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ADVANCED MATERIALS

CENTER FOR ADVANCED CONSTRUCTION MATERIALS

UNIVERSITY OF TEXAS ARLINGTON

A new scalable method for the dispersion of carbon nanotube – alumina hybrid nano-materials in concrete : Effect on mechanical properties, electrical conductivity and strain sensing ability

Ricardo Prada Silvy [a*]	David J. Arthur [a],	Panagiotis A. Danoglidis [b],	Maria S. Konsta-Gdoutos [b]
rprada@chasmtek.com	darthur@chasmtek.com	panagiotis.danoglidis@uta.edu	Maria.konsta@uta.edu

a Chasm Advanced Materials, 2501 Technology Place, Norman Oklahoma 73072

b Center of Advanced Construction Materials (CACM), The University of Texas, Engineering Lab Building 501 W. 1st ST, Arlington, TX 76010

* Presenting Author

Creating innovative product platforms for a **SAFER, MORE CONNECTED** *and* **SUSTAINABLE** *world.*

Our mission is to develop and manufacture advanced carbon nano materials to create a safer, more connected and sustainable world.

CHASM PRODUCT PLATFORMS

NTeC®

Reinforcing Additives
for sustainable concrete

Conductive Additives
for better Li-ion batteries

AgeNT®

Transparent Heaters
for reliable ADAS sensors

Transparent Antennas
for 5G, IoT and beyond

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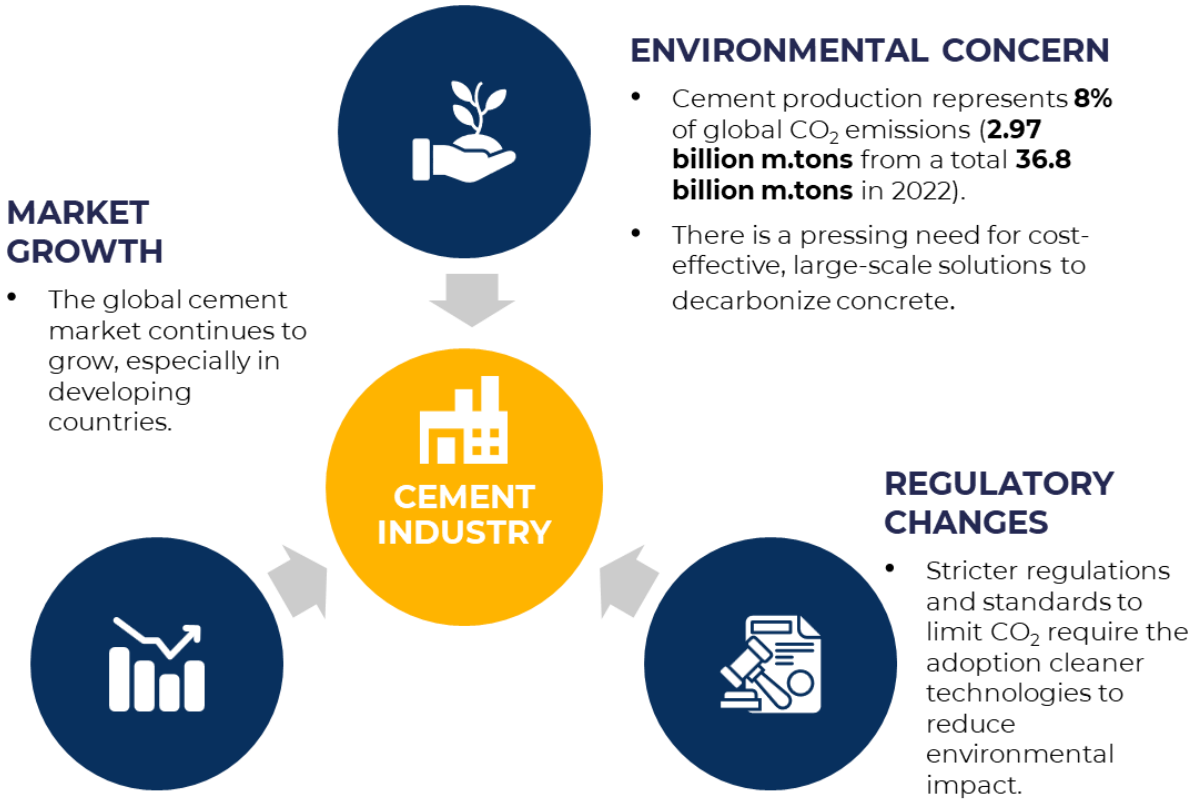
Current Scenario of the Cement Industry

WORLD CEMENT INDUSTRY IS ENCOUNTERING DIFFICULTIES AND EXPERIENCING SIGNIFICANT TRANSFORMATIONS



ENVIRONMENTAL CONCERN

- Cement production represents **8%** of global CO_2 emissions (**2.97 billion m.tons** from a total **36.8 billion m.tons** in 2022).
- There is a pressing need for cost-effective, large-scale solutions to decarbonize concrete.

MARKET GROWTH

- The global cement market continues to grow, especially in developing countries.

REGULATORY CHANGES

- Stricter regulations and standards to limit CO_2 require the adoption cleaner technologies to reduce environmental impact.

TECHNOLOGICAL ADVANCEMENT

- Creating eco-friendly cement production.
- Carbon capture and storage (CCS) more efficient kilns.
- Convert CO_2 into useful products, such as building materials or chemicals, to offset emissions.
- Energy-efficient technologies and practices.
- Capturing and utilizing waste heat from cement kilns for electricity generation or other industrial processes.
- Incorporating renewable energy sources, such as solar and wind power.

DIGITALIZATION

- Adopting digital technologies for process optimization and automation to enhance operational efficiency and reduce costs.
- Utilizing advanced process control systems leading to lower energy consumption, reduced emissions, and minimizing potential environmental impact.

ALTERNATIVE MATERIALS

- Use of alternative materials (calcined clay, limestone, fly ash, slag, and pozzolans in combination with nanomaterials) which can partially replace traditional cement in concrete production.

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Carbon Nanotubes as Alternative Materials for Partially Replace Cement

Improved mechanical properties
By making the resulting concrete stronger.

