Role of nanosheets and nanofibers for CO_2 capture in cementitious system

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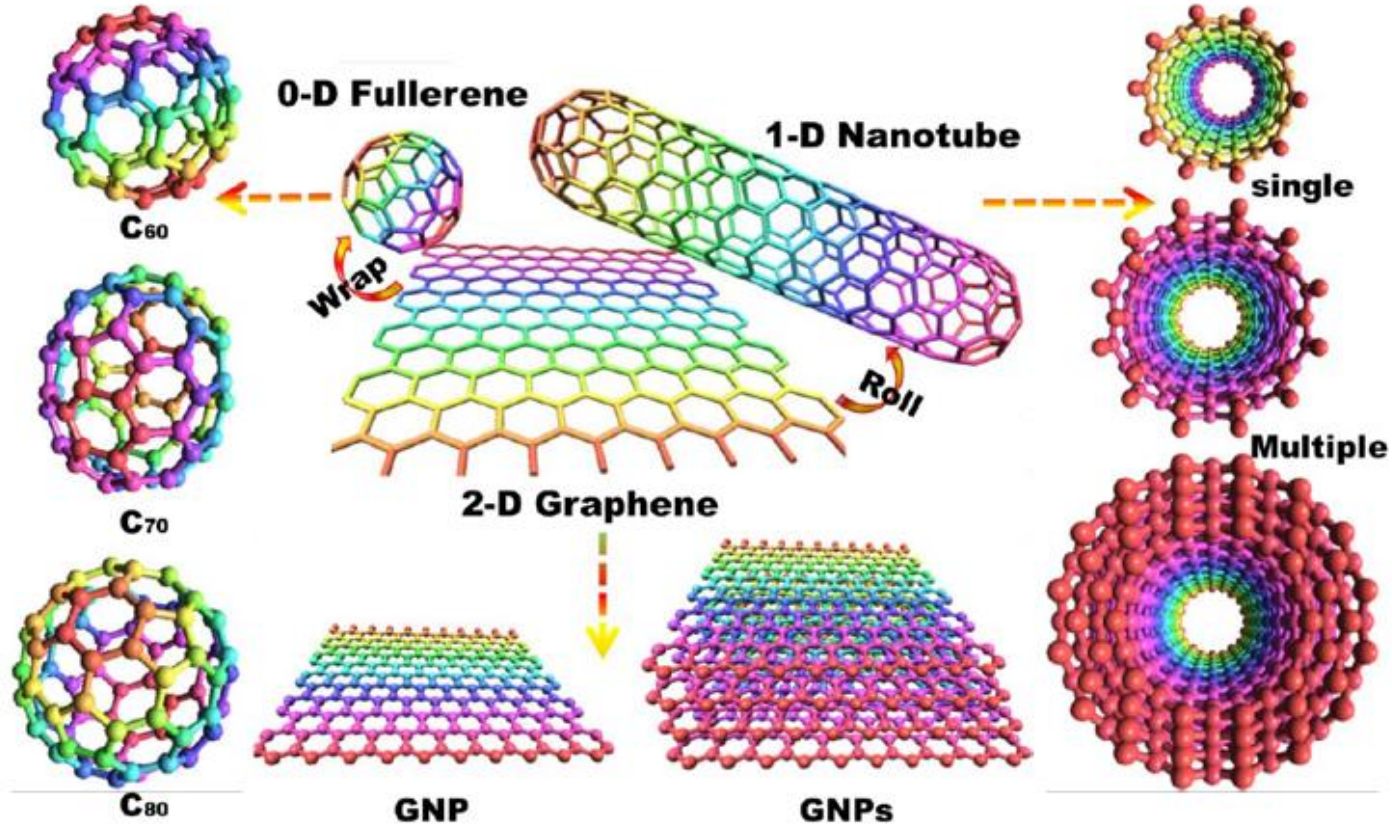
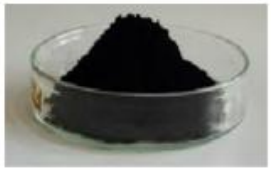
Introduction to Carbon-based nanomaterials



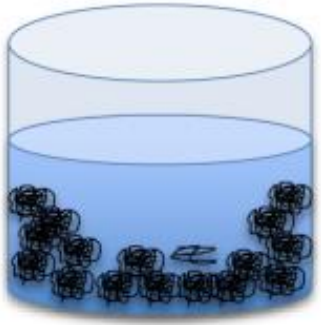
Modulus and conductivity of CNT, GO and Graphene

