for all testing and kept tasks of same duration
4. Set up 5 stations equidistant (approx. 4') around subject with area samples and two personals with cyclones
5. Followed NIOSH methods with 10% blanks

Tester always worked in a PAPR and Tyvec with gloves and hearing protection, if needed

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Sampling methods

Agent	Method	Media
Total Dust	0500	37-mm cassette with 5-micron pre-weighed, PVC filters
Titanium dioxide	7300	37-mm cassette with 5-micron pre-weighed, PVC filters
Titanium dioxide	7402 modified TEM	25mm open-face cassettes with 0.45-micron MCE filters

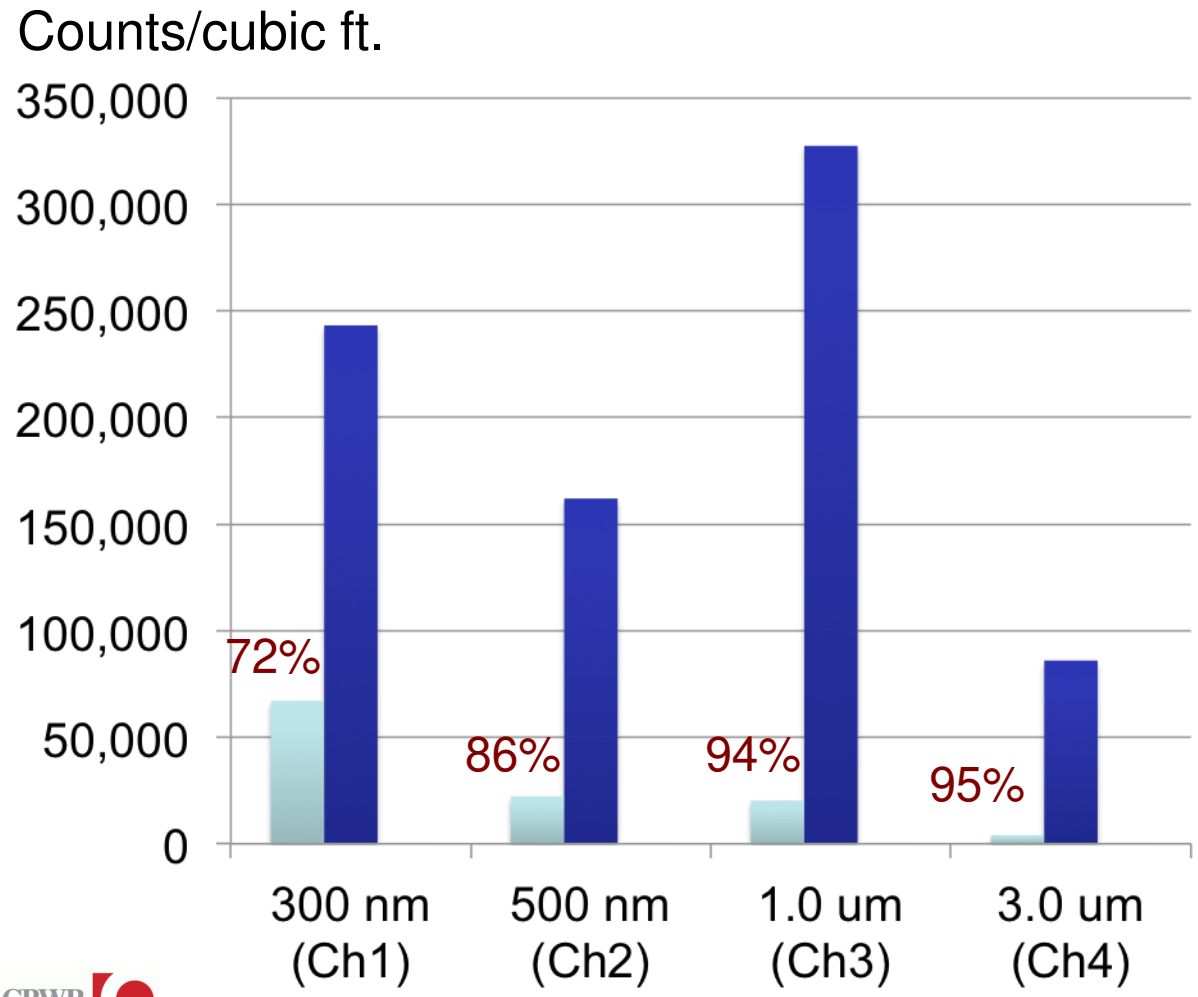
Sequence of sampling

1. Background concentrations with no activities
2. Running the angle grinder and electric drill without doing any work
3. Grinding of roofing tiles with LEV operating
4. Grinding of roofing tiles with no LEV
5. Drilling of holes in the tiles.
6. Nailing of tiles to 4x8 sheet of ¾” plywood

Most results were encouraging

- All measurements were below the new NIOSH REL for ultrafine TiO_2 of 0.3 mg/m^3
- Ventilation reduced total dust by 52.8% based on NIOSH 0500 (n=5 LEV on, n=5 LEV off)