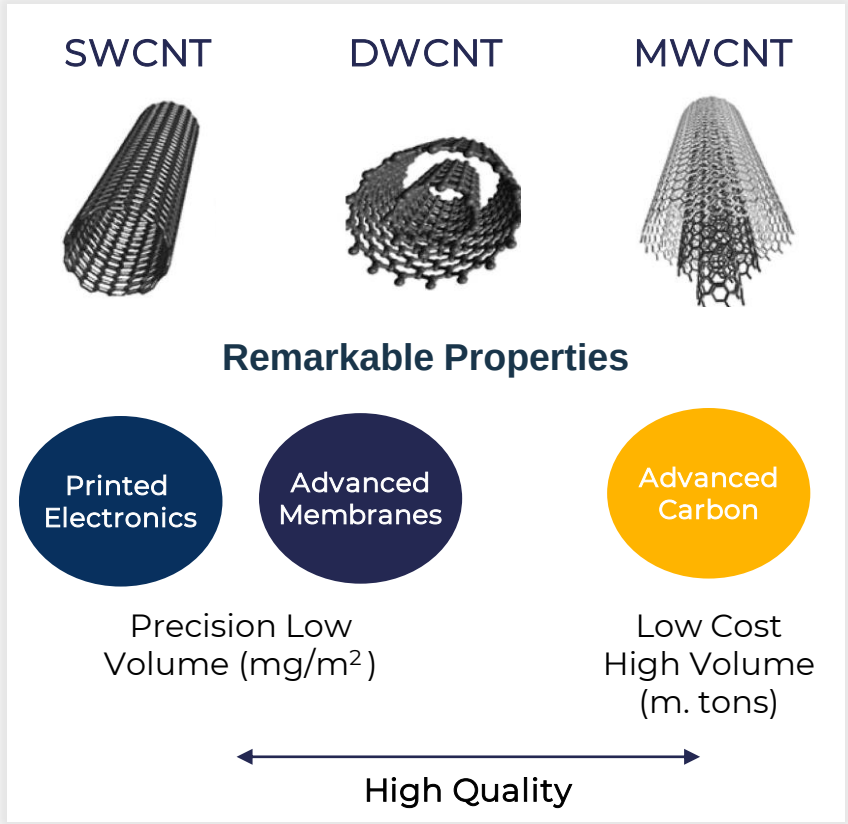
Enhanced Durability
Indicating that the concrete porosity reduced and pore diameters diminished as a consequence of the inclusion of CNTs.

Carbon Nanotubes Benefits in Cement

Enhanced electrical conductivity and piezo-electric response
Applications-self-heating pavements to prevent ice formation, or for embedding sensors in concrete structures (SMART CONCRETE).

High thermal conductivity
It is beneficial for applications where heat dissipation or thermal insulation is important, such as in the construction of buildings with energy-efficient designs.

- Challenges associated with the dispersion of CNTs in cement.
  Makes concrete more viscous, less workable by reducing flowability.
- Production cost considerations.
- Concerns related to the environmental and health impacts of nanomaterials handling.



Research is ongoing to address these issues at CHASM Advanced Materials and at the Center of Advanced Construction Materials.

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Methods Used for Dispersing Carbon Nanotubes in Cement

Mechanical Mixing

(Simplest method and involves mixing CNTs directly with the dry cement or concrete ingredients during the batching process. Achieving uniform dispersion can be challenging, and CNT agglomeration may occur).

CHASM's Mixing

(Achieve better dispersion by applying strong mechanical forces to break apart CNT agglomerates effective for improving dispersion in cementitious materials).

Ultra-sonication

(Effective in achieving good dispersion but requires careful control of sonication time and power to prevent damaging the CNTs).

Surfactant assisted dispersions

(Improve the dispersion of CNTs in water or other liquid media preventing agglomeration).

Functionalization

(Enhance cement compatibility,
disperse more easily in water or other liquids).

Polymers Coating

(Prevent CNT agglomeration).

Multi steps mixing

(Use of high shear and then Ultra-sonication).

- Proper CNT dispersion in cement is crucial for achieving desired electro-mechanical property improvements an piezo-electric response.
- The dispersion method choice may depend on factors such as CNT type and morphology properties, cement material, and application.
- The dispersion method must be both safe and commercially scalable.

Powder Suspensions

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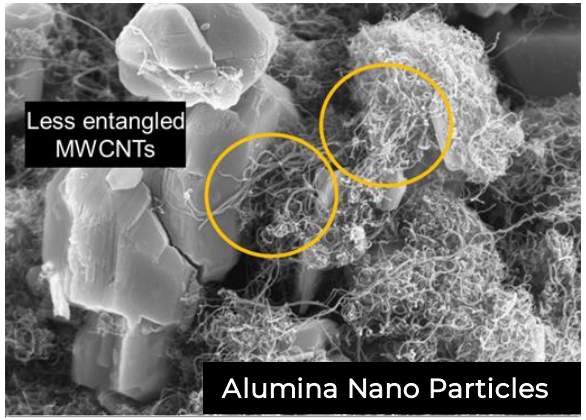
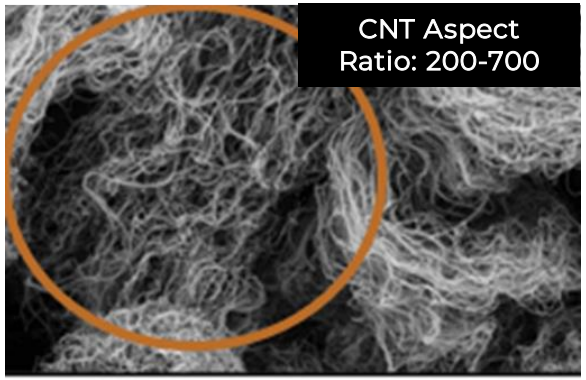
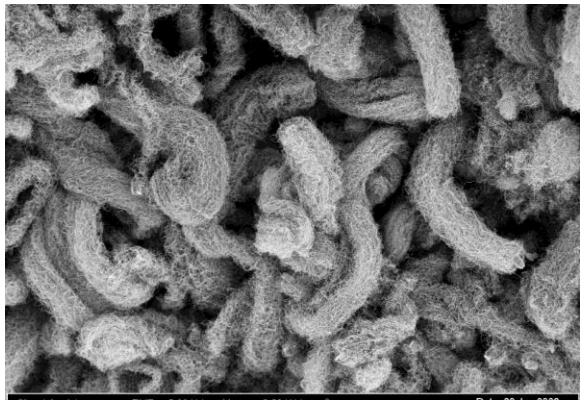
CHASM Carbon Nanotubes – Alumina Nano Hybrid Material for Cement Applications