	Elastic Modulus (GPa)	Electrical Conductivity (S/m)	Thermal Conductivity ($Wm^{-1}K^{-1}$)
CNTs	950	10^6-10^7	>3000
Graphene	1000	$8 \cdot 10^7$	2000-5000
Graphene oxide	380-470	10^{-4}	2-1000

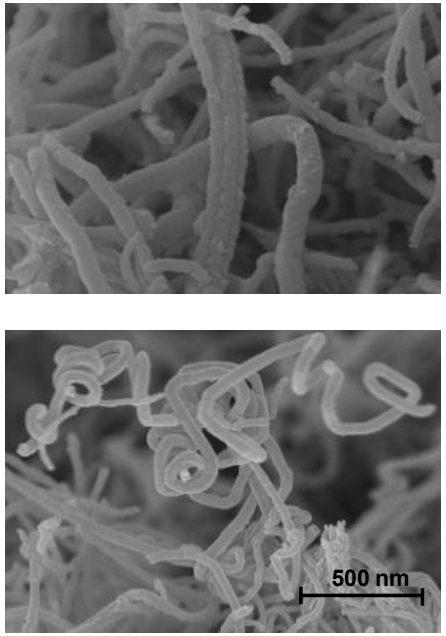
Dispersion – CNTs and CNFs



CNTs/CNFs



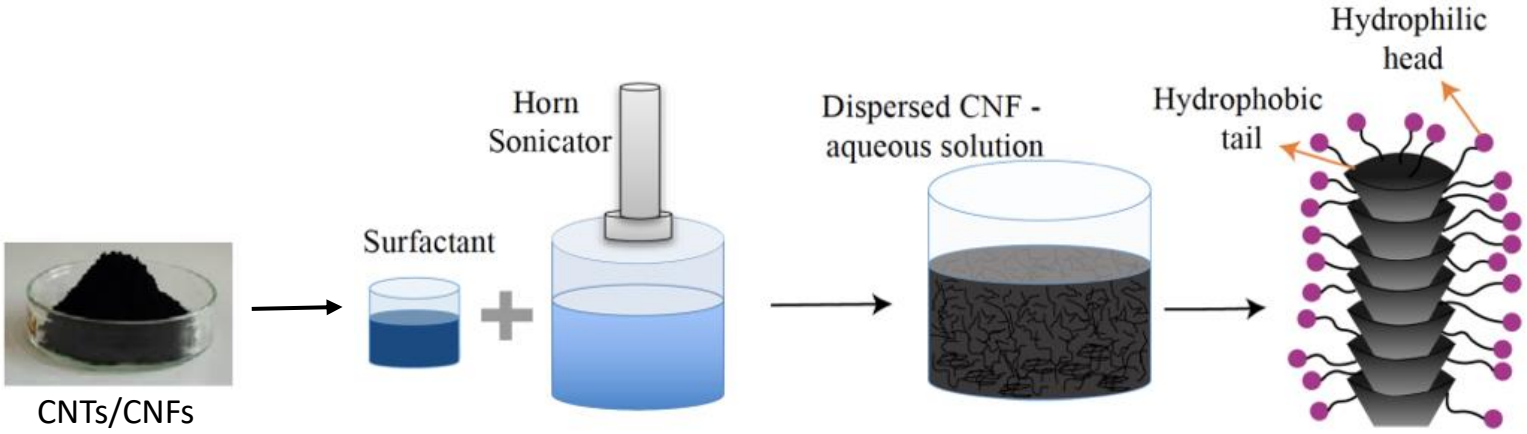
CNTs/CNFs in aqueous solutions

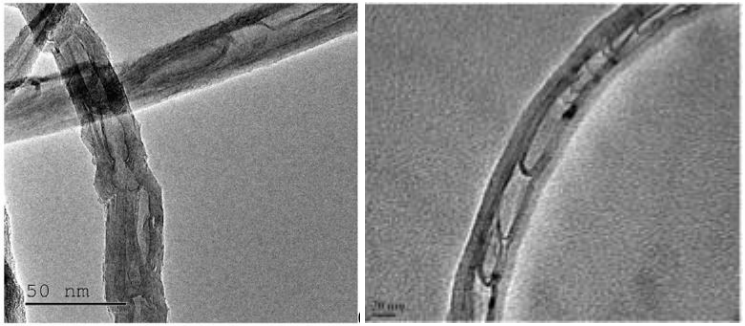


SEM pictures of bundled CNTs/CNFs

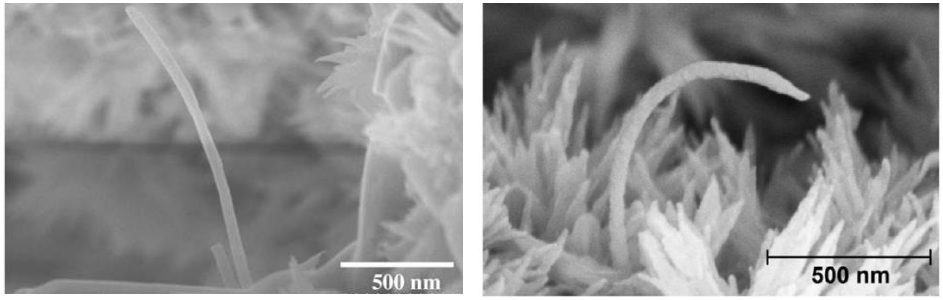
Konsta-Gdoutos et al, Cement and Concrete Research 40 (2010) 1052–1059

