A Chemical Admixture with Carbon Nanotubes

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Content

- **Background**
- **Effect of CNT in cement composites**
  - Mechanical properties
  - Autogenous shrinkage, shrinkage cracking
  - Reinforcement corrosion
- **Processing of CNT suspension**
  - Dispersion
  - Characterization
  - Chemical admixture
- **Conclusions**

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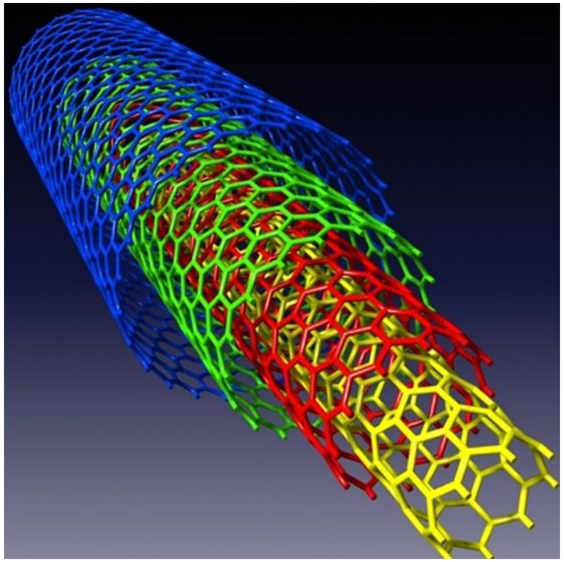
Background

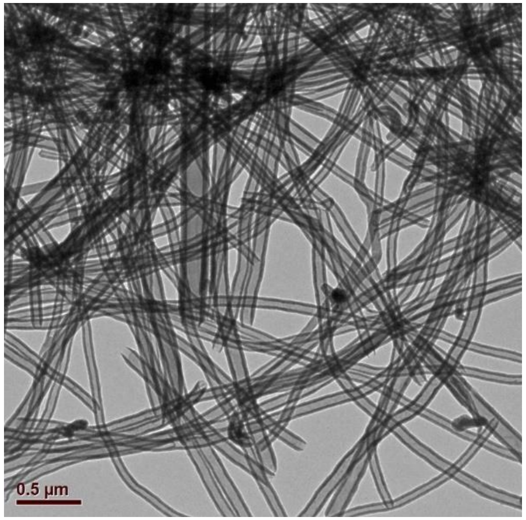
Carbon nanotube/nanofiber

- Young's Modulus: 0.6-1 TPa
- Tensile Strength: ~100 GPa



Multiwall Carbon Nanotube

Carbon Nanofiber



TEM of Carbon Nanofiber

1. *Ozkan T, Naraghi M, Chasiotis I. Mechanical properties of vapor grown carbon nanofibers. Carbon 2010;48:239–44.*
2. *Mordlkovich VZ. Carbon nanofibers: a new ultrahigh-strength material for chemical technology. Theor Found Chem Eng 2003;37(5):429–38.*

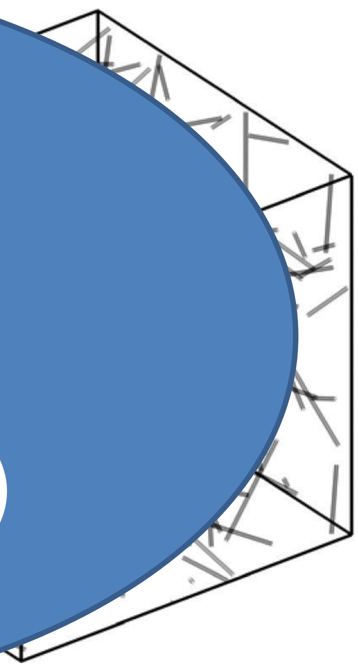
Challenge of Using CNTs/CNFs

Cost

Small Dosage:

0.08-0.15 wt%

(to cement weight)



Dispersion

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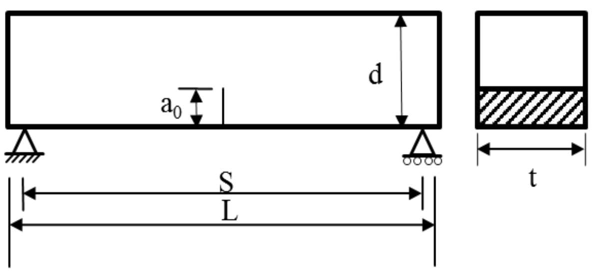
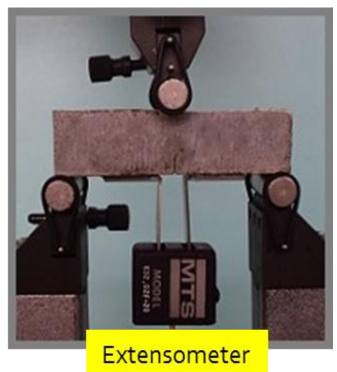
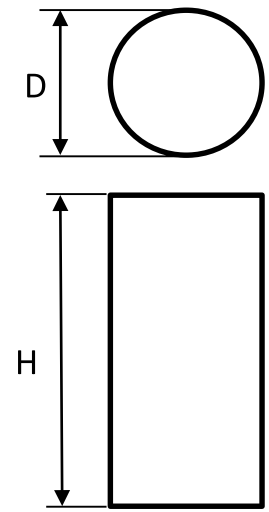
Mechanical Properties