Only 1 kg of CNT per 1 MT of Cement

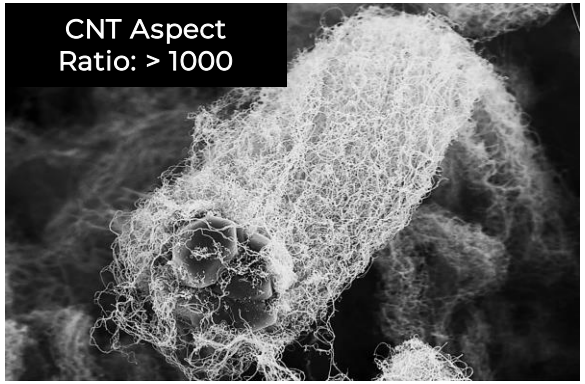
NTeC-C Mesh Morphology







NTeC-C Bundle Morphology



Bundle
L ≥ 10 µm
D: 1-2 µm
Tubes
D: 10+/- 2 nm

NTeC stands for Nano Tubes enhanced Cement

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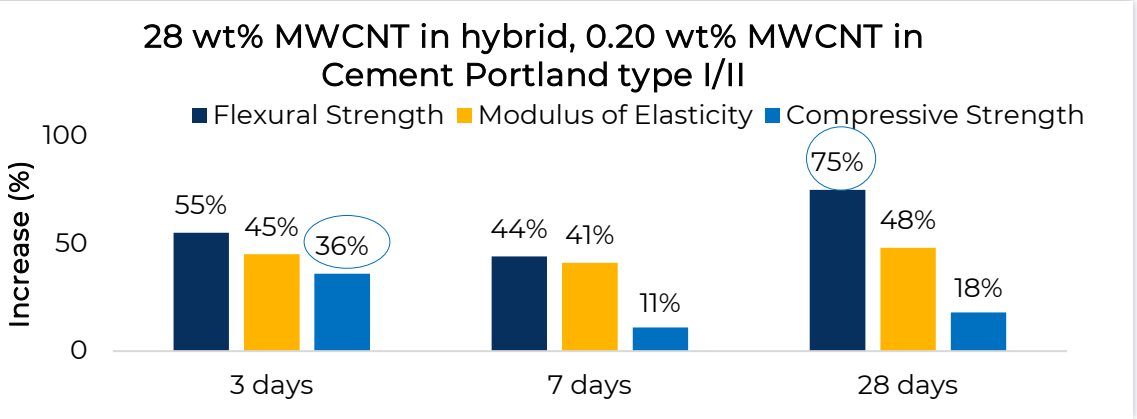
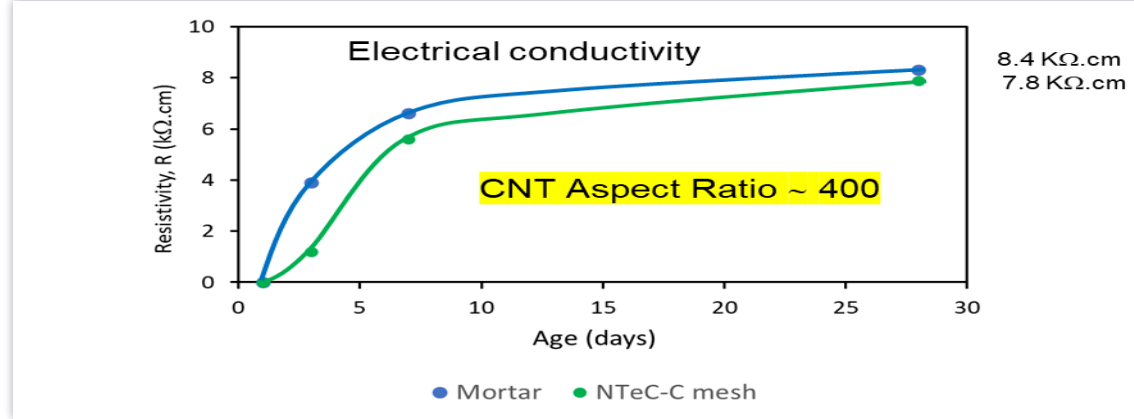
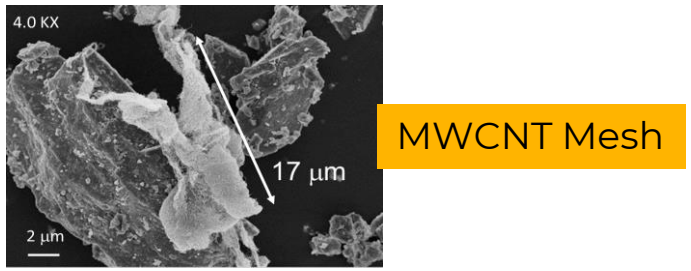
CHASM Carbon Nanotubes – Alumina Nano Hybrid Material for Cement Applications