Dispersion – CNTs and CNFs





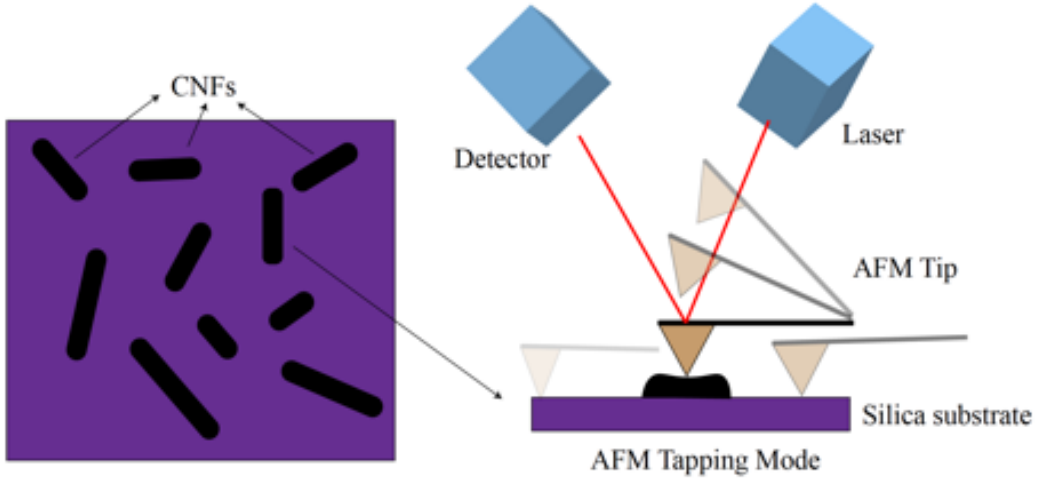
TEM pictures of
individual CNTs

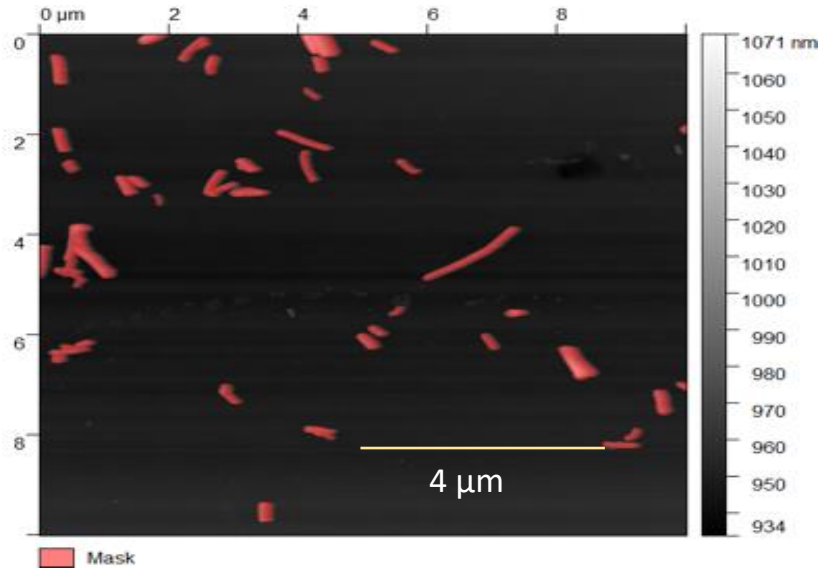


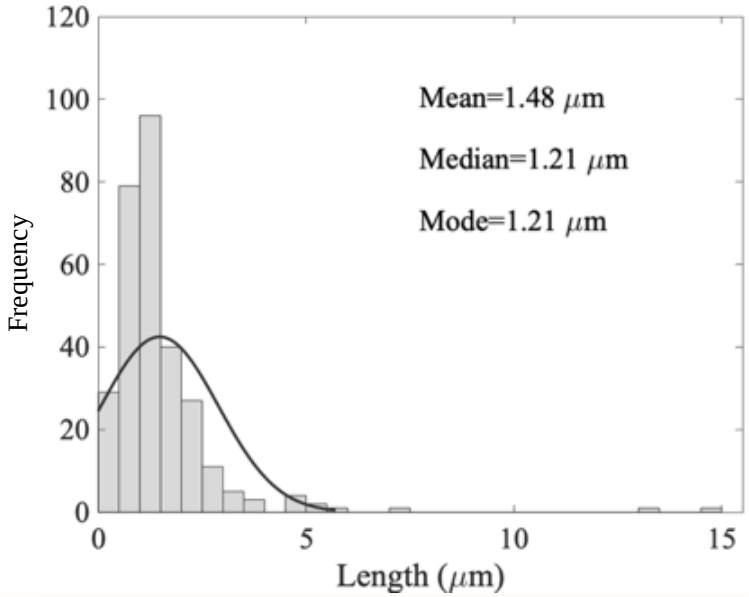
SEM pictures of individual CNTs/CNFs
in the fracture surface of cementitious nanocomposites

Konsta-Gdoutos et al, Cement & Concrete Composites 32 (2010) 110–115
Konsta-Gdoutos et al, Cement & Concrete Composites 82 (2017) 137–151