Flexural Test

2x2x8 cm

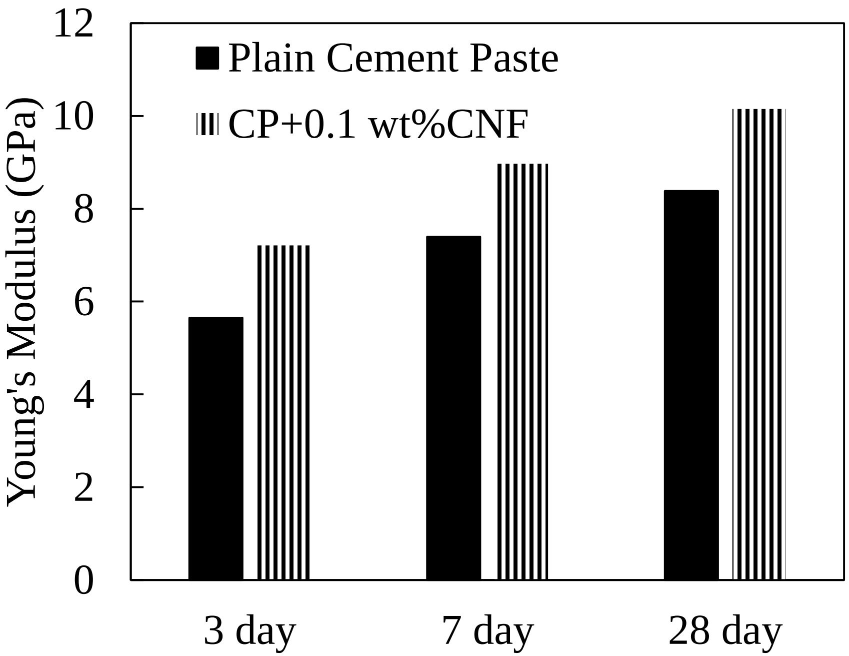
Compression Test

10x20 cm

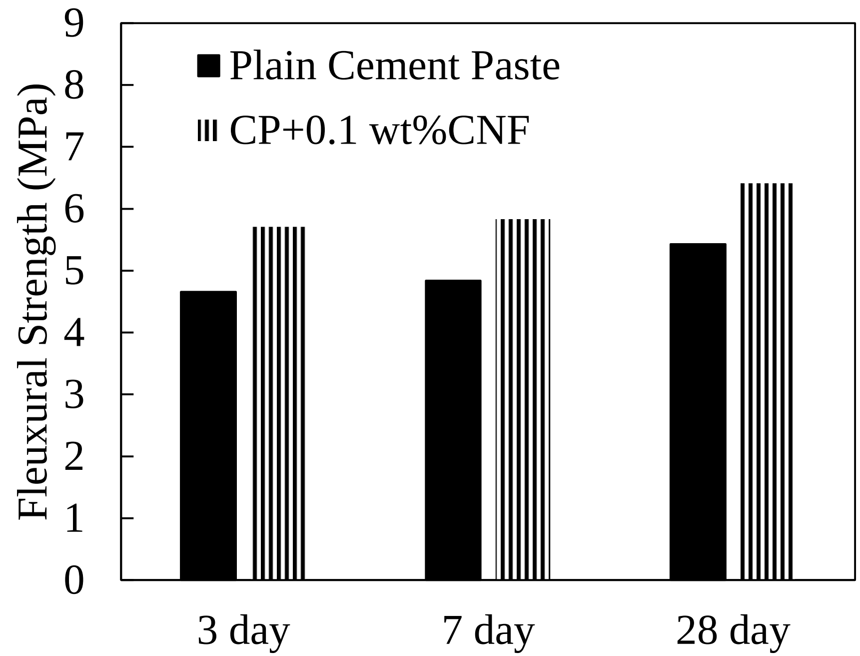
Flexural Test

Cement Paste

(w/c=0.485:1)



Young’s Modulus

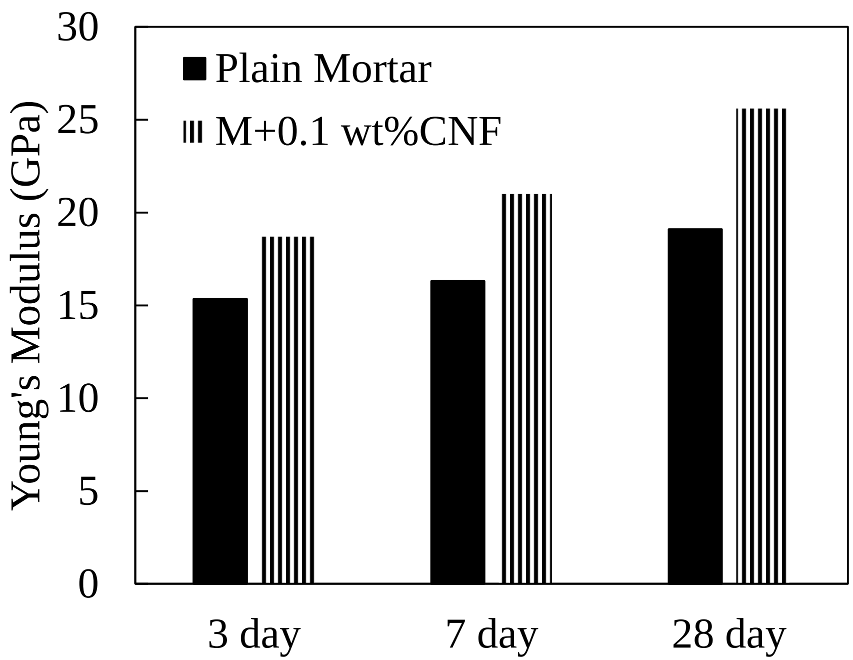


Flexural Strength

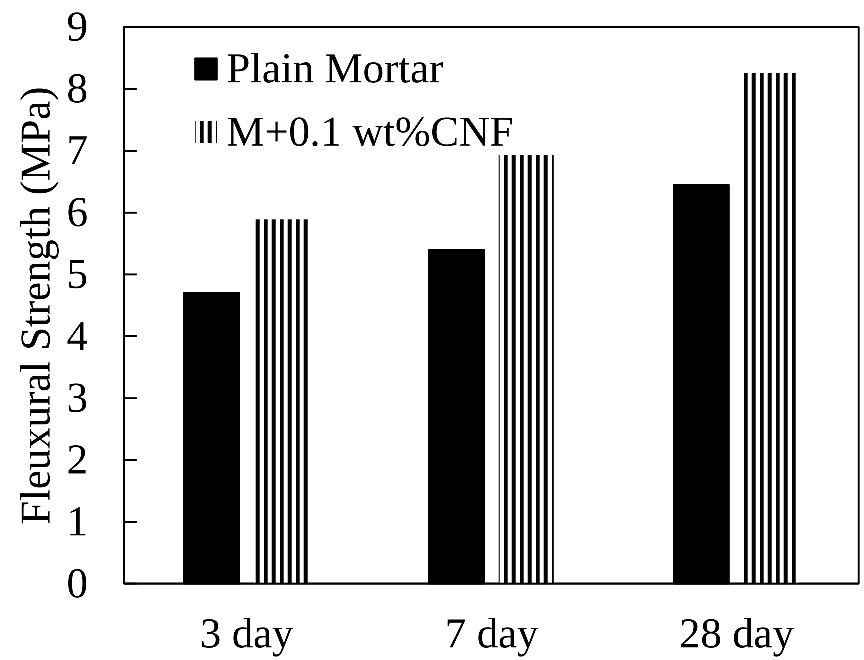
Flexural Test

Mortar

(w/c/s=0.485:1:2.75)



