



NRC-CNRC

*Institute for
Research in
Construction*

Nanotechnology for the Construction Industry: Applications, Research and the Role of Standards

Jon Makar

jon.makar@nrc-cnrc.gc.ca



National Research
Council Canada

Conseil national
de recherches Canada

Canada

Introduction



- The Construction Industry
- Developing and Applying Nanotechnology
- Research Examples

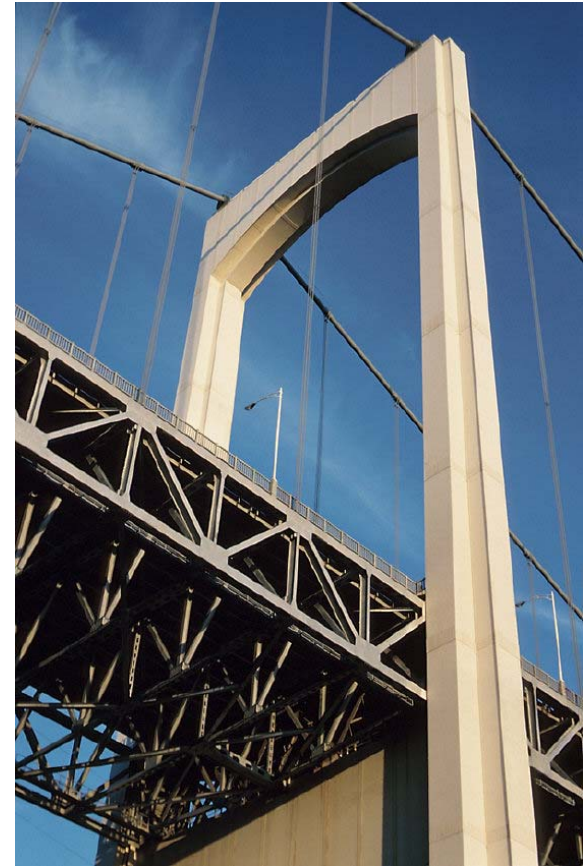
Construction Industry

- Single most important industry in almost all developed countries
- Represents 8-12% of GDP in developed countries
- Employs more than 1,000,000 people in Canada
- \$164 Bn / year in Canada
- Most companies have fewer than 6 employees



Construction Industry

- Structure as a whole very different from other large industries
- Large companies at bottom of supply chain, not at top
- Innovation hampered by industry structure



Construction Industry

- Construction companies are process innovators
- Key players for product innovation:
 - Product suppliers
 - Consulting professionals
 - Owners
- Difficult to be knowledgeable about all issues related to a project
- Most projects are unique
- Expectations different from other products – very long expected lives

Role of Codes and Standards

- Building codes are used to set minimum standard of construction
- Exact mechanism varies by country
 - NRC manages national model building code in Canada
- Codes can be an impediment to innovation
 - 2005 building code uses objectives to encourage innovators
- Codes can also be a safety net for contractors during litigation
- Individual products and specific materials are governed by standards, usually provided by national organizations
- Some countries have processes to verify performance of products (Canadian Construction Materials Centre)

Materials Issues

- Extremely diverse materials in use
- Complex needs and operating conditions
- Products are in systems, not used alone
- Products in use for long periods of time
- Human factors



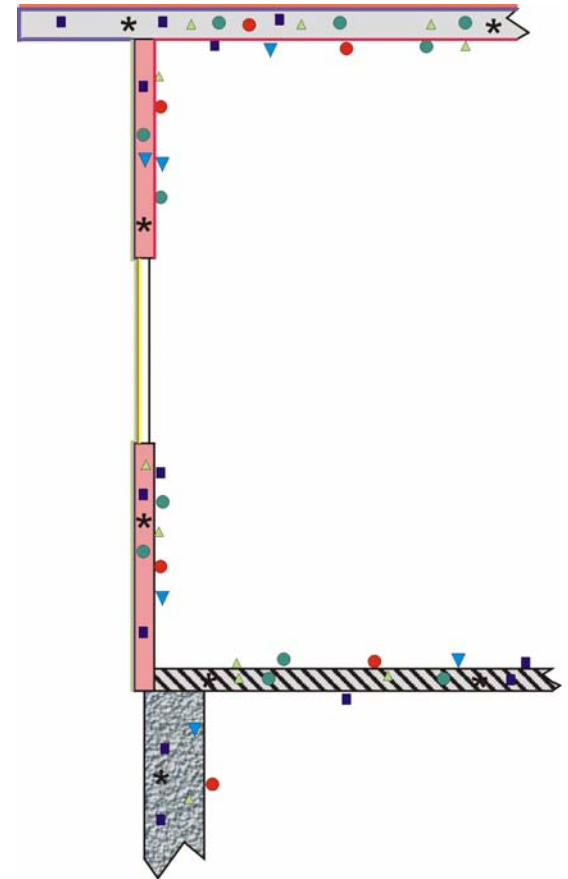
Cement and Concrete

- Concrete is the single most used construction material
- 1.5 billion tonnes of cement were produced worldwide in 1998
- In Canada alone, \$5 billion is spent annually on concrete
- 16% of construction expenditures are concrete related
- Production of cement is a major source of greenhouse gases