Optical particle counts during surface grinding showed better LEV efficiency



TSI 9306 Aerotrack

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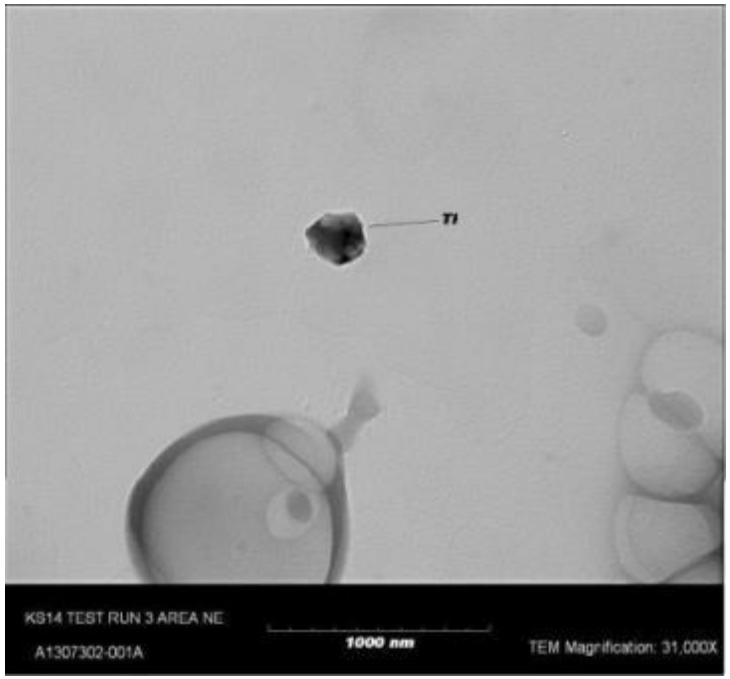
There were clearly free TiO_2 particles, however

41% of structures counted via TEM were free and not agglomerated



65% of free TiO_2 particles were less than 300 nm by TEM

Width (nm)	Length (nm)	Frequency	%
140	140	4	4.8
210	210	30	36.1
210	280	1	1.2
280	280	15	18.1
280	410	4	4.8
280	1040	1	1.2
350	350	12	14.5
350	410	2	2.4
410	690	1	1.2
620	620	1	1.2
690	690	4	4.8
690	900	1	1.2
1040	1040	1	1.2
1170	1170	1	1.2
1380	1380	2	2.4
1380	1730	1	1.2
1730	1730	1	1.2
2070	4140	1	1.2

65%
< 300 nm

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We next tested *cutting* in EPI's chamber using a Bosch saw with 12" blade and Ermator vacuum

Cutting across bevels was challenging for the ventilation

Use of ventilation in chamber was quite effective (cutting longitudinally)

Sample	LEV On (mg/m^3)	LEV Off (mg/m^3)	% Reduction
Total dust (area)	19.79 (n=15)	675 (n =12)	97.1%
TiO_2 (area)	0.11 (n=15)	1.97 (n=12)	94.2%
Resp dust (personal)	4.44 (n=8)	81.17 (n=6)	94.5%
TiO_2 (personal)	0.04 (n = 8)	0.34 (n=6)	88.4%