Young’s Modulus

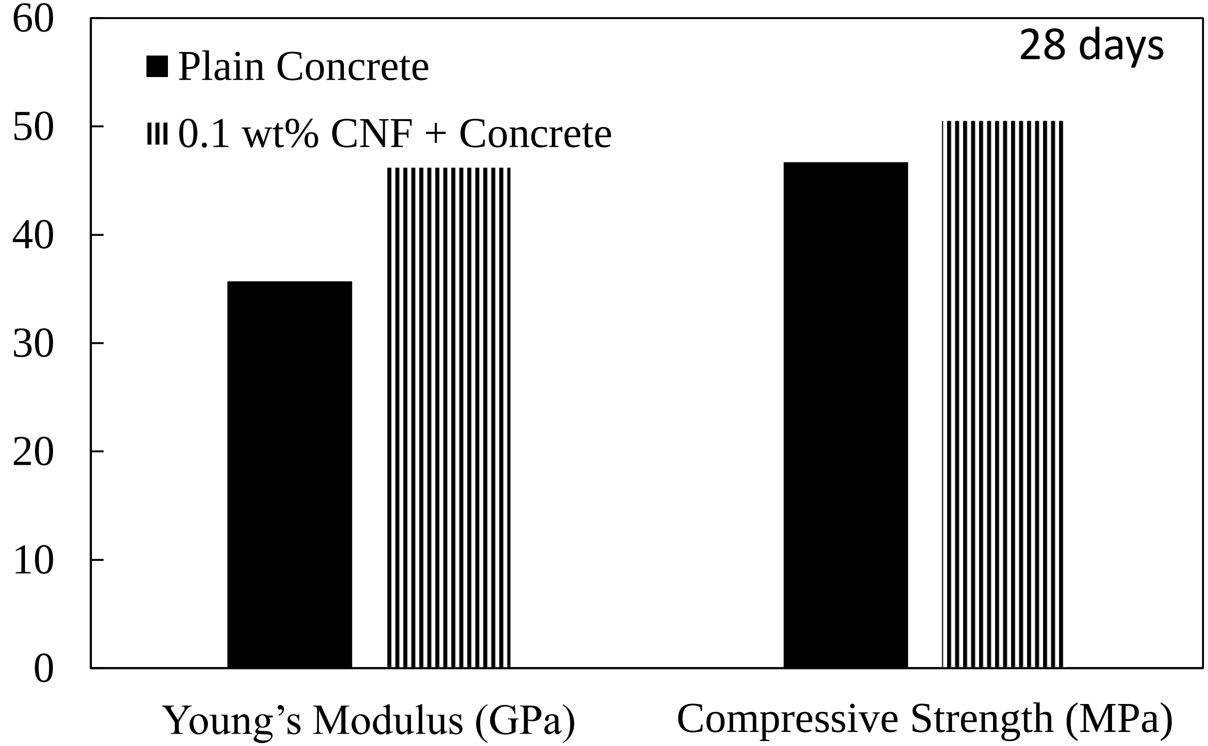


Flexural Strength

Compression Test

Concrete

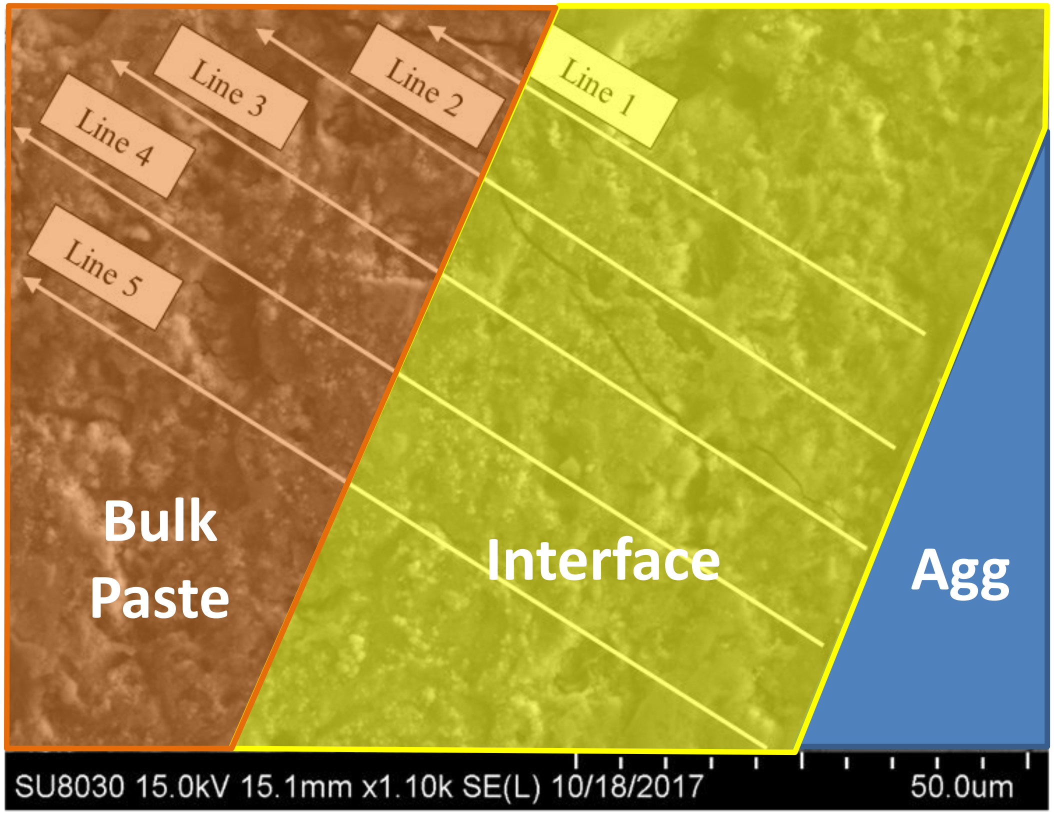
(w/c/s/a.g=0.51:1:2.46:3.5)



Mechanical Properties Improvement

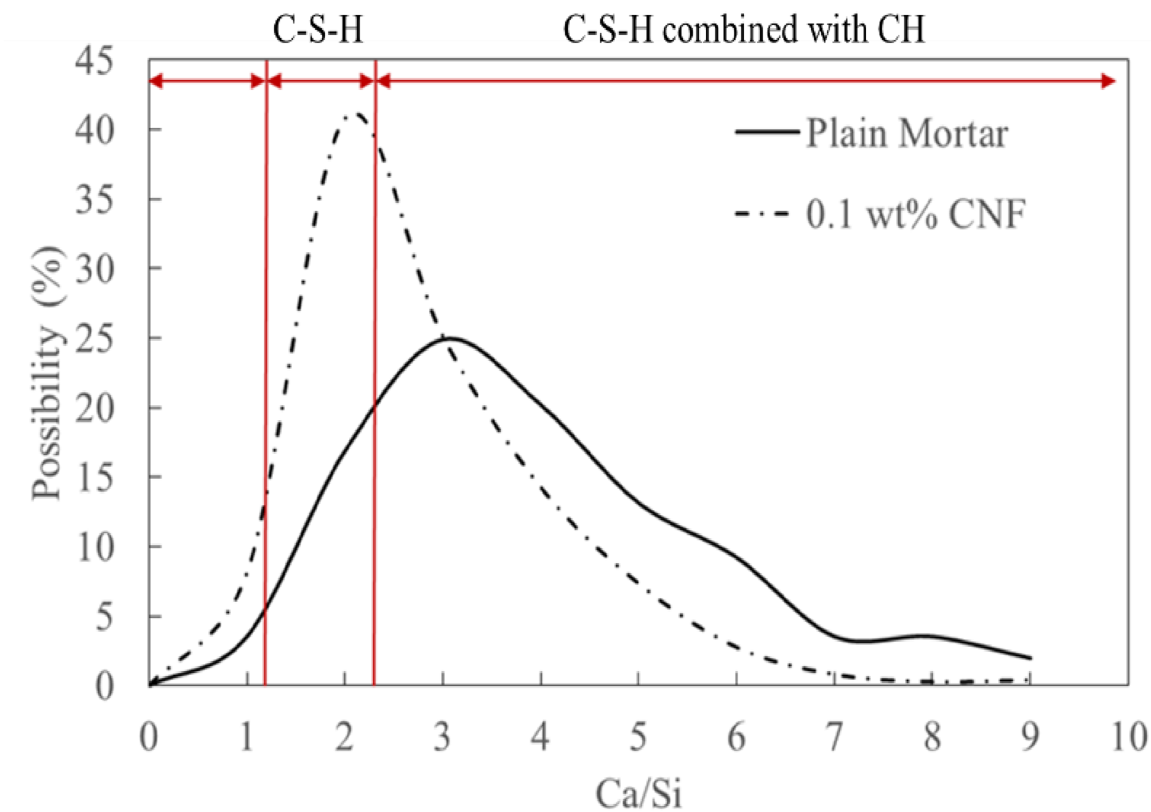
	Tests	CNF Volume Fraction (%)	Young's Modulus Improvement (%)
Cement Paste (CP)	Flexural	0.083	**21**
Mortar (M)	Flexural	0.036	**34**
Concrete (C)	Compression	0.022	**29**

SEM/EDS on Interface



Hydration Products	Ca/Si Ratio
Calcium-Silicate-Hydrate (C-S-H)	0.8~2.5
Calcium Hydroxide (CH)	>10
Ettringite (AFm)	>4.0