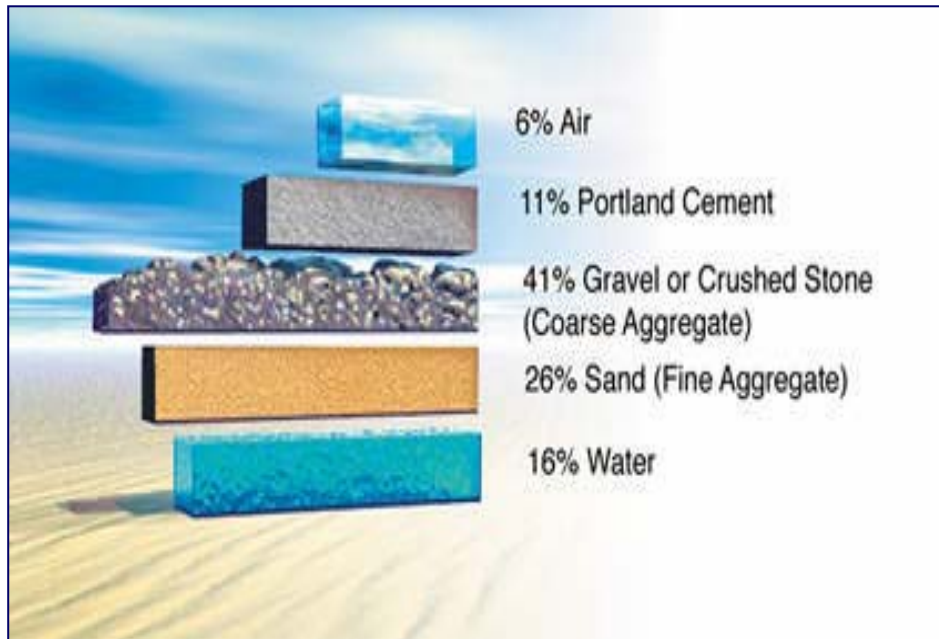


Need for Nanotechnology

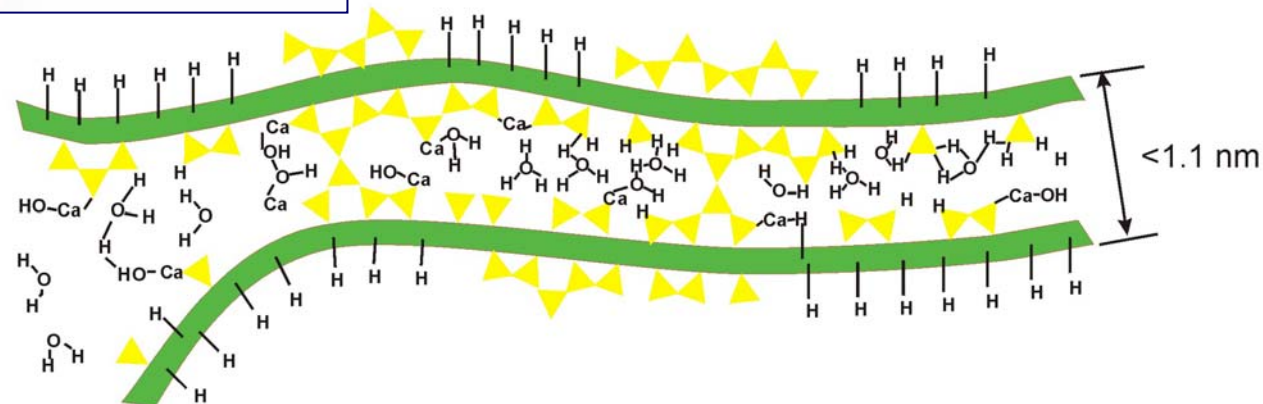
- Reduced environmental impact
- Cheaper solutions
- Significantly better performance
- Better durability
- New capabilities
- Performance of existing materials affected by nanoscale behaviour