Dust levels without controls were extraordinarily high, but TiO_2 levels were acceptable

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Second round of testing was of a nano-enabled mortar

Manufacturer claims:

- High ductility allowing flexes without failure
- 500 times the tensile strain capacity of other cement-based products
- Resistant to UV rays
- Expected life of 100 years

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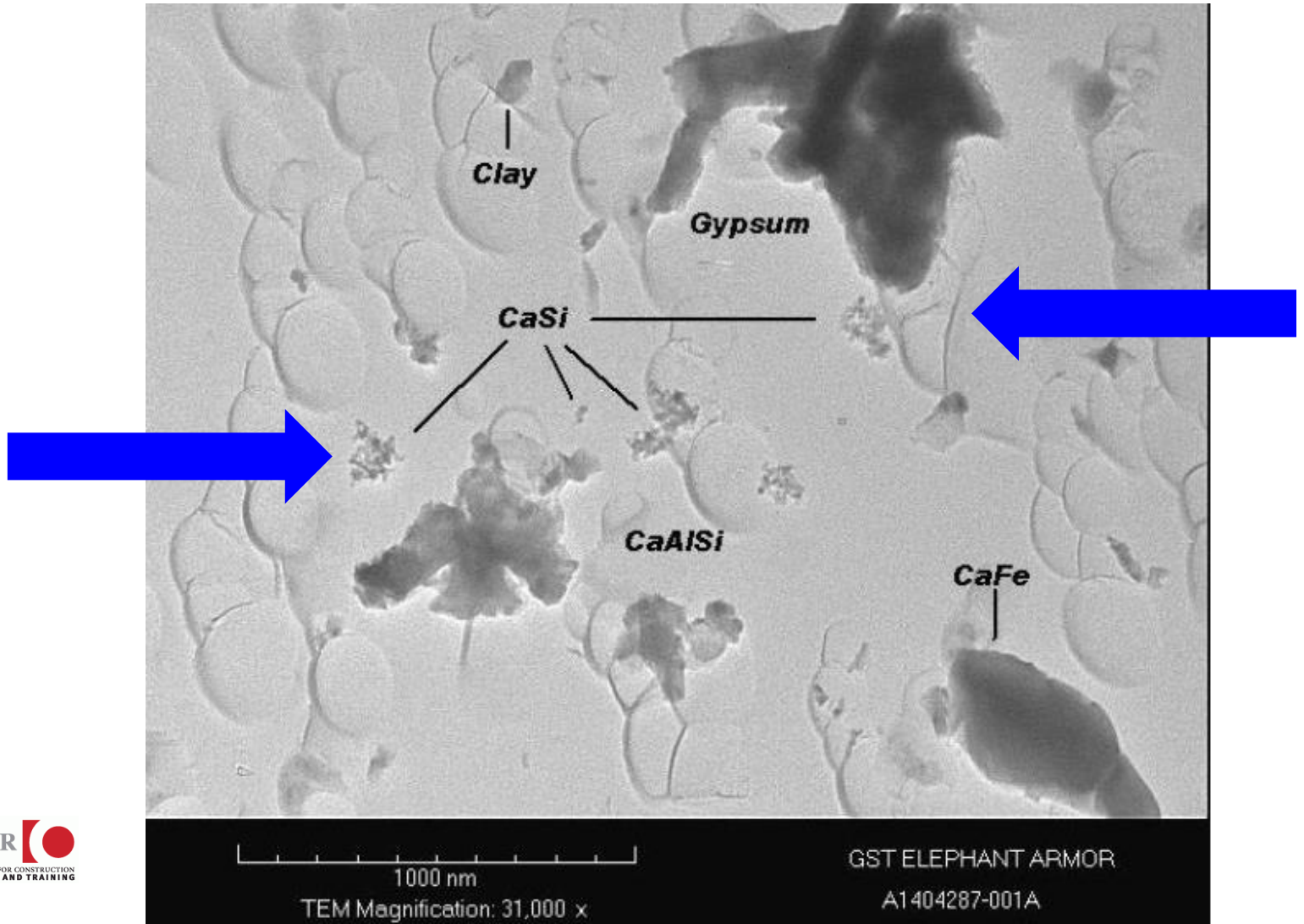
The mortar contains 1.5% nano calcium silicate