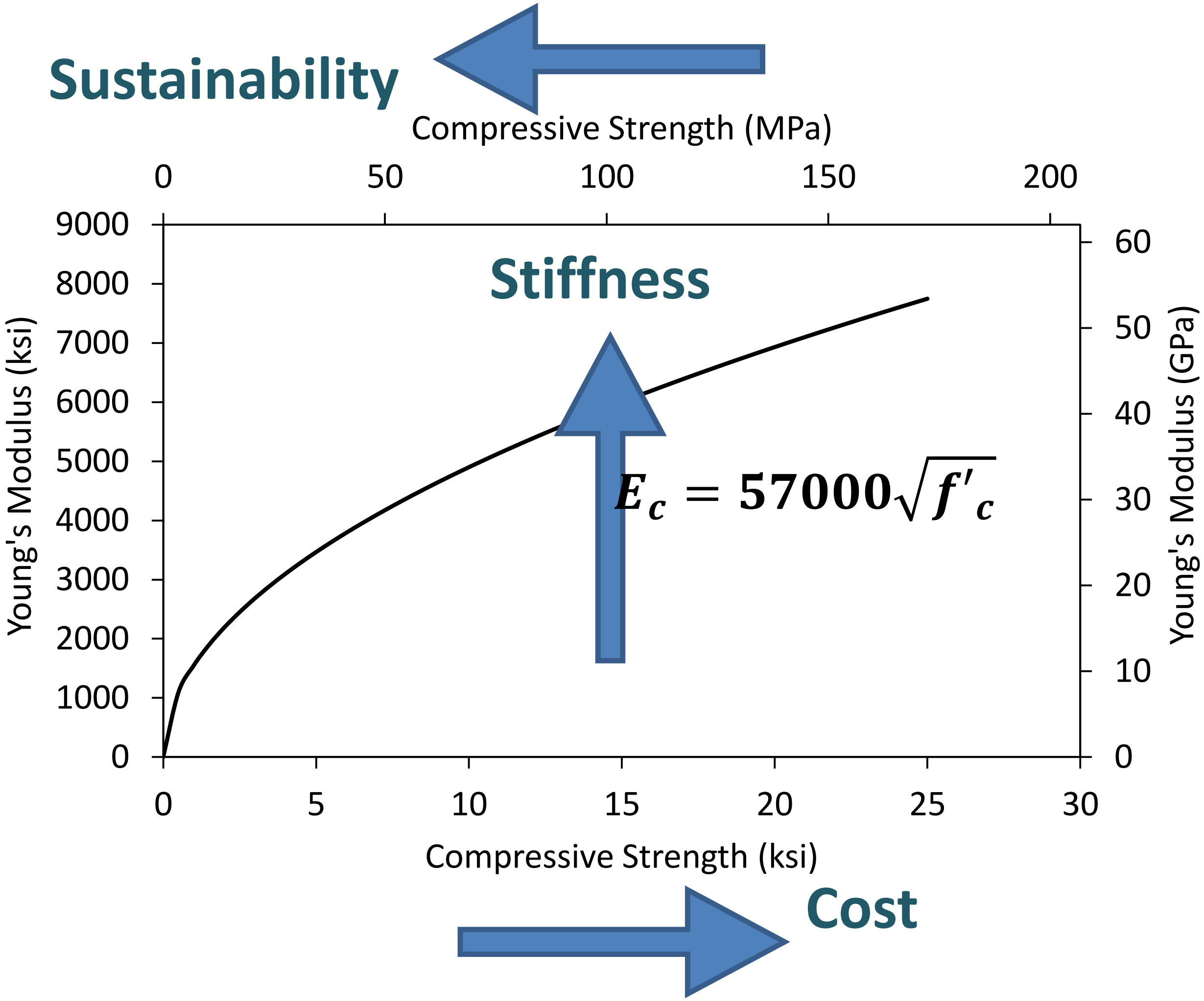
SEM/EDS on Interface



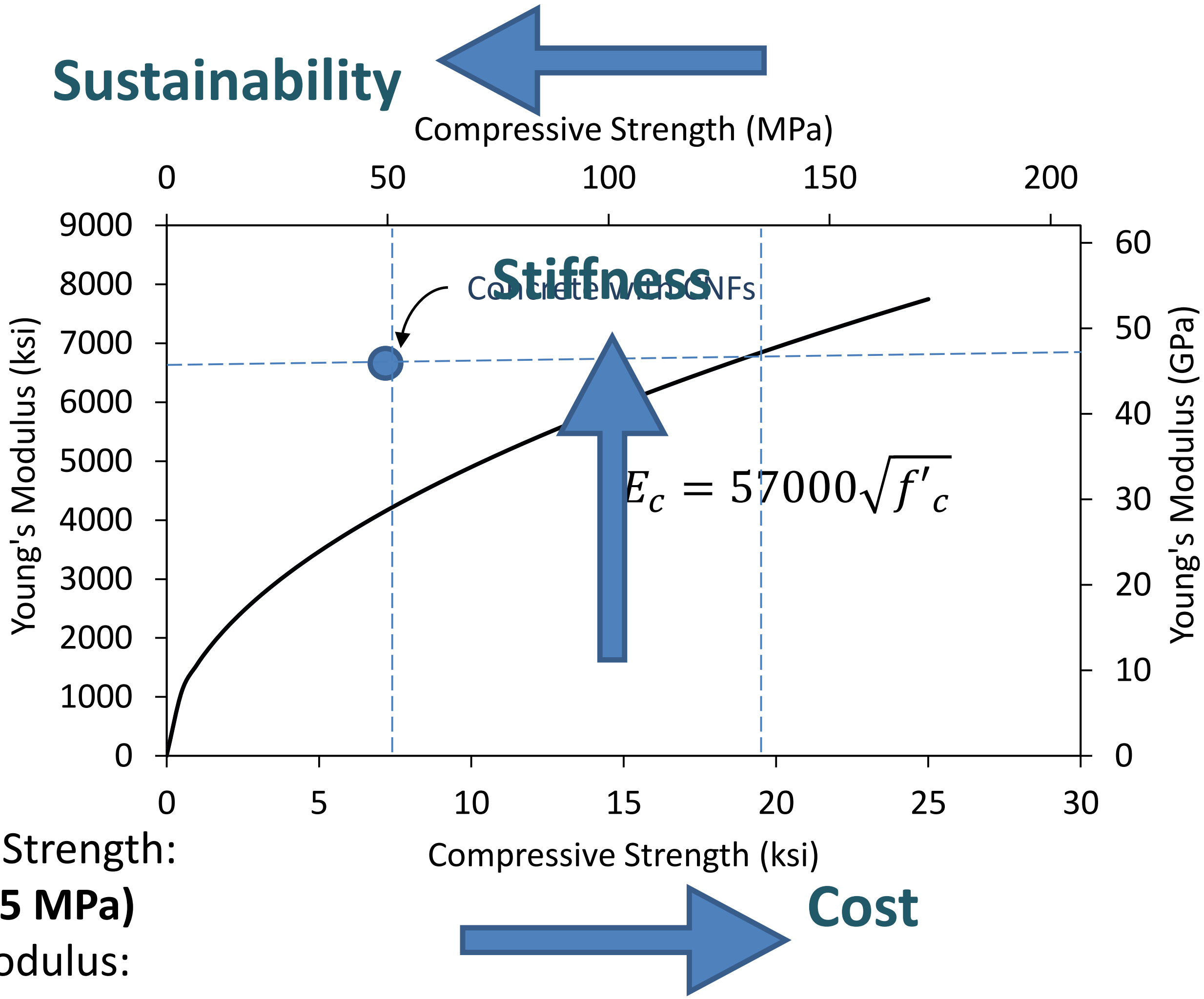
Jeddah Tower (Jeddah)

E: 58 GPa (8500 ksi)