Macro Composition – Nanoscale Structure



- Cement has a complex, nanoscale structure
- Cement pore sizes: nanometers to millimeters
- Chemical reactions produce the bulk material



State of the Art

- Construction identified as a strong candidate for nanotechnology in early studies
- Slow progress
- Some products
- Developing research interest, mainly in Europe, Canada, Far East
- Developing commercial interest, but companies unsure of benefits

Product Acceptance

- Difficulties in innovation likely enhanced
- Simpler, cheaper or more effective substitutes for existing technology will gain more rapid acceptance
- More exotic products will require greater testing and time to gain acceptance
- Product demonstrations, independent evaluations, standards are ways to build confidence
- Long term environmental performance is key for new products

Current Applications

- Corrosion resistance steels
- Window coatings to prevent dirt build up
- Lighting technology
- Anti – graffiti coatings and paints
- Insulation
- Fuel cells and photovoltaics
- Proprietary products in cement and concrete

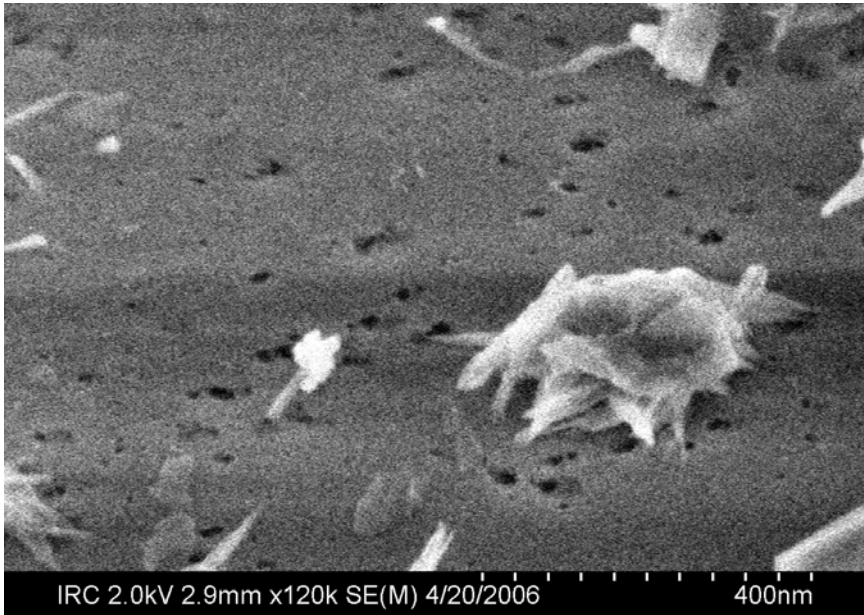
Metrology Challenges

- Rough materials
- Inhomogeneous materials
 - Multiple phases
 - Inherent composites
- Natural materials
 - high degree of variation
- Systems need to be examined
- Challenging to image and measure
 - Charging effects
 - Volatile