Chasm Mixing Process - NTeC-C Mesh Morphology







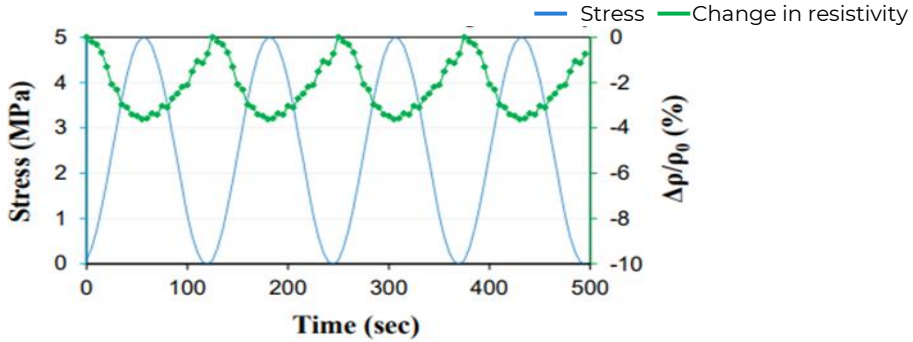
MWCNT Mesh

SEM image of CNTs deposited on Cement

OPC- I 0.15% MWCNT

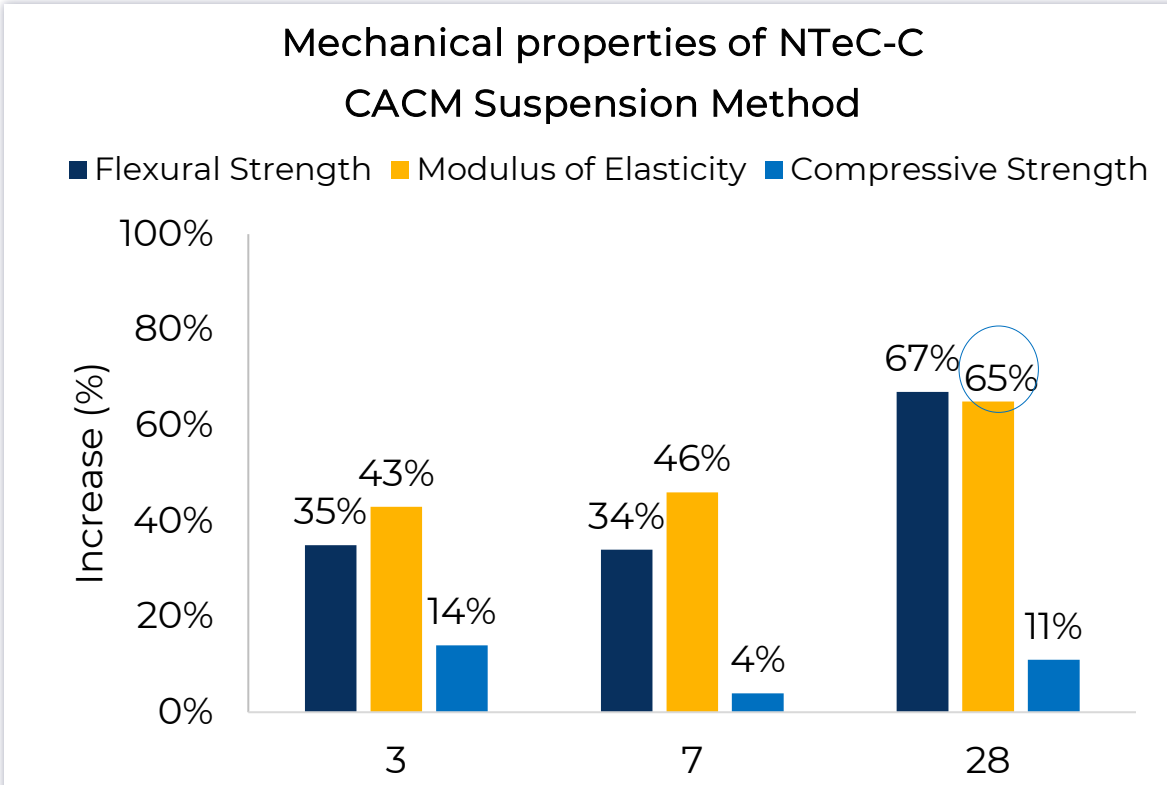
$\Delta\rho/\rho o$=3.6%

Piezo-electric response

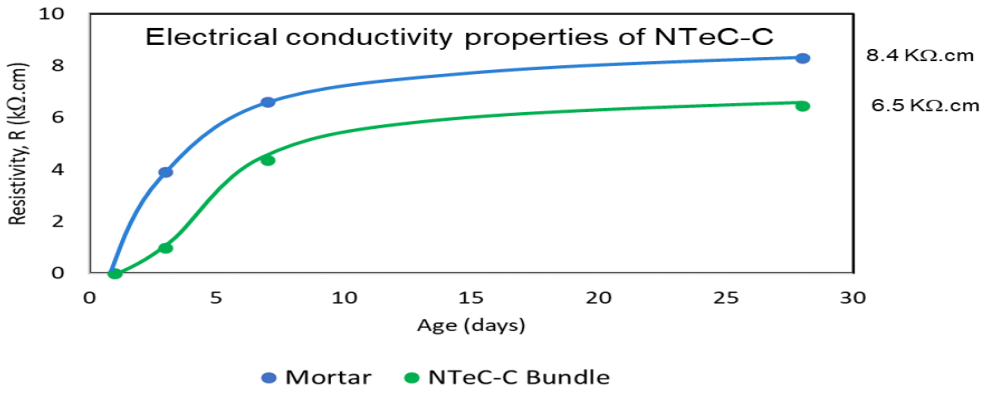


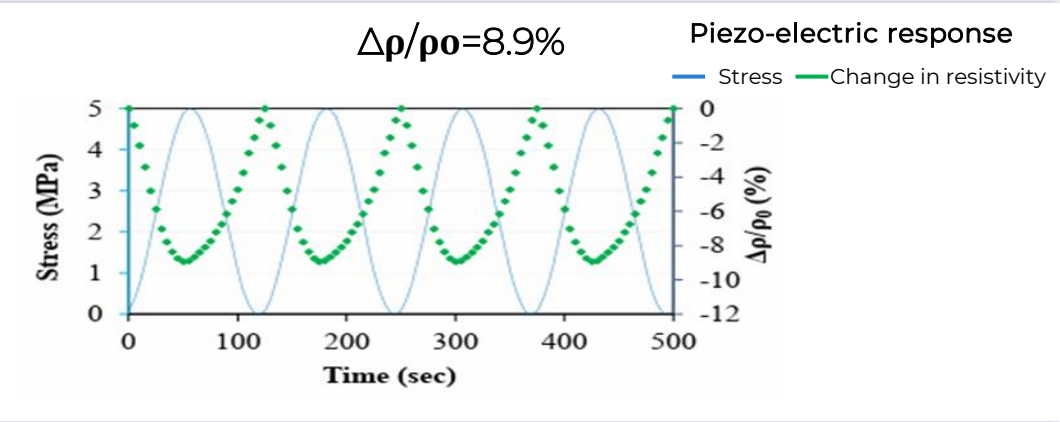
CHASM Carbon Nanotubes – Alumina Nano Hybrid Material for Cement Applications