Mechanical Properties Improvement

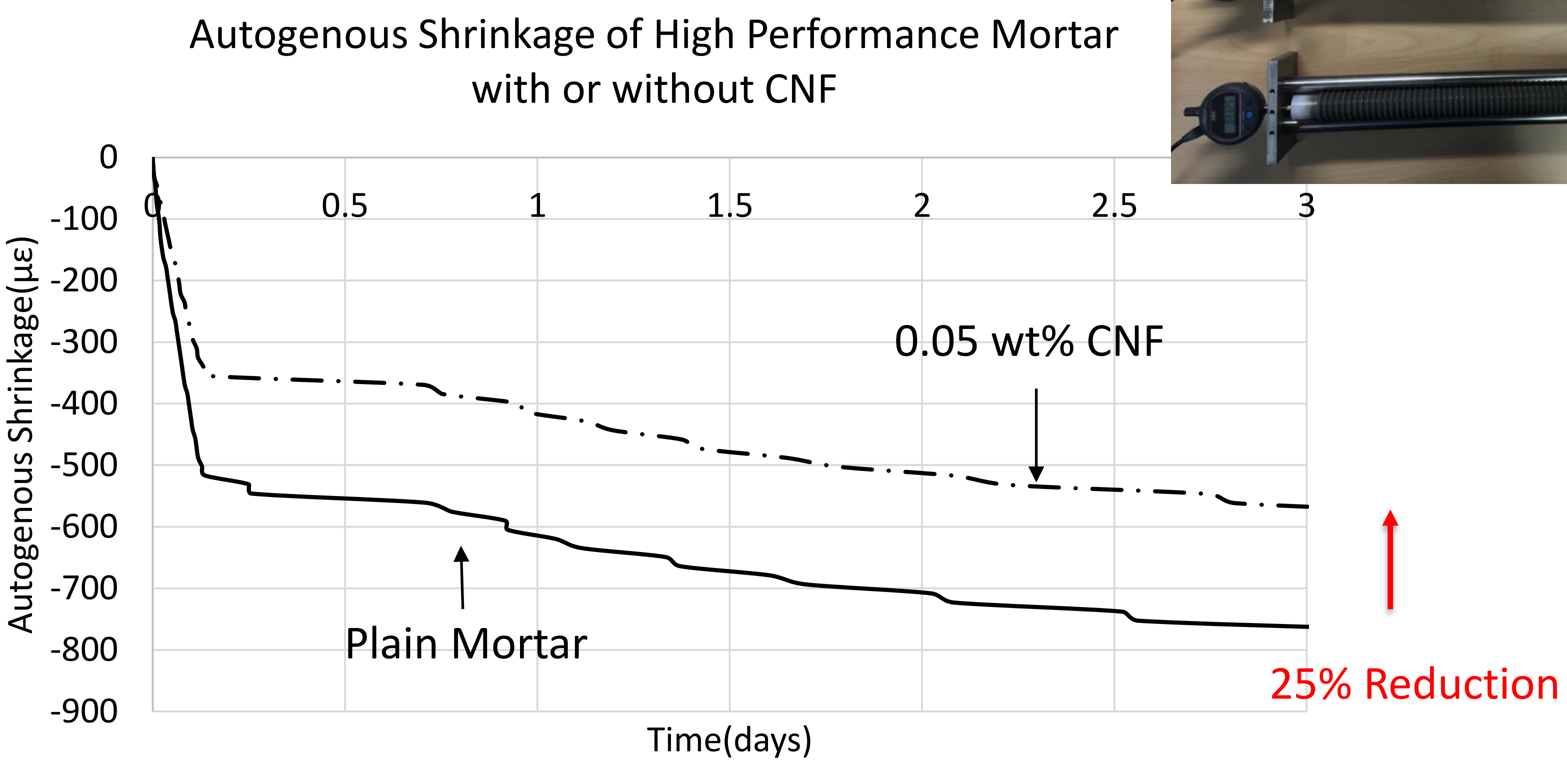


Mechanical Properties Improvement



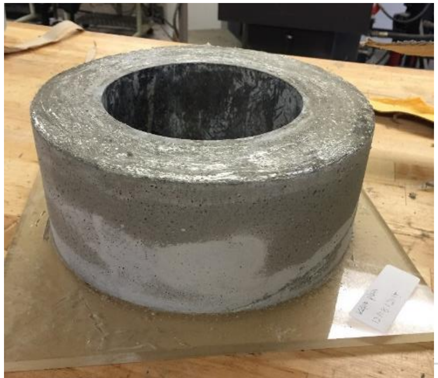
Compressive Strength:
7.3 ksi (50.5 MPa)
Young’s Modulus:
6700 ksi (46.8 Gpa)

