Production of geopolymer foam with addition of nanoparticles

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Geopolymer Camp 2018
10/07/2018
• NAMI – Your Materials Expert

• Nanotechnology

• Foam

• Geopolymer application

• Good to know
Nano and Advanced Materials Institute Ltd.

- NAMI established in 2006 by Hong Kong government
- Focused on applied research
- Key figures:
  - HK$ 150M+ annual R&D
  - ~200 technical talents
  - >HK$ 100M equipment
  - 400+ filed patents
  - 40,000 ft² lab area
MISSION

Cultivate research **Talent**
Contribute to HK’s **Technology** advancement
Collaborate with industries for **Commercialization**

R&D MODEL

**Applied Research Eco-system**

- **Academia, Universities**
- **Applied R&D Centres**
- **Industry, Startups**

**Traditional Research, Development & Implementation Cycle**

- **Ideas**
- **Research**
- **Bench-top Prototypes**
- **Technology Development “Scale-up”**
- **Manufacturing**
- **Refinement**
Nano and Advanced Materials Institute Ltd.

Energy

Healthcare

Electronics

Environment

Construction

NAMI Core Technology Platforms

Energy
- Power Battery
- Metal & Metal Oxide Devices
- Transparent Conductive Film
- Polymer & Ceramic Composite

Healthcare
- Healthcare Nanofiber
- Functional Plastics
- Restorable Neutralizer
- Advanced Delivery Biomaterials
- Quantum Dot for detection

Electronics
- Flexible Battery
- Flexible Supercapacitor
- Electrically Driven QD
- Flexible Lighting
- Nanofiber for E-textile

Environment
- Nano Coating
- NAMI Bubble
- Waste Recycling
- Water & Air Quality
- Environmental Technology Material

Construction
- Super Concrete
- Capsule Technology
- Eco Building Materials
- Waterproof Coating
History of Nanotechnology

Lycurgus cup 4th Century
British Museum, London

Gold Colloid, Faraday, 1857
Royal Institute of Science, London

Richard Feynman, “There’s Plenty of Room at the Bottom” American Physical Society meeting at Caltech, 1959
Key Concepts

- 1 mm
  - 1,000,000 nm
  - 6 mm²
  - 6x10^{12} nm²

- 100 nm
  - Surface area of one 100 nm cube
    = 60,000 nm²
  - 60,000 mm²
  - 0.06 m²

1 mm particle is divided into 1,000,000,000,000 cubes.
Key Concepts
Key Concepts
Nanoparticles in Geopolymer

- Strength
- Density
- Water resistance
- Thermal conductivity
- Electrical conductivity
- Load transfer
- Retarding effect
- Photocatalytic
- Antibacterial

✓ nano-SiO$_2$
✓ nano-Al$_2$O$_3$
✓ nano-clay
✓ Carbon nanotube
✓ Graphene oxide
✓ Carbon nanotube
✓ Graphene oxide
✓ TiO$_2$
✓ nano-Ag
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Motivation

Energy-saving construction

Special applications

Civil Engineering

Environmental protection

FOAM

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Challenge

Foam + Cement paste = Commercial Foam

Foam

Cement paste

Ultra-stable Foam

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Solution

Market available product

NAMI’s NANOFOAM

Large pore size, >500 um

450 kg/m³ 0.4 MPa

450 kg/m³ 2.5 MPa

Small pore size, 65 um

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Modified nanomaterials assemble at the pore surface

SEM, TEM and TOF-SIMS analysis

Self-assembly of Nanoparticles

Nanoparticles are part of cement matrix after hydration

Solution
# Business case

## Studio City – Macau approximate indoor wall area 140,000 m²

<table>
<thead>
<tr>
<th>Material</th>
<th>Density ($\text{kg/m}^3$)</th>
<th>Compressive strength (MPa)</th>
<th>Water resistance</th>
<th>Thermal conductivity ($\text{W/mK}$)</th>
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</thead>
<tbody>
<tr>
<td>Geopolymer</td>
<td>700</td>
<td>8</td>
<td>Yes</td>
<td>0.2</td>
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<tr>
<td>Gypsum</td>
<td>900</td>
<td>5–8</td>
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<td>0.14</td>
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<tr>
<td>Nanoparticle foam</td>
<td>800</td>
<td>10</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Studio City – Macau</td>
<td></td>
<td></td>
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</tbody>
</table>
Foams in Geopolymer

- $\text{H}_2\text{O}_2$
- Al-powder
- Traditional foaming agent
- NAMI’s alkaline resistant NANOFOAM
Scaling up tests

Product properties:
- Easy to cast, spread diameter 160-180 mm
- Smooth surface
- Density 700 kg/m³, 8 MPa CS
- Density 900 kg/m³, 17 MPa CS.

Foaming agent mixing
Raw materials mixing
Foam pour into paste
Foam paste mixing
Casting
Foam geopolymer wall block
Testing Procedures: BS EN 1364

Fire resistance test

Thermal couples on unexposed surface

Block during test

Video monitoring

Unexposed surface after test

Exposed surface after test

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Performance

Initial Temp.: 23.0 (deg C)
Max. Temp. rise limit
Average Temp. rise limit

Temperature rise (deg C)
Time/min

Temperature (deg C)

Average Temp. rise limit

3d compressive strength
28d compressive strength

Effect of nanoparticle foam in 1300 kg/m³ foam geopolymer

1100 kg/m³ foam geopolymer wall block fire test according to BS EN 1364. Specimen size 340mm*190mm*100mm

Before
After

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Conclusions

- Foam geopolymer material has been prepared by using nanoparticle stabilized physical foaming agent.

- Developed material has been applied in manufacturing of indoor partition wall blocks with density of 600-1100 kg/m³.

- Scaling up, mechanical and fire performance has been tested in NAMI.
Working with Nanomaterials

- Quality of bulk materials
- Dispersion methods
- Surface charge, pH and surfactants