CHASM Ultra-Sonication Dispersion Method- NTeC-C Bundle Morphology



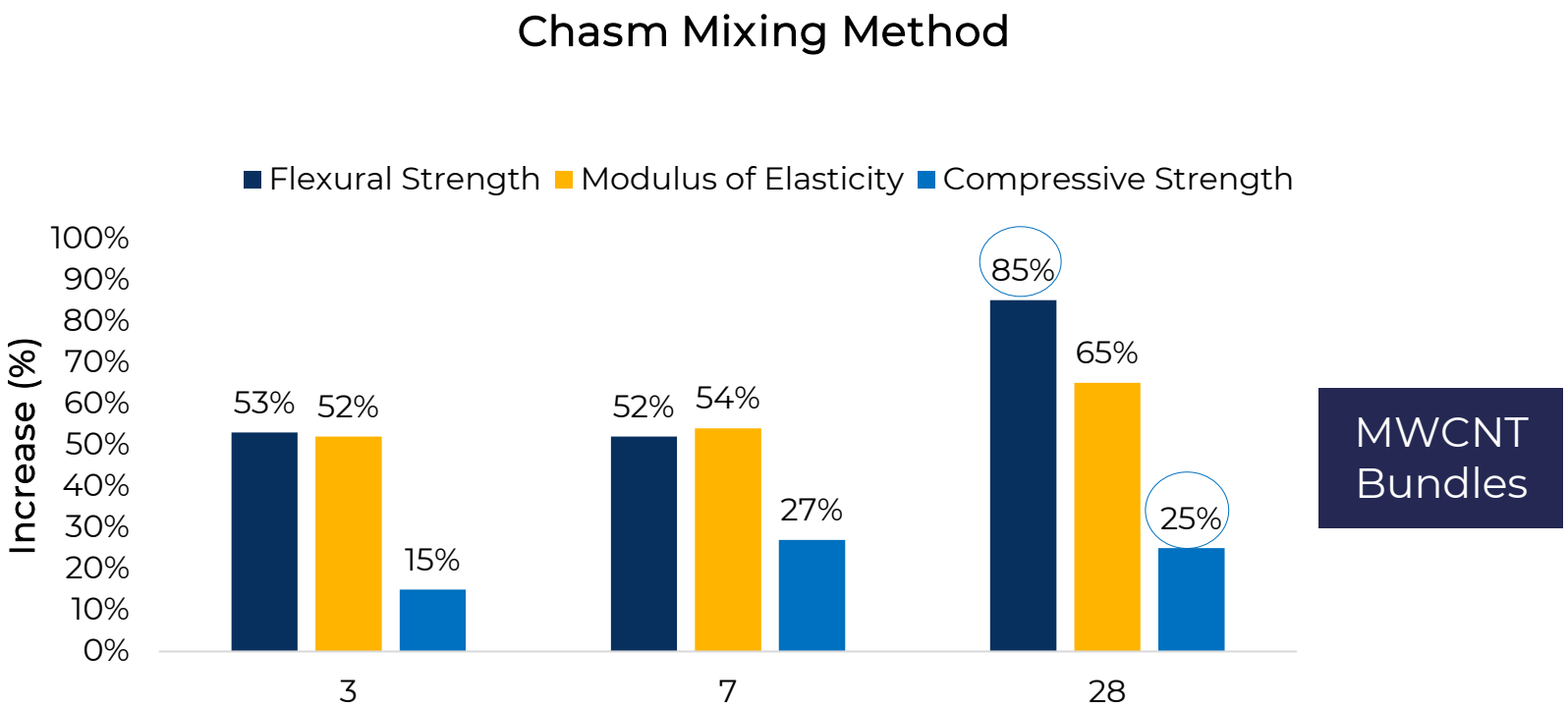
0.10 wt% MWCNT on Cement OPC-I, 60% MWCNT in NTeC-C



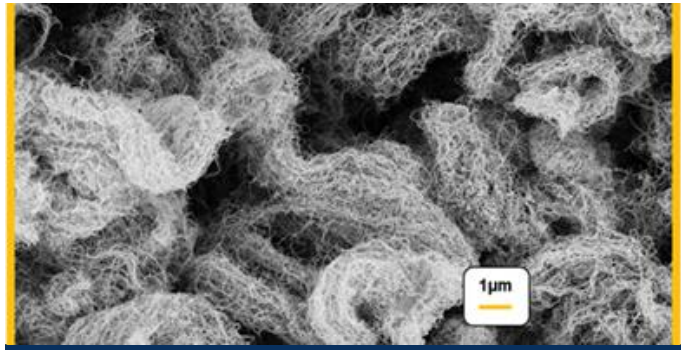


CHASM Carbon Nanotubes – Alumina Nano Hybrid Material for Cement Applications

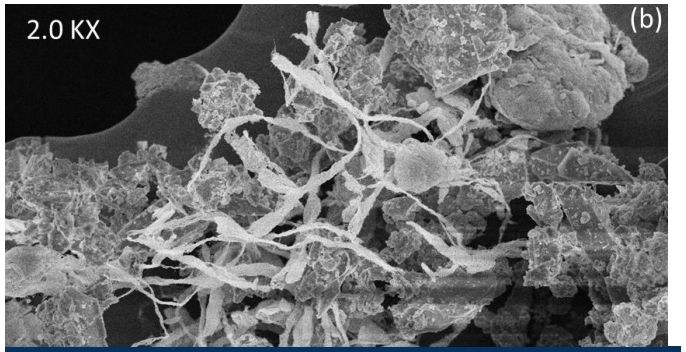
Improved Chasm's Mixing Method – NTeC-C Bundle Morphology



MWCNT Bundles



SEM image of "as produced" CNTs



SEM image of CNTs deposited on Cement

Electrical conductivity and Piezo electric response analysis are in progress

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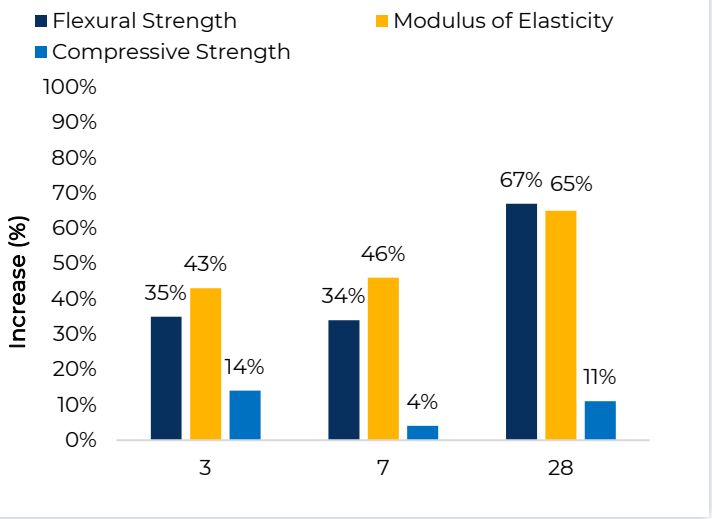
0.20 % MWCNT on Cement Portland I/II, 72 % MWCNT in NTeC-C MWCNT Bundle Morphology