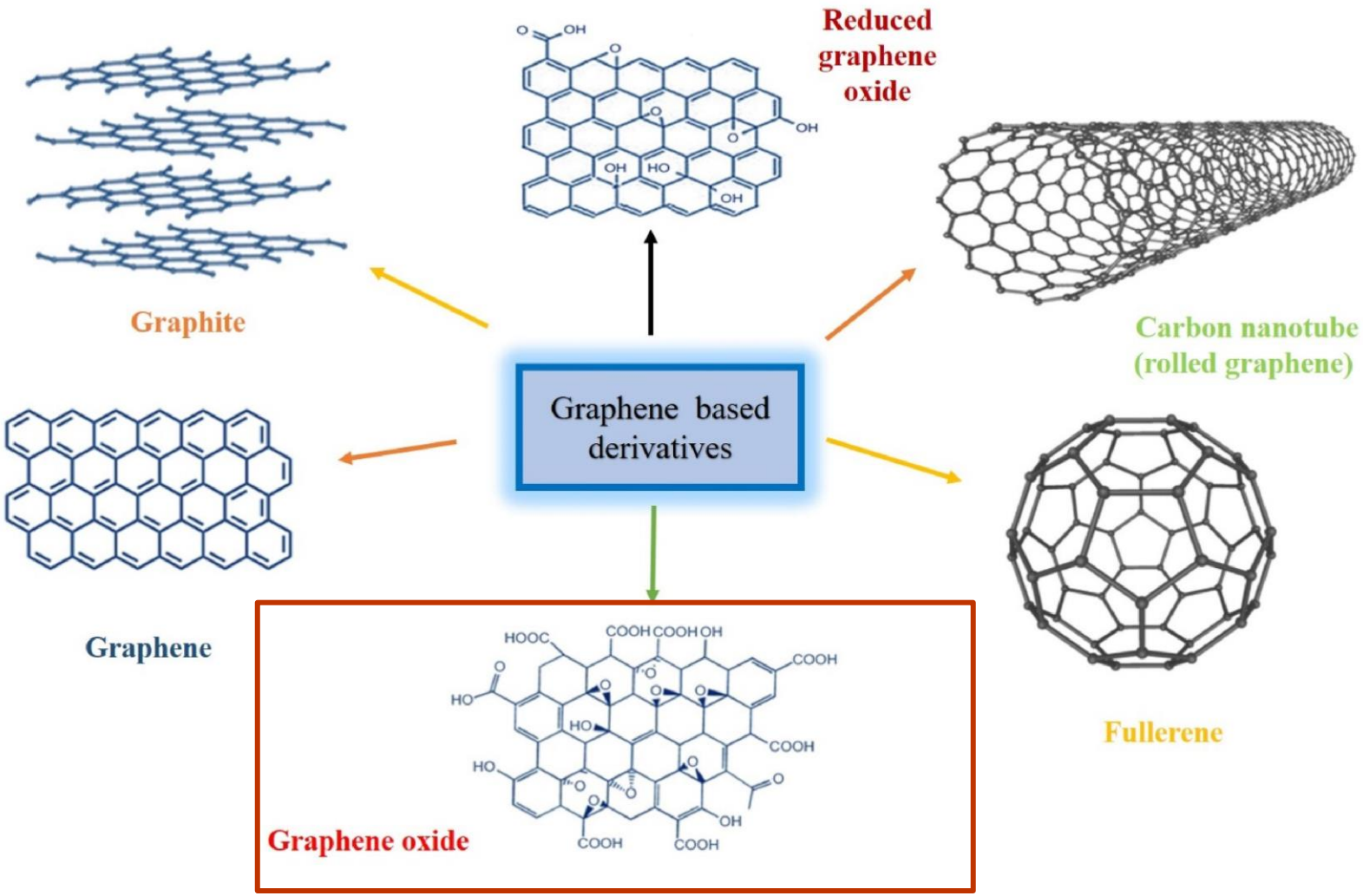
Drop test Characterization & AFM



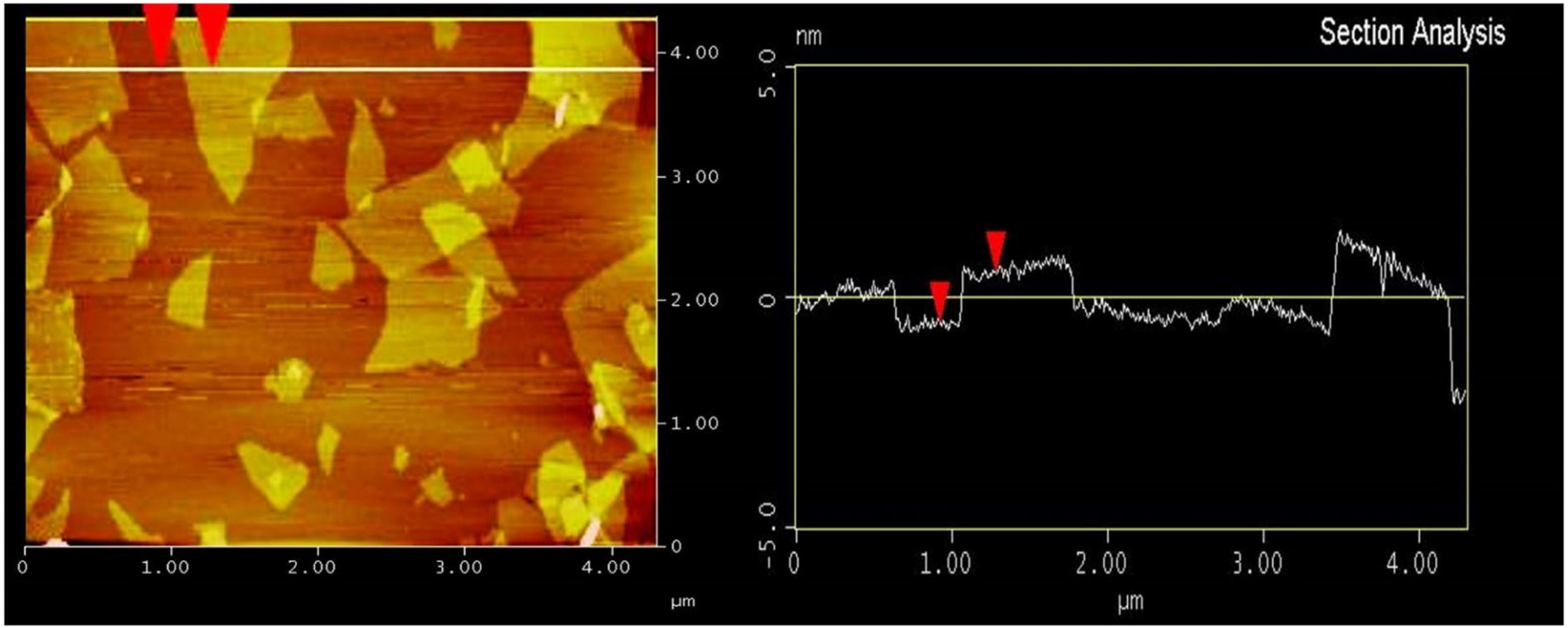




Introduction to graphene oxide (GO)



AFM image of GO

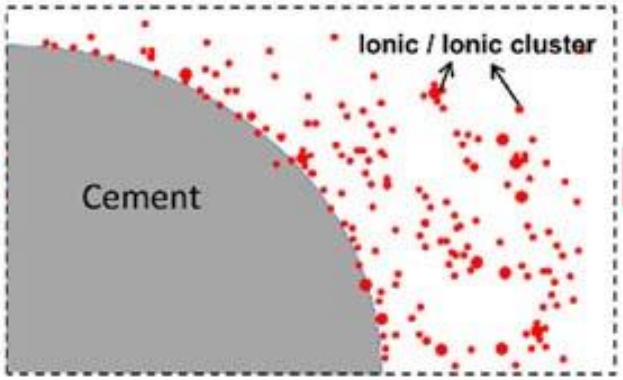