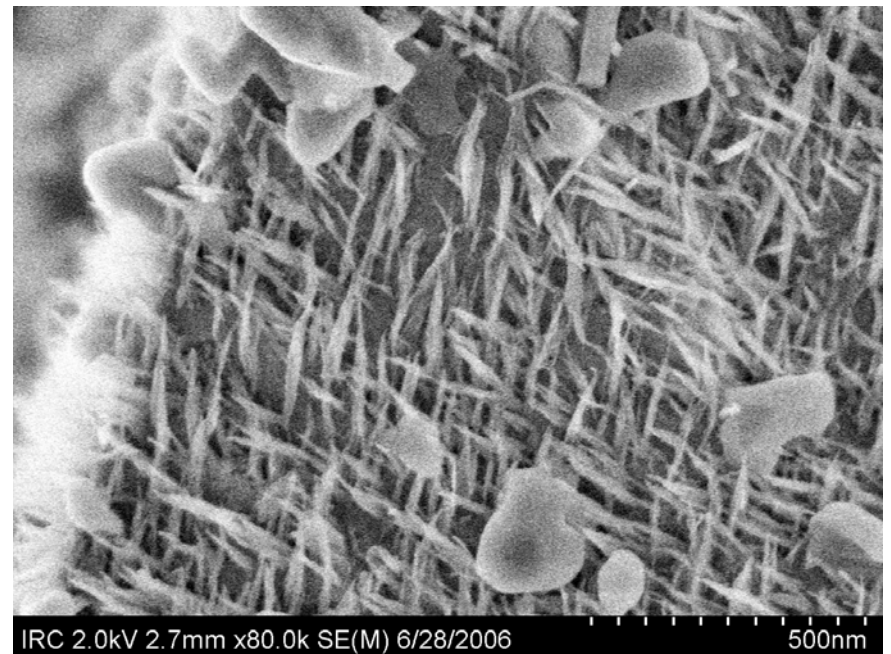
Metrology Approaches

- Traditional investigation techniques at high resolution
 - Thermal Analysis (Thermogravimetric Analysis, Conduction Calorimetry, Differential Scanning Calorimetry...)
 - X-ray Diffractometry
 - Mechanical Testing
- High resolution imaging and analysis for nanoscale work
 - Cold Field Emission Scanning Electron Microscopy
 - Atomic Force Microscopy
 - Transmission Electron Microscopy
 - Etc....