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Calcium silicate accelerates concrete hardening

- ACGIH TLV of 10 mg/m^3
- Braun et al. showed with rat exposures to **nano** calcium silicate:
  - minimal to slight local irritation of the larynx at concentration 3X the nuisance dust limit.
  - Mild local toxicity (granulomatous inflammation and squamous metaplasia in larynx) was only observed in animals exposed to the high concentration of 50 mg/m3

Arch Toxicol (2012) 86:1077–1087


We followed the same approach, performing sampling last month (all results aren't in)

We used Sakrete for comparison

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We sampled during the dumping and mixing with water of one bag at a time for approx 13 minute

We measured total and respirable dust, calcium silicate by NIOSH 7020 and particle counts with OPC

After each batch was mixed, it was troweled onto Hardiebacker board *outside* the chamber

The space was wet wiped and HEPA vacuumed and purged for 20 air changes

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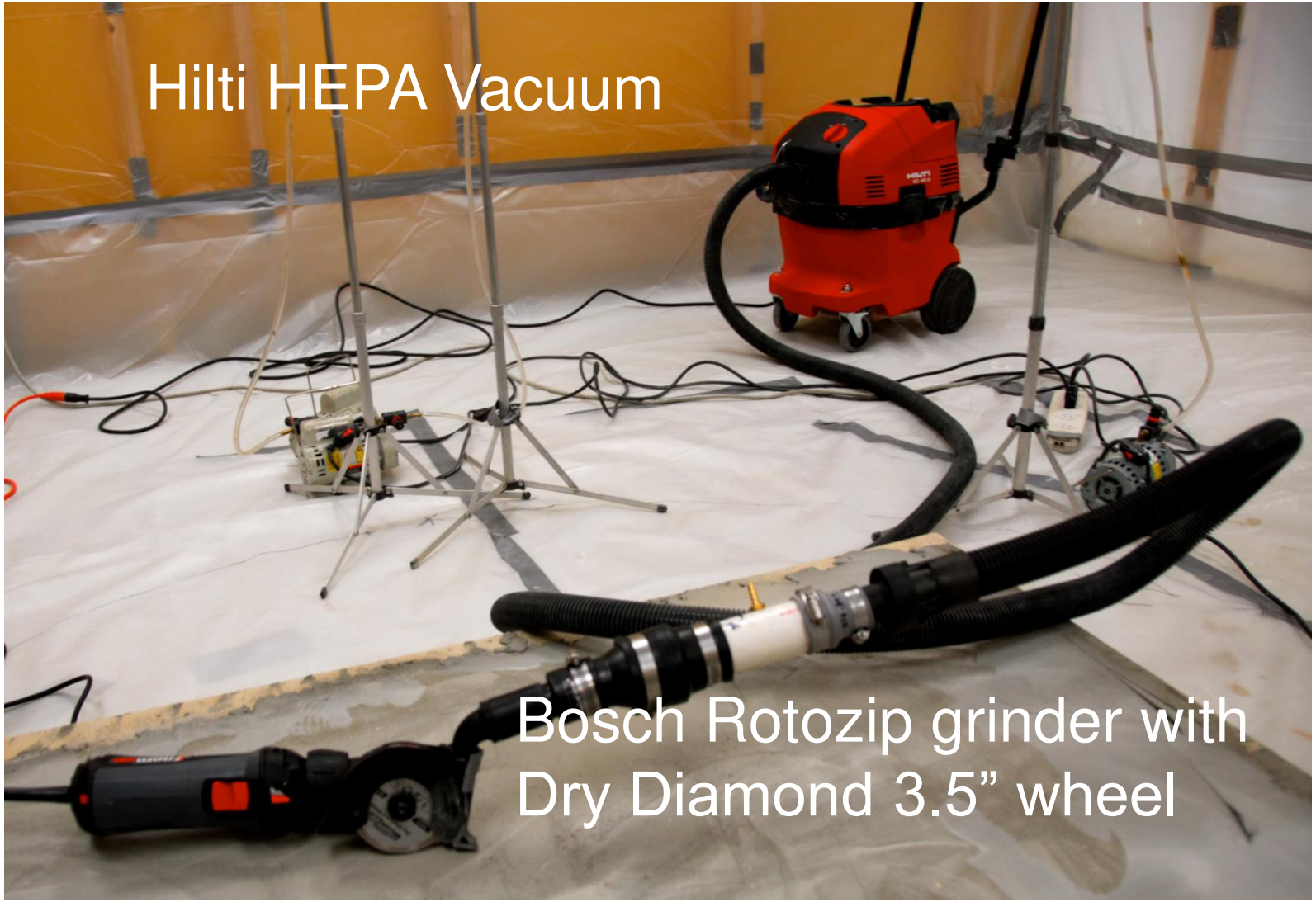
5 days later we ground the dry surface using this equipment