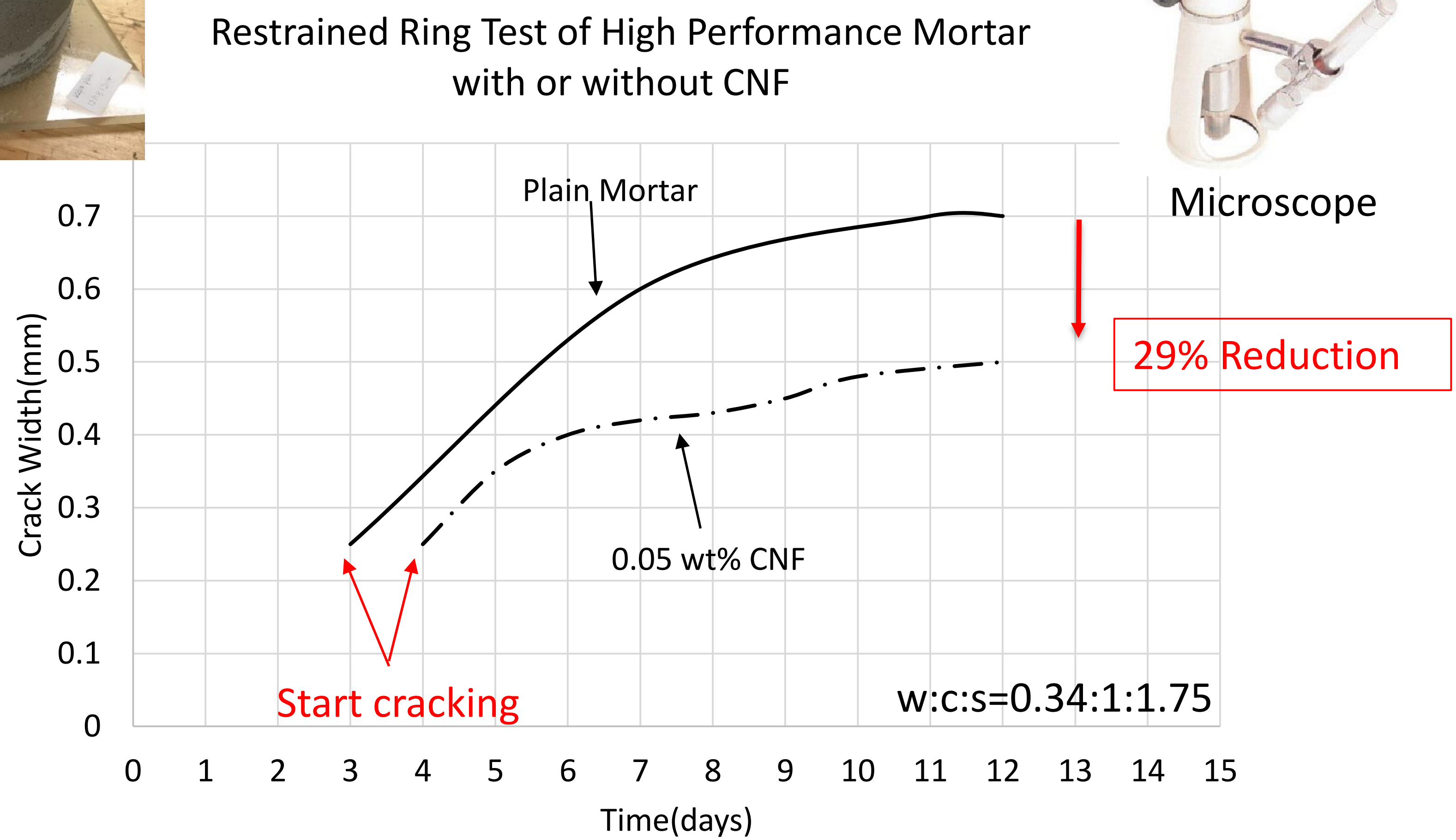
Autogenous Shrinkage Measurement



w:c:s=0.34:1:1.75

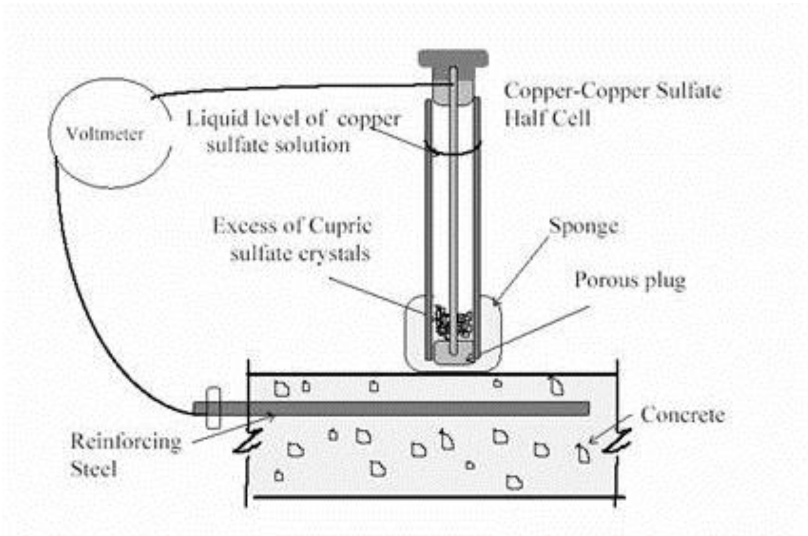
Shrinkage Cracking

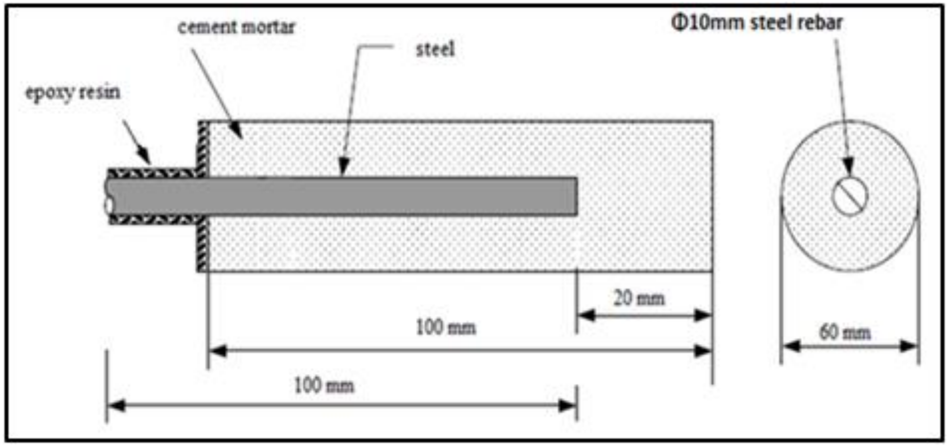




Microscope

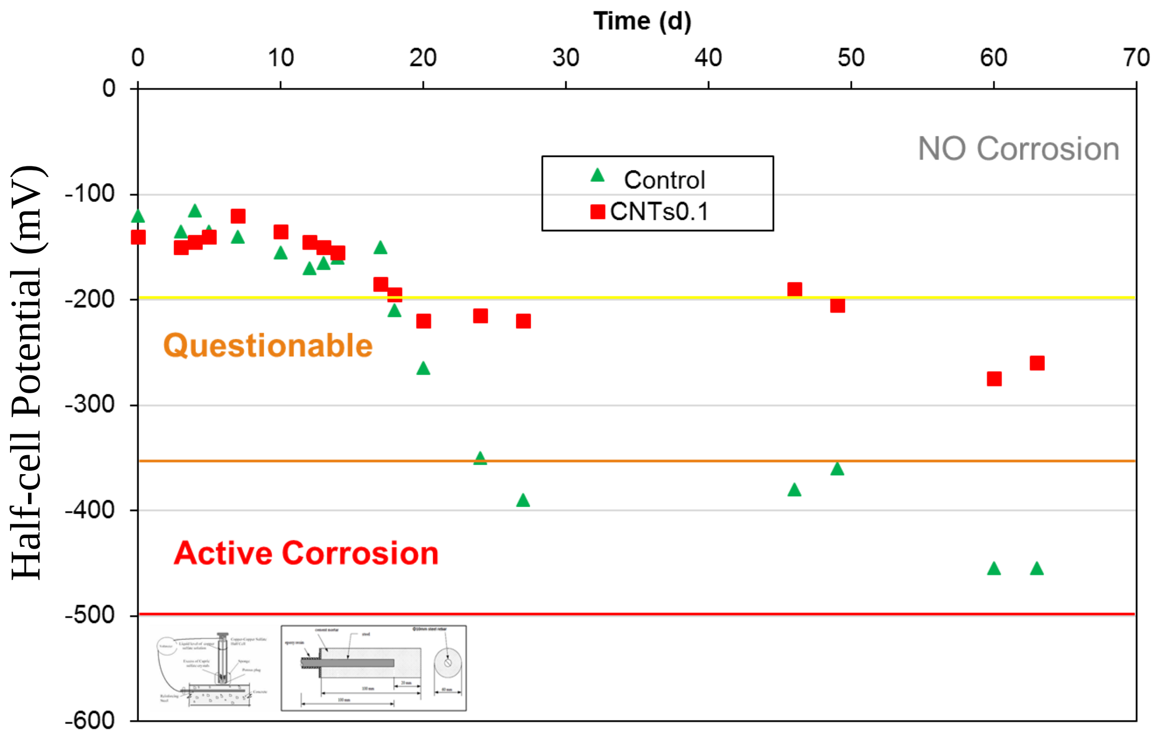
Reinforcement Corrosion





Half Cell Potential (mV)	Corrosion Probability
0-200	No corrosion
200-350	Possible corrosion
350-500	Corrosion
>500	Strongly Corroded

Reinforcement Corrosion



0.1 wt% CNTs could increase the resistance to corrosion

M .S. Konsta-Gdoutos, G. Batis, P.A. Danoglidis, A. K. Zacharopoulou, E. K. Zacharopoulou, M.G. Falara, S.P. Shah, Effect of CNT and CNF loading and count on the corrosion resistance, conductivity and mechanical properties of nanomodified OPC mortars, 2017. doi:10.1016/j.conbuildmat.2017.04.112.