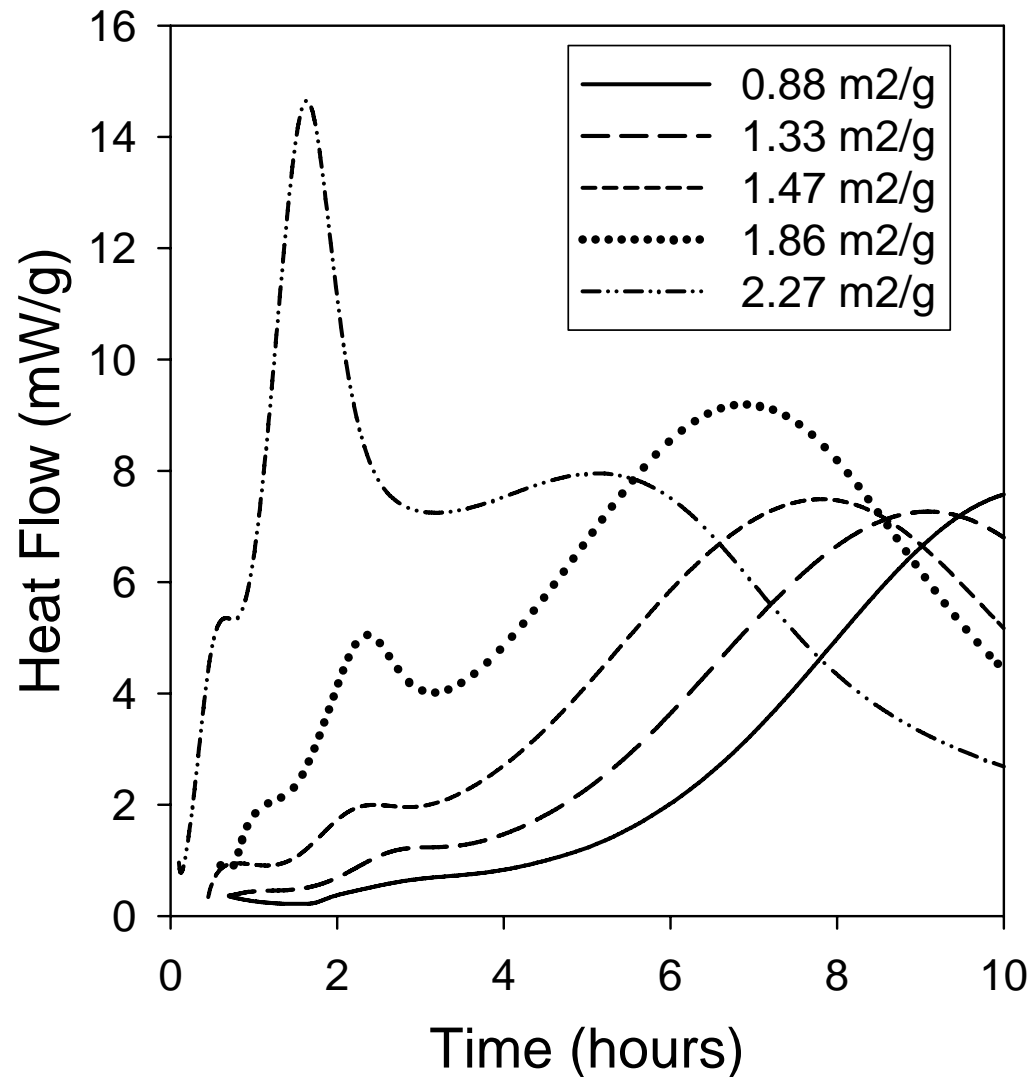
Research Examples – Cement Hydration



J. Makar, NRC



Research Examples – Cement Hydration



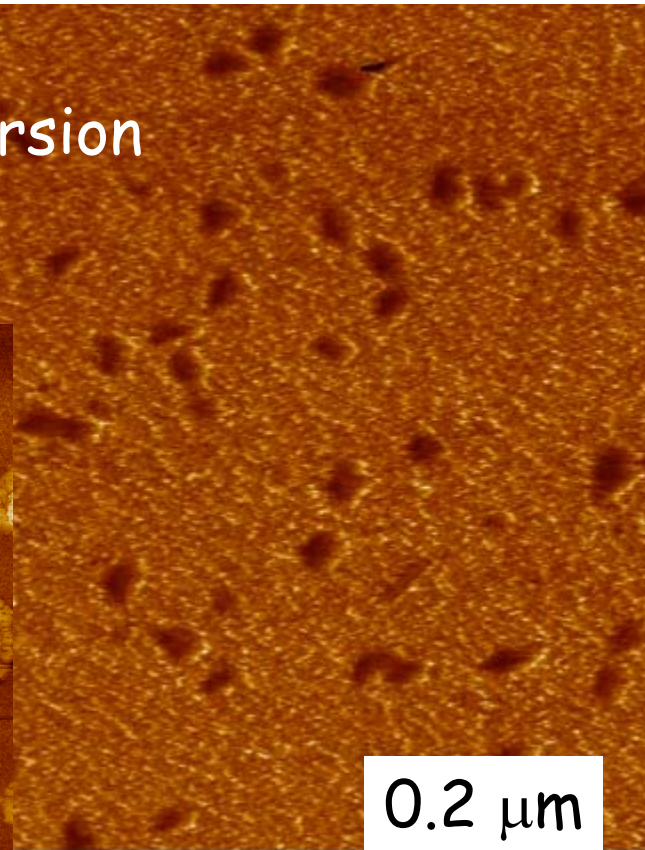
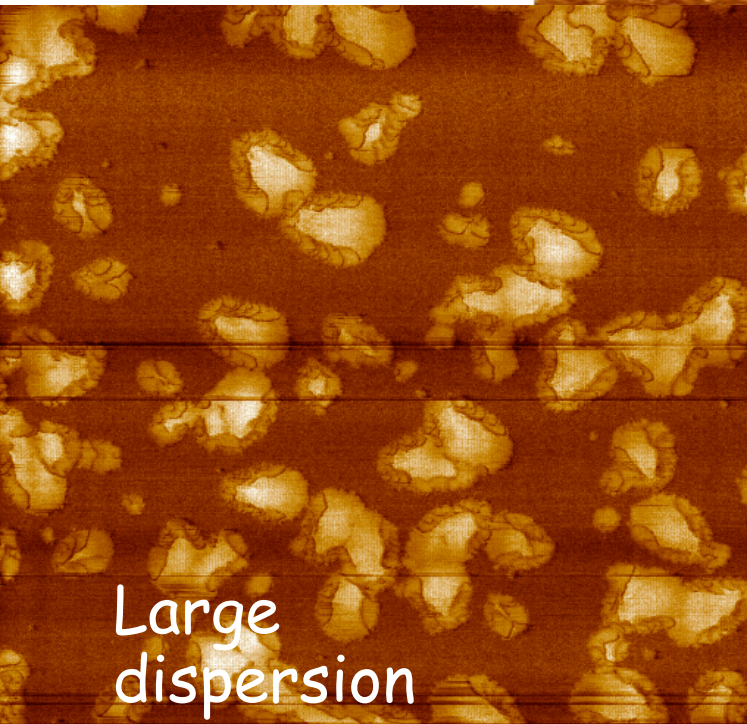
Research Examples - Bitumens for Roadways & Roofing

- Complex mixtures
 - Alkanes
 - Alkyl aromatics
 - Fused alkylated aromatics
- Three classes of bitumens are found by AFM-phase detection microscopy
 - Multi-phase systems
 - Fine dispersions
 - Large dispersions