We ground with and without
ventilation on both products

Mean particle counts during mixing were significantly higher with the Sakrete than the nano-enabled Elephant Armor for larger particles

	Control Mortar		Experimental Mortar		
Particle Size (µm)	Mean ± SD (p/cubic ft)	95% CI (p/cubic ft)	Mean ± SD (p/cubic ft)	95% CI (p/cubic ft)	T-Test P-Value
0.3 – 0.5	142,900 ± 47,218	125,580 – 160,219	134,190 ± 36,440	120824 – 147557	0.42
0.5 – 1	482,270 ± 140165	430,857 – 533,683	371,593 ± 133,825	322,505 – 420,680	0.0023*
1 – 3	1,131,537 ± 356383	1,000,815 – 1,262,259	756,191 ± 268,620	657,660 – 854,721	<.0001
3 – 5	586,027 ± 202,038	511918 – 660,135	291,547 ± 104,588	253,184 – 329,911	<.0001
5 – 10	400,084 ± 140,288	348,625 – 451,542	170,524 ± 58,903	148,918 – 192,129	<.0001

* Statistically significant at alpha of 0.05

Median particle counts showed significant reductions with LEV for both at larger sizes

Mortar Type	Particle Size (microns)	LEV (p/cubic ft)	No LEV (p/cubic ft)	% Reduction	P-Value
Experimental	0.3 – 0.5	302,124	204,609	N/A	0.31
Control	0.3 – 0.5	341,496	177,857	N/A	0.15
Experimental	0.5 - 1	252,141	743,001	66%	0.41
Control	0.5 - 1	372,844	667,377.5	44%	0.0019
Experimental	1 - 3	198,622.5	2,737,892	93%	0.016
Control	1 - 3	361,348	2,593,298	86%	< 0.001
Experimental	3 – 5	55,390	1,343,551	96%	0.023
Control	3 – 5	121,963	1,619,919	92%	< 0.001
Experimental	5 – 10	33,479.5	1,076,389	97%	0.047
Control	5 – 10	87,534	1,727,897	95%	< 0.001
Experimental	10+	4,729.5	176,941	97%	0.099
Control	10+	13,149	353,211.5	96%	< 0.001

*** Statistically significant at alpha of 0.05**

Discussion and Future plans

Section 4

1 2 3 4

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Discussion and Future Plans

- Workers performing the tasks measured should not be overexposed to nano TiO_2 even when total dust PEL is greatly exceeded
- LEVs significantly reduce dust levels and configurations are available for many applications
- We will conduct focus groups with the trades to determine products to test and do two per year for next 5 years
- We will be disseminating results to the trades via training and the web

Resources

Section 5

1 2 3 4 5

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NIOSH, of course

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AIHA Nanotechnology Working Group

AIHA
Protecting Worker Health

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Nanotechnology Working Group

Mission

Provide AIHA members and technical committee representatives with opportunities to identify, organize, and conduct information sharing, educational activities, and community outreach in the cross-cutting area of nanotechnology safety and health.