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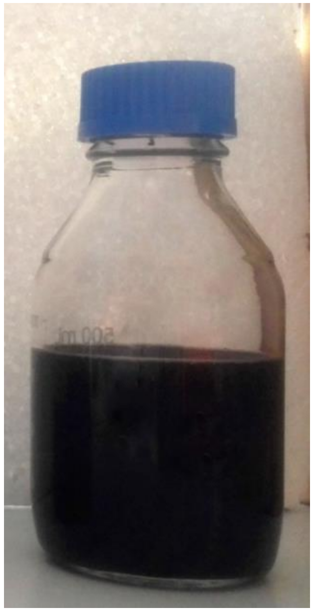
Processing of CNT Suspension

Poor Dispersion

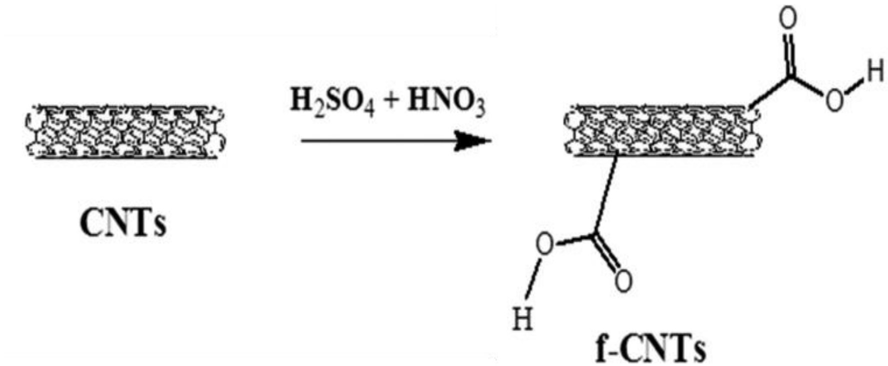


Good Dispersion

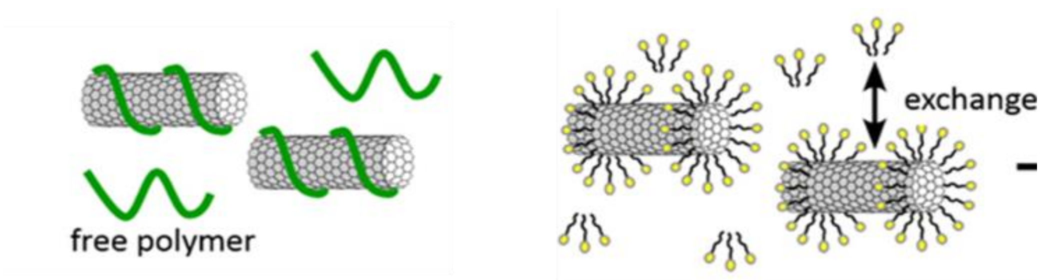
Existing Dispersion Methods

- **The chemical approach**
  - – Non-covalent methods
  - – Covalent methods
- **The mechanical approach**
  - – Ultra-sonication
  - – High shear mixing

The Chemical Approach



covalent
functionalization



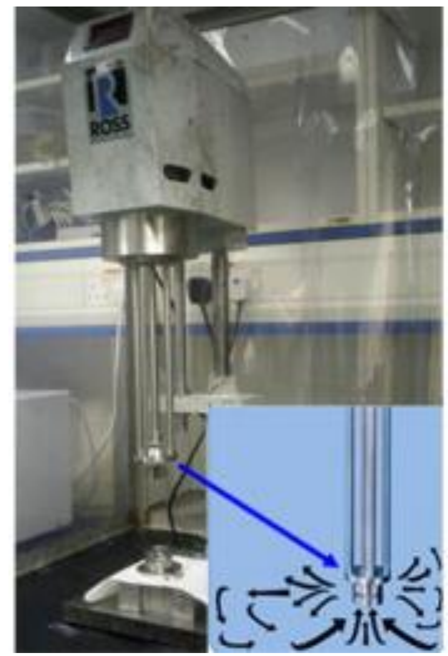
polymer wrapping

surfactant attaching

noncovalent
functionalization

The Mechanical Approach

Ultra-sonication Probe



Shear Mixing

Dispersion Characterization

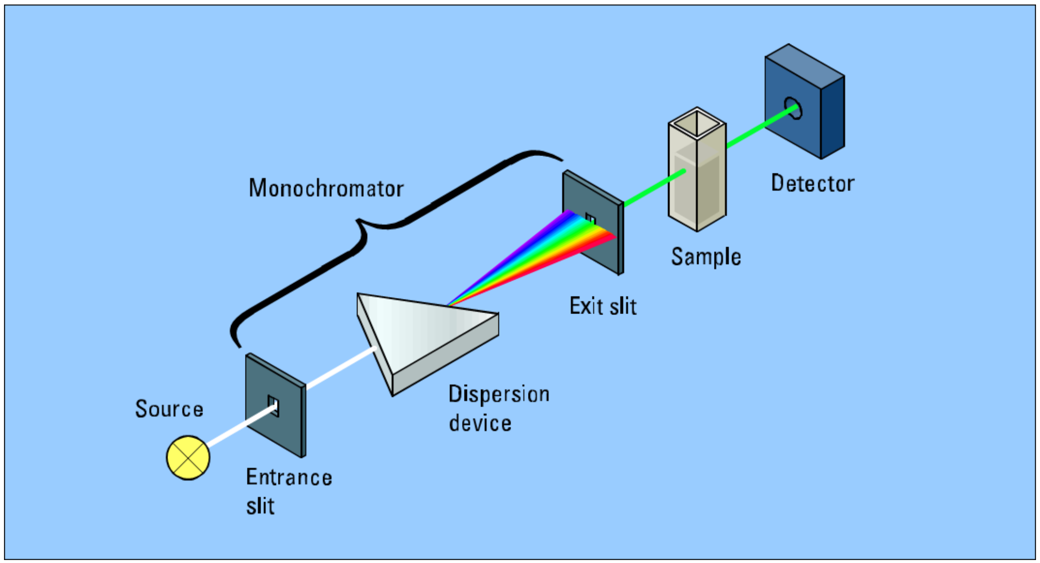


Figure 1. Schematic of Ultraviolet-visible Spectroscopy

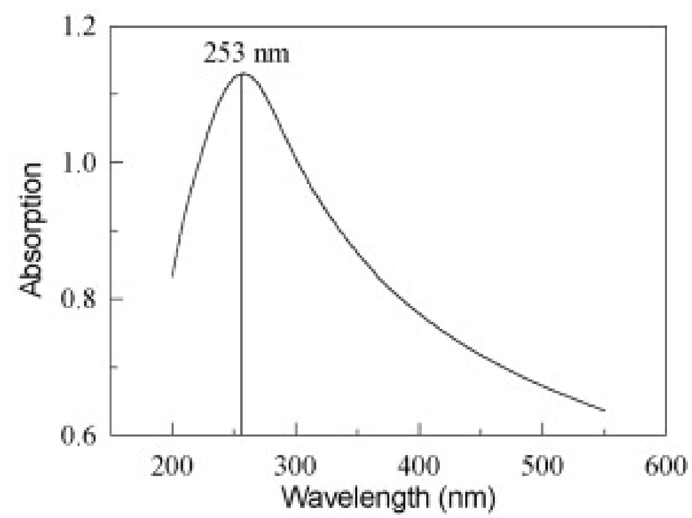
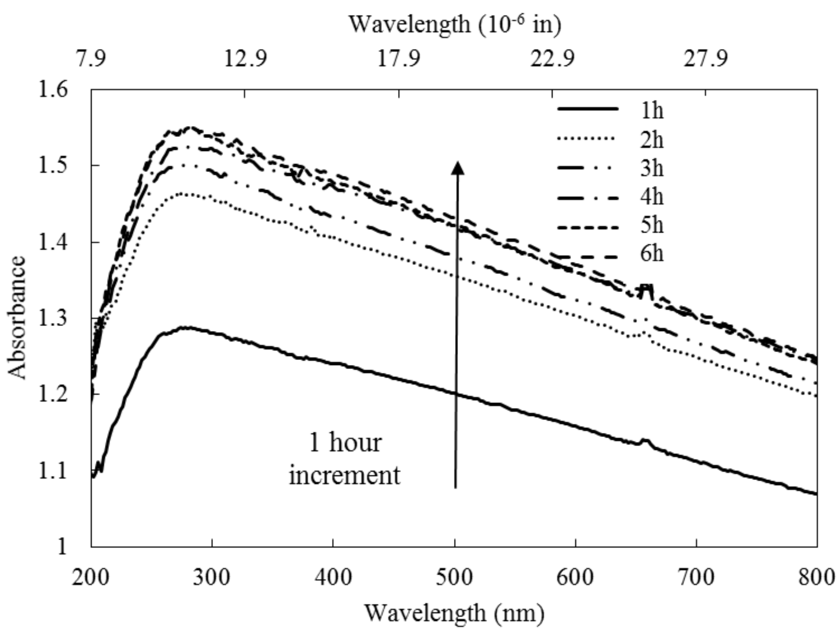