CHASM Carbon Nanotubes – Alumina Nano Hybrid Material for Cement Applications

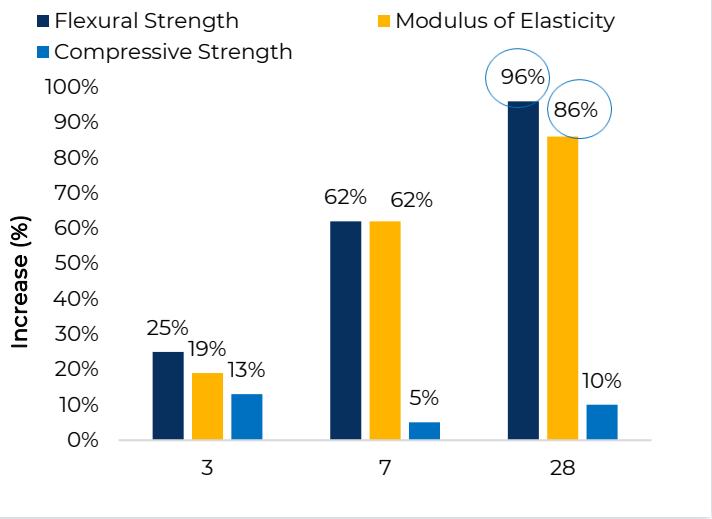
MECHANICAL PROPERTIES USING DIFFERENT DISPERSING NTEC-C METHODS

CACM Suspension Method



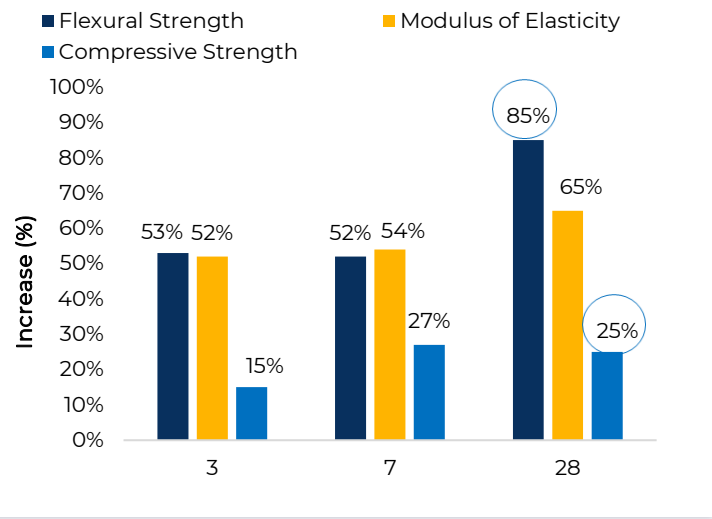
0.10 % MWCNT on Cement OPC-I,
60 % MWCNT in NTeC-C
MWCNT Bundle

Multi-Step - Suspension Method



0.10 % MWCNT on Cement OPC-I,
68 % MWCNT in NTeC-C
MWCNT Bundle

Improved Chasm Mixing Method



0.20 % MWCNT on Cement Portland I/II,
72 % MWCNT in NTeC-C
MWCNT Bundle

Commercially Scalable Method

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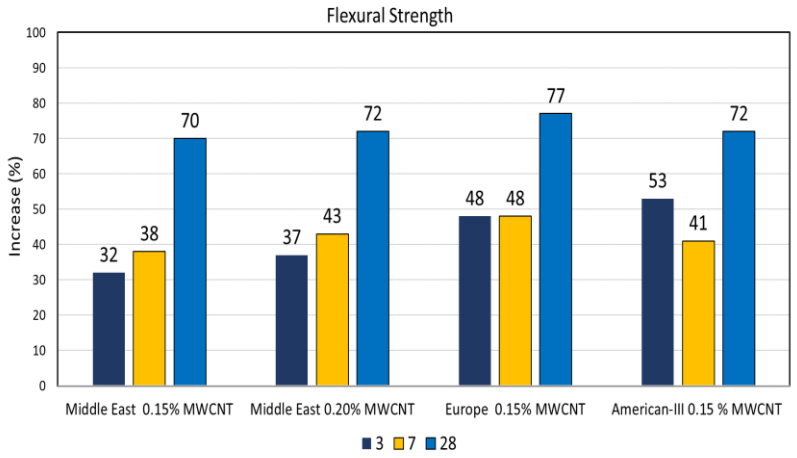
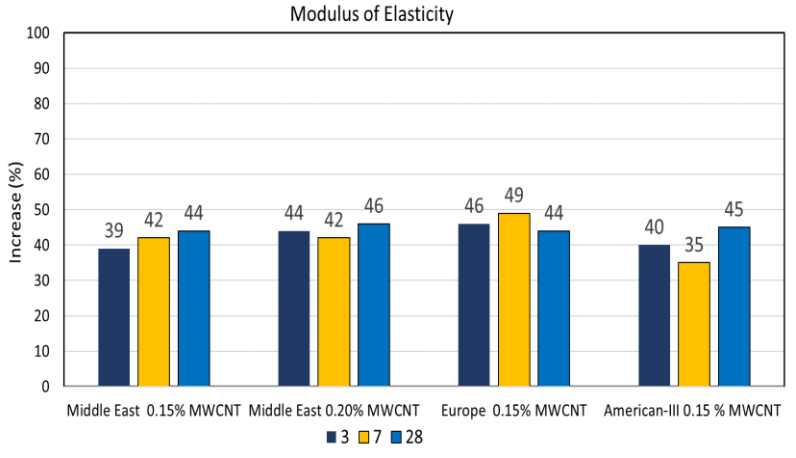
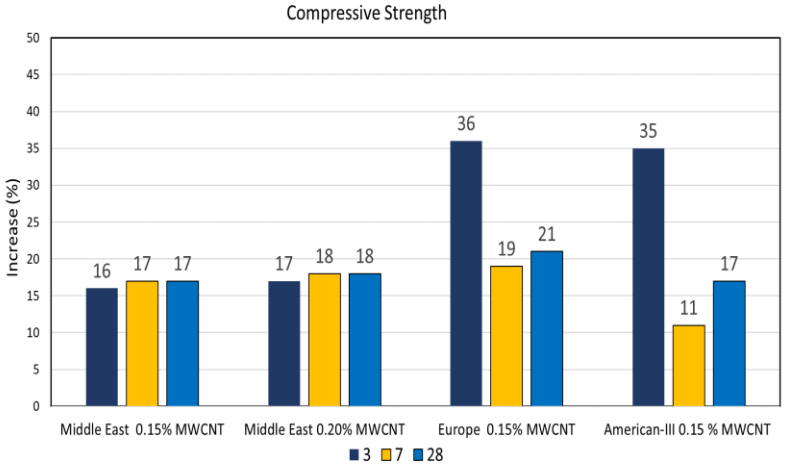
Proof of Concept Using Different Commercial Cements