Research Examples - Bitumens for Roadways & Roofing

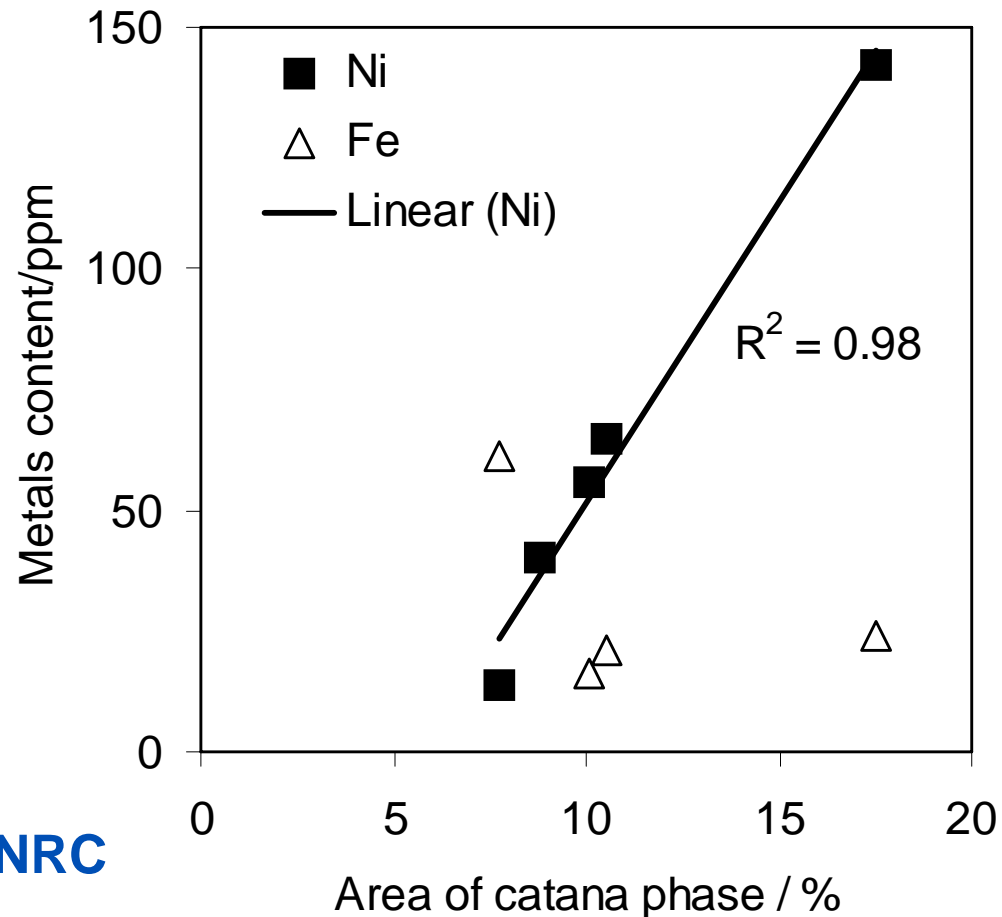
Fine
dispersion

J.F. Masson, NRC

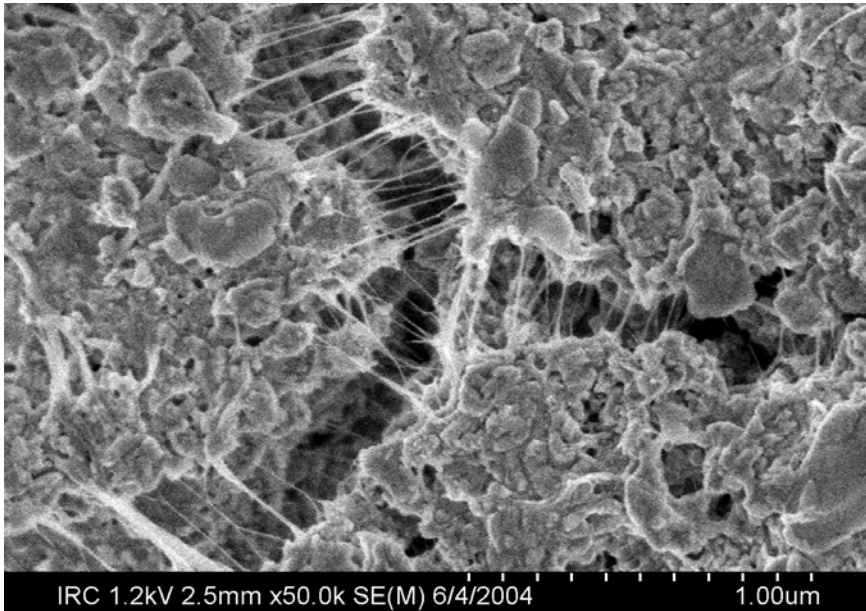


Research Examples - Bitumens for Roadways & Roofing

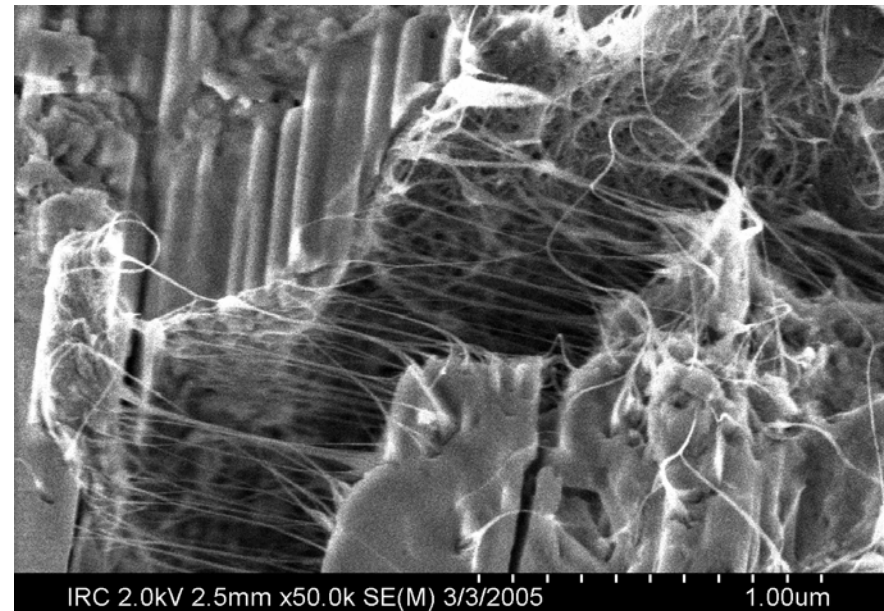
- AFM groups correlate with Bitumen stiffness and polarity
- Stiffness
 - 3,4,5 fused rings
- Polarity
 - Va and Ni Contents