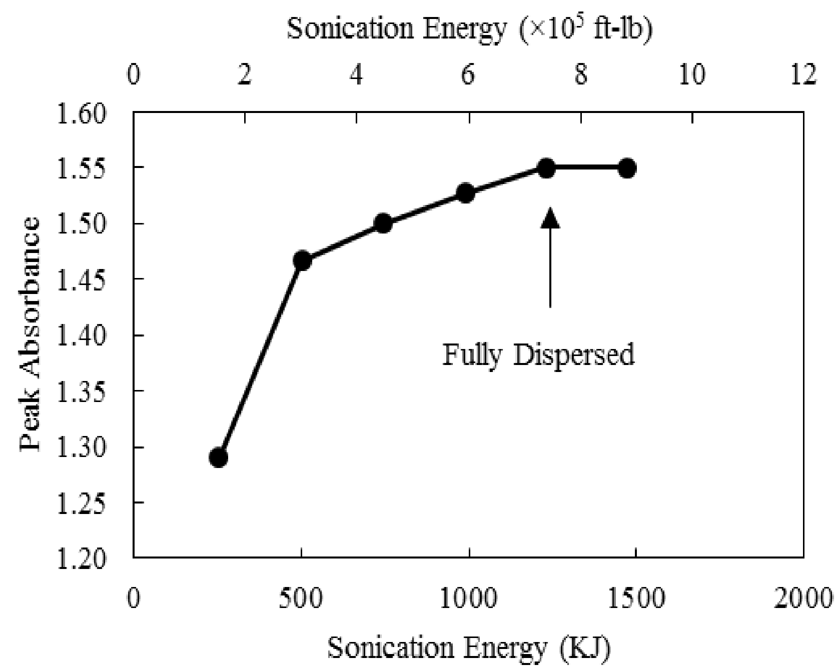
Figure 2. Typical absorption curve for CNTs[1]

1. Linqin Jiang, Lian Gao, Jing Sun, “Production of aqueous colloidal dispersions of carbon nanotubes,” *Journal of Colloid and Interface Science*, Volume 260, Issue 1, 2003, Pages 89-94,

Characterization

Ultraviolet Visible Spectroscopy (UV-Vis)



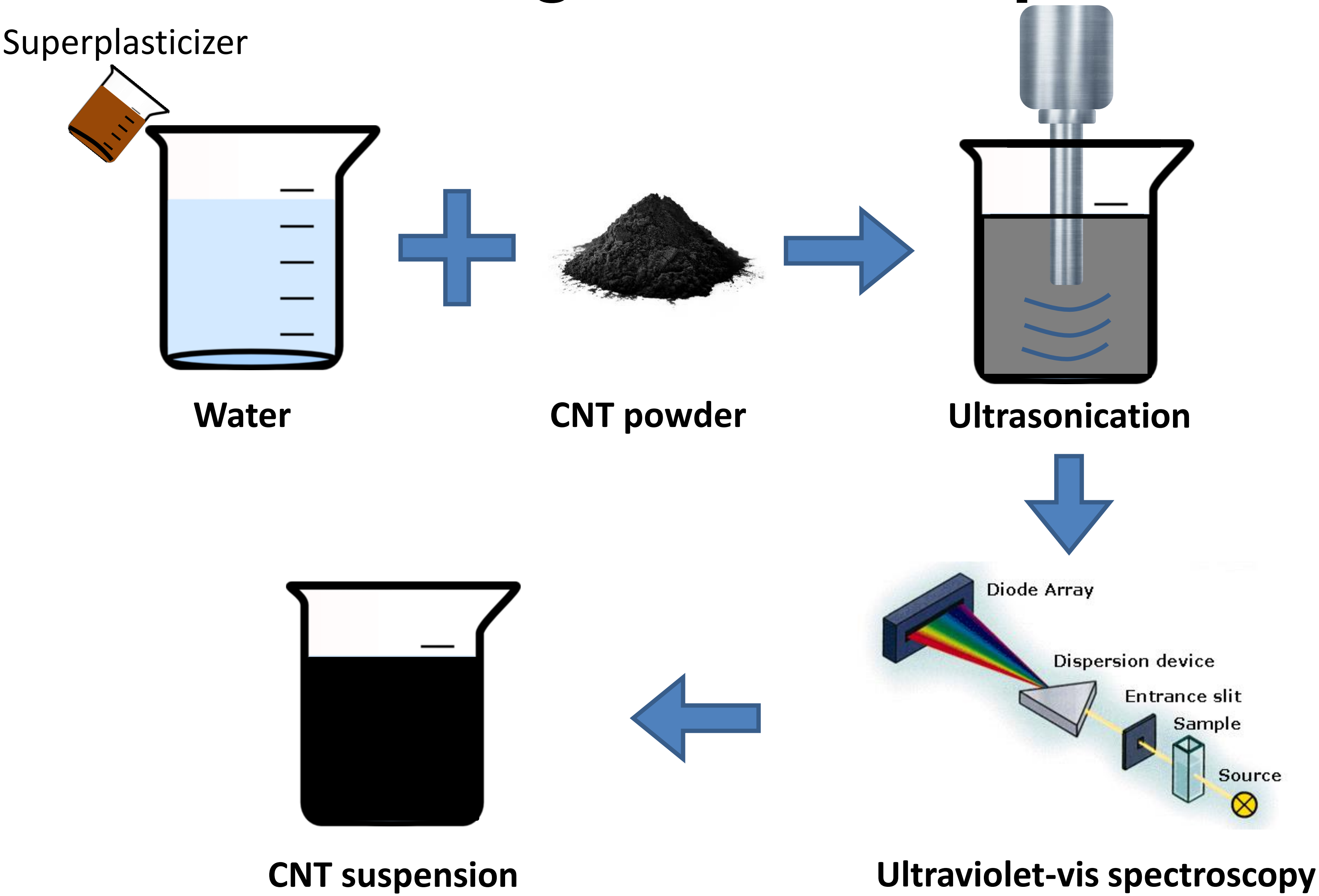


Dispersion

A combination of the use of **superplasticizer** and **ultrasonication**

S.P. Shah, M.S. Konsta-Gdoutos, Z.S. Metaxa (2016), Highly-dispersed carbon nanotube-reinforced cement-based materials, US9499439B2

Processing of CNT Suspension



Chemical Admixture

- Small dosages of CNTs (0.08-0.15 wt%)
- Nano modification of the hydration products

Conclusions

- CNTs significantly improve the mechanical properties, such as flexural strength, Young's modulus
- CNTs reduce autogenous shrinkage and shrinkage cracking
- CNTs increase the resistance to reinforcement corrosion
- Good dispersion has been obtained in lab scale
- Dispersion needs to be scaled up for industry application

Thanks!

Thanks!