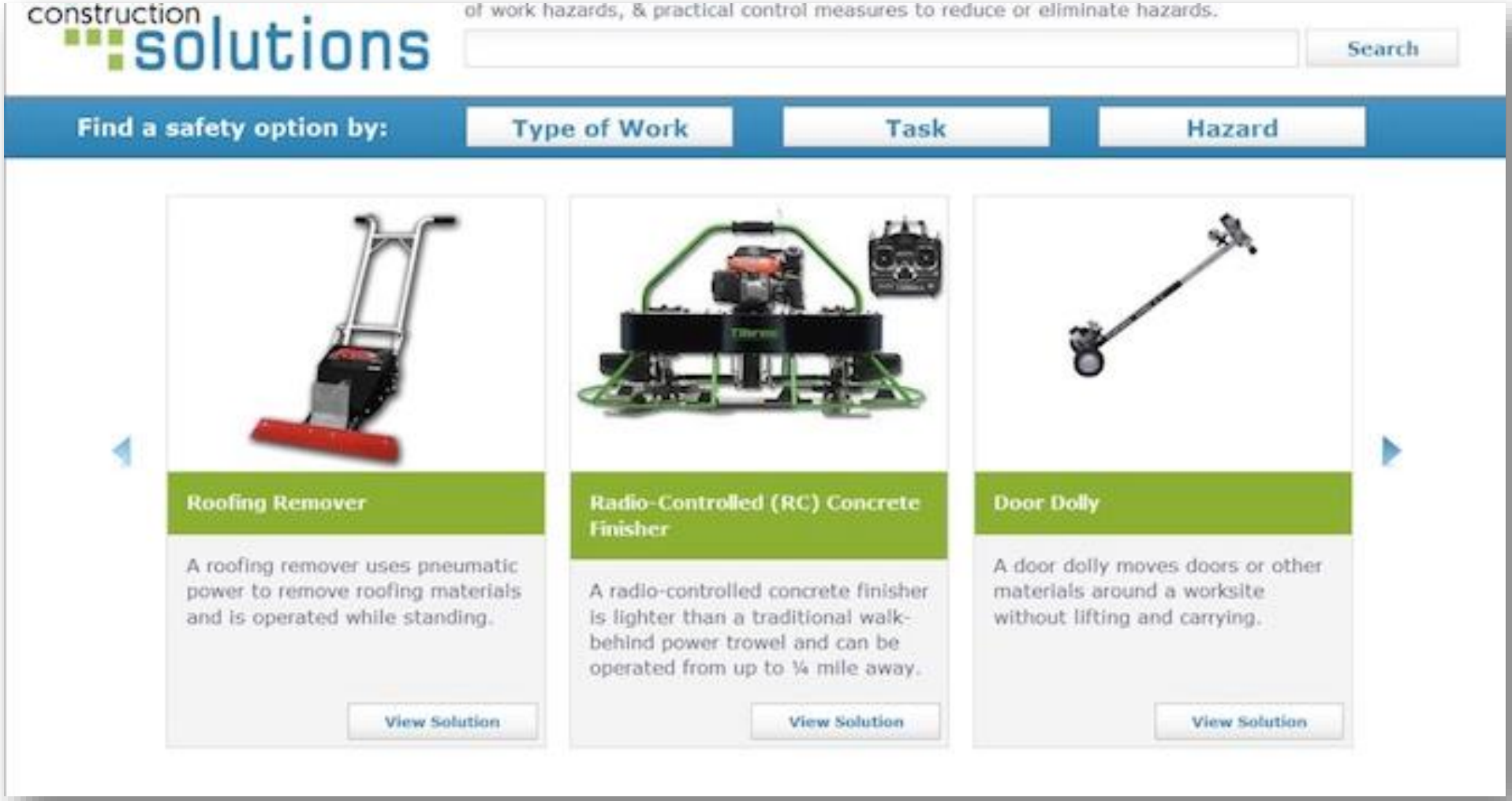
Ongoing and Upcoming Activities and Events:

- Establishing and maintaining useful content on the AIHA Nanotechnology topic page
- Education, information, authoritative guidance, and funding resources
- Links to national and international partnering organizations Information on AIHA member and technical committee needs assessments to help guide effective collaboration and progress

Fostering industrial hygiene input to the development of national and international standards

Construction Solutions

http://www.cpwrconstructionsolutions.org



Thanks! Questions?

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