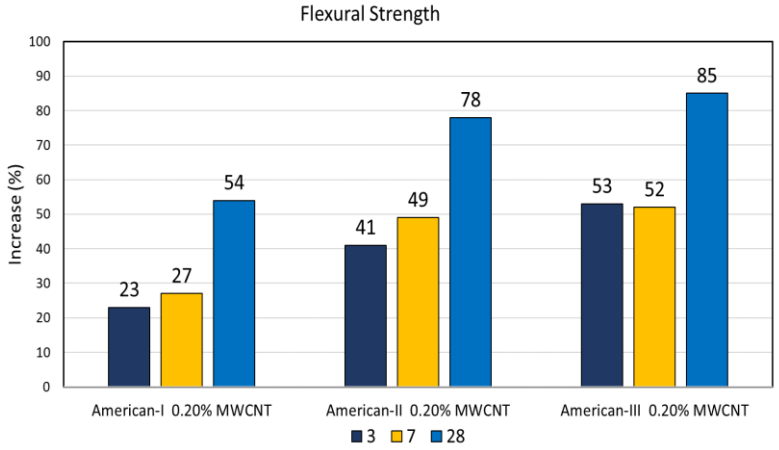
NTeC-C Mesh Morphology

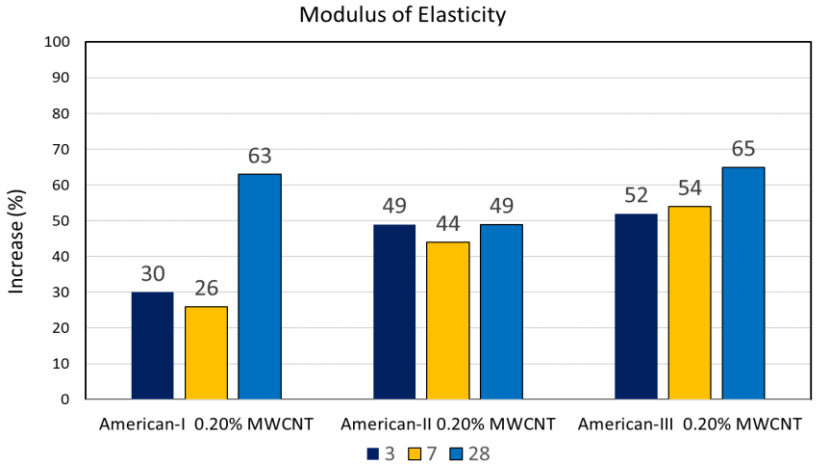


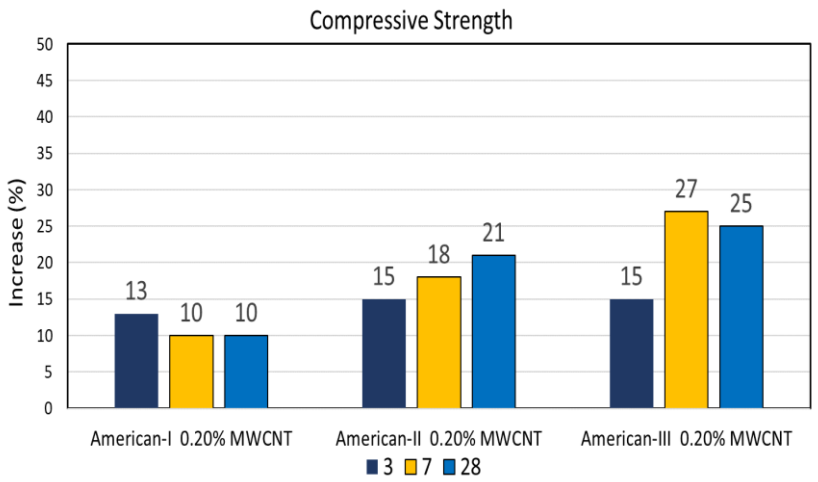




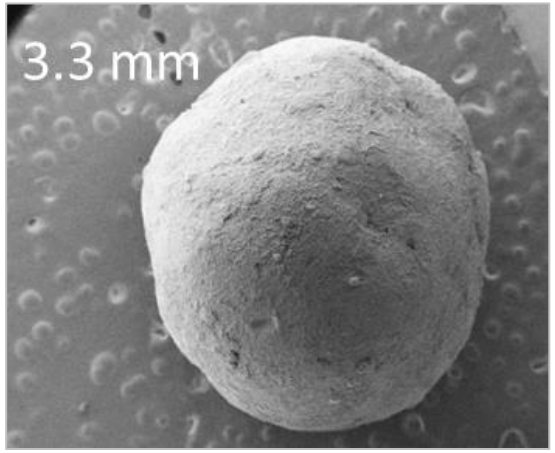
NTeC-C Bundle Morphology







Easy and Self Integration of NTeC-C on Cement Using CHASM Dispersing Method



NTeC-C Synthesis

NTeC-C Granulation

Ready Mix Producer

Precast Producer

Cement Plant

Deposition on Cement

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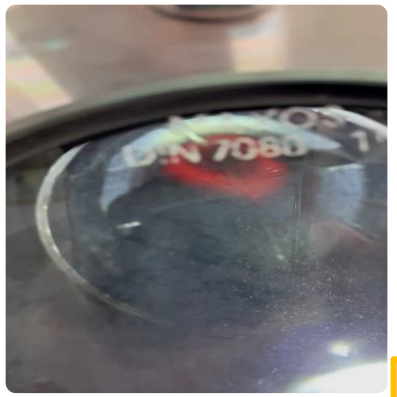
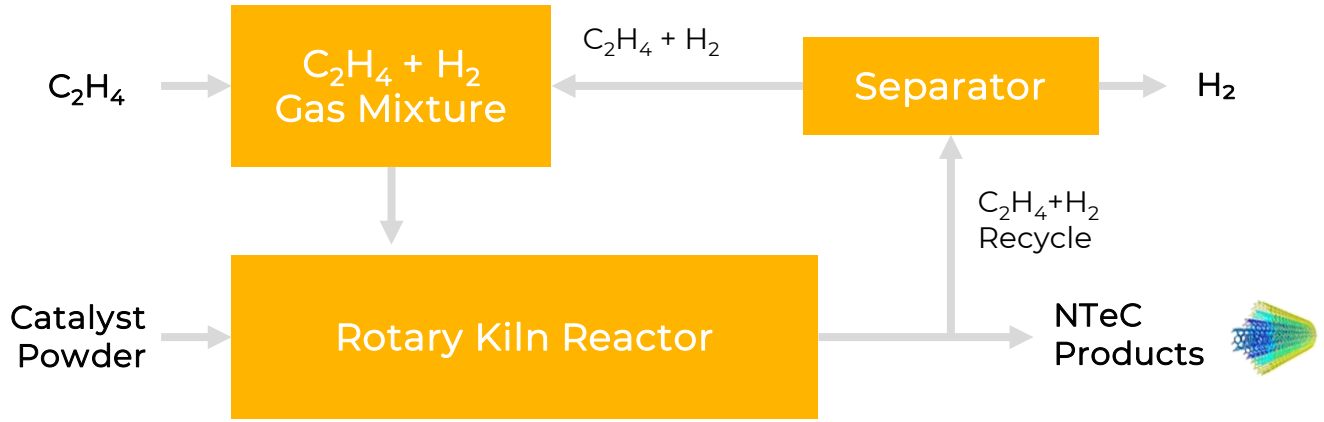
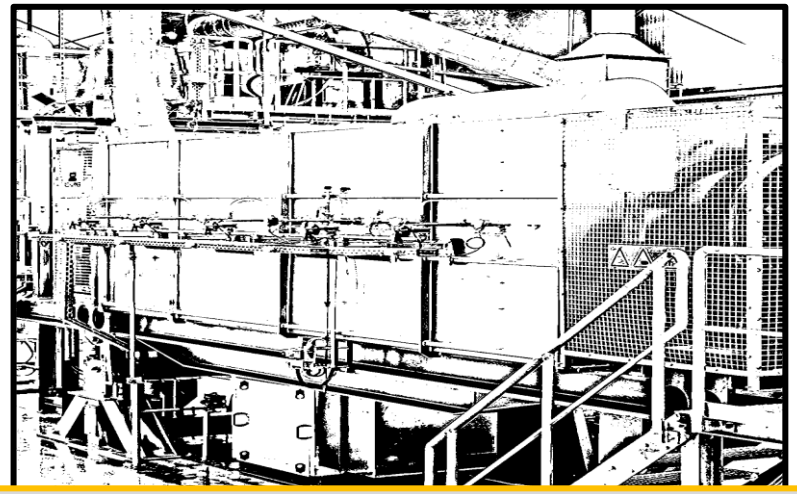
"CNT integration into cement must be effective and safe"

Low Cost – Green Process CNT Synthesis for Sustainable Concrete

Lowest Cost, Most Scalable CNT Production



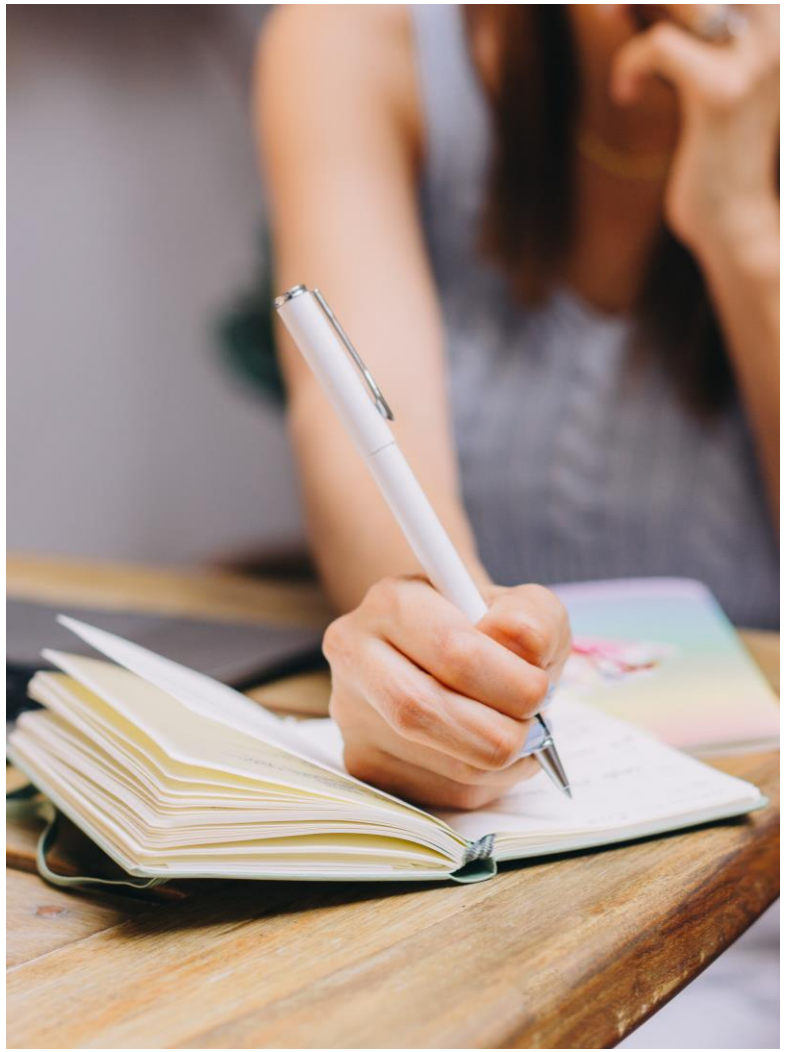




World's Largest Capacity CNT Reactor coming online Q4 2024 at 1,500 MTA

Target Pricing < $20/kg for Mass Production

Conclusions



The morphology of NTeC-C hybrid material greatly enhances carbon nanotube dispersion in the cementitious matrix compared to conventional MWCNT materials. This leads to easier dispersion at lower energy levels because the CNTs are less entangled.

CHASM dispersion method yields mechanical strength improvements in cement comparable to the ultra-sonication dispersion method. However, it requires further optimization for enhancing electrical conductivity and piezoelectric response in SMART Concrete applications.

CHASM dispersion method offers an easy and commercially scalable solution for integrating NTeC-C hybrid material into cement.

Granulating NTeC-C provides a practical, safe, and cost-effective method for incorporating the hybrid material into the cementitious matrix, minimizing environmental and health impact concerns.

Chasm Technology's Rotary Tube Reactor results in high-production, low-cost, and environmentally friendly CNT synthesis for sustainable concrete.

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CNT Additives for Low-Cost and Low-Carbon Concrete the easy way

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Dr. Ricardo Prada Silvy, CTO

rprada@chasmtek.com

+1 (405) 613-2400 mobile

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