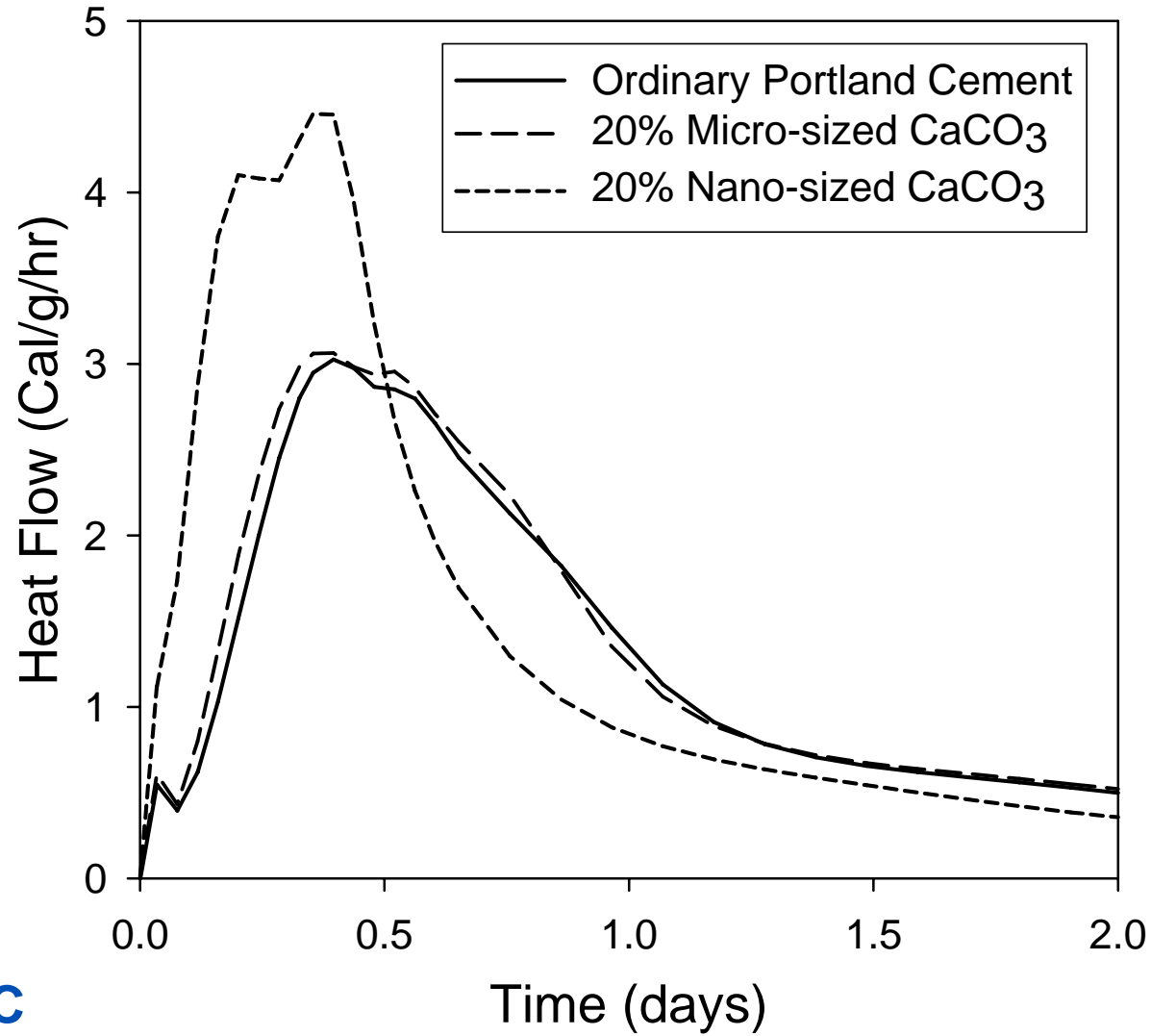
Research Examples - Nanocomposites



J. Makar, NRC



Research Examples – Process Control Through Nanoparticles

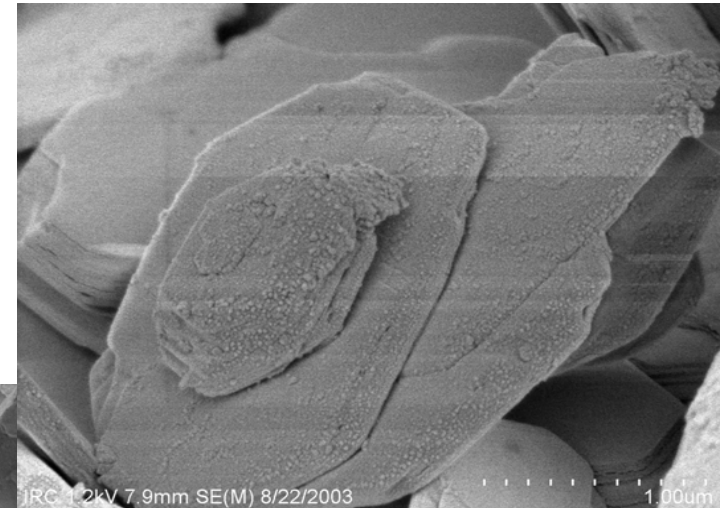
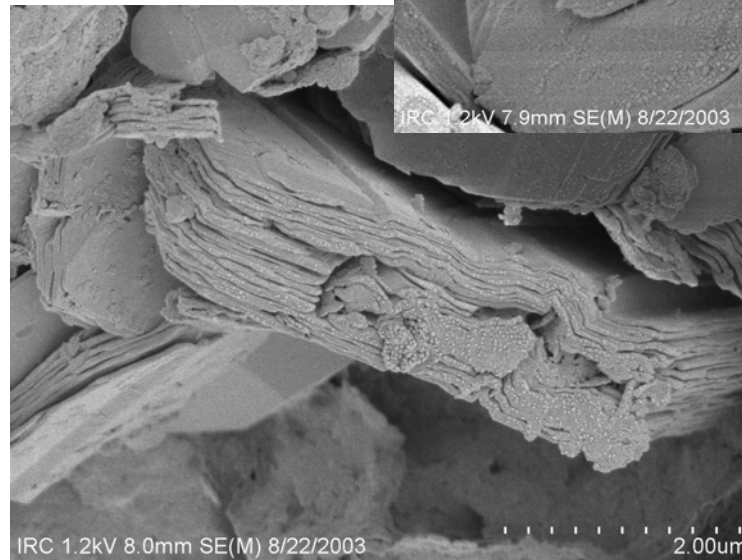


Research Examples – New Admixture Delivery Systems

- Chemical admixtures are used to modify cement hydration behaviour, change rheology, improve durability, etc...
- Admixtures added at cement plant
- May lose effectiveness by the time cement is poured

Research Examples – New Admixture Delivery Systems

- Inorganic materials modified to store admixtures between layers
- Chimie-douce technique
- Timing of release can be controlled
- Patented



L. Raki, NRC

Conclusions

- The process of introducing nanotechnology to the construction industry is more complex than in other industries
- First commercial products have been developed
- Many other research and product opportunities – fundamental and applied work to be done
- Extensive standards will need to be developed to facilitate advanced products

NRC CNRC

*Institute for
Research in
Construction*

Science
— at work for —
Canada



National Research
Council Canada

Conseil national
de recherches Canada

Canada^{🇨🇦}