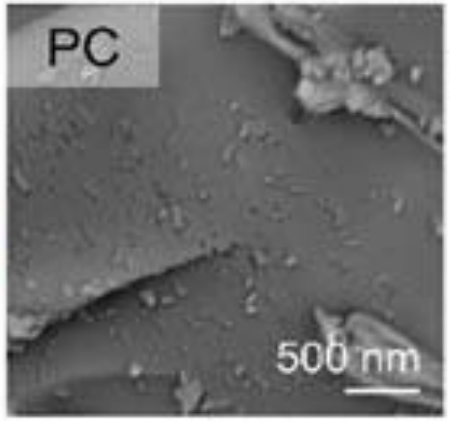
its morphology, size (about 1 µm) and thickness (about 1 nm) are characterized by AFM

Effect of GO on cement paste hydration

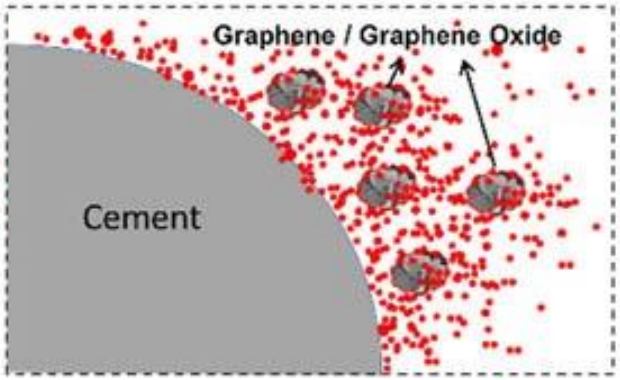
Cement paste preparation → **Ion dissolution and adsorption** → **C-S-H nucleation**

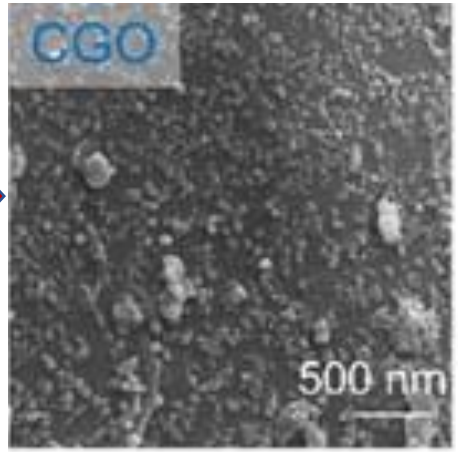
Cement paste without nano materials (**PC**)





Cement paste + graphene oxide (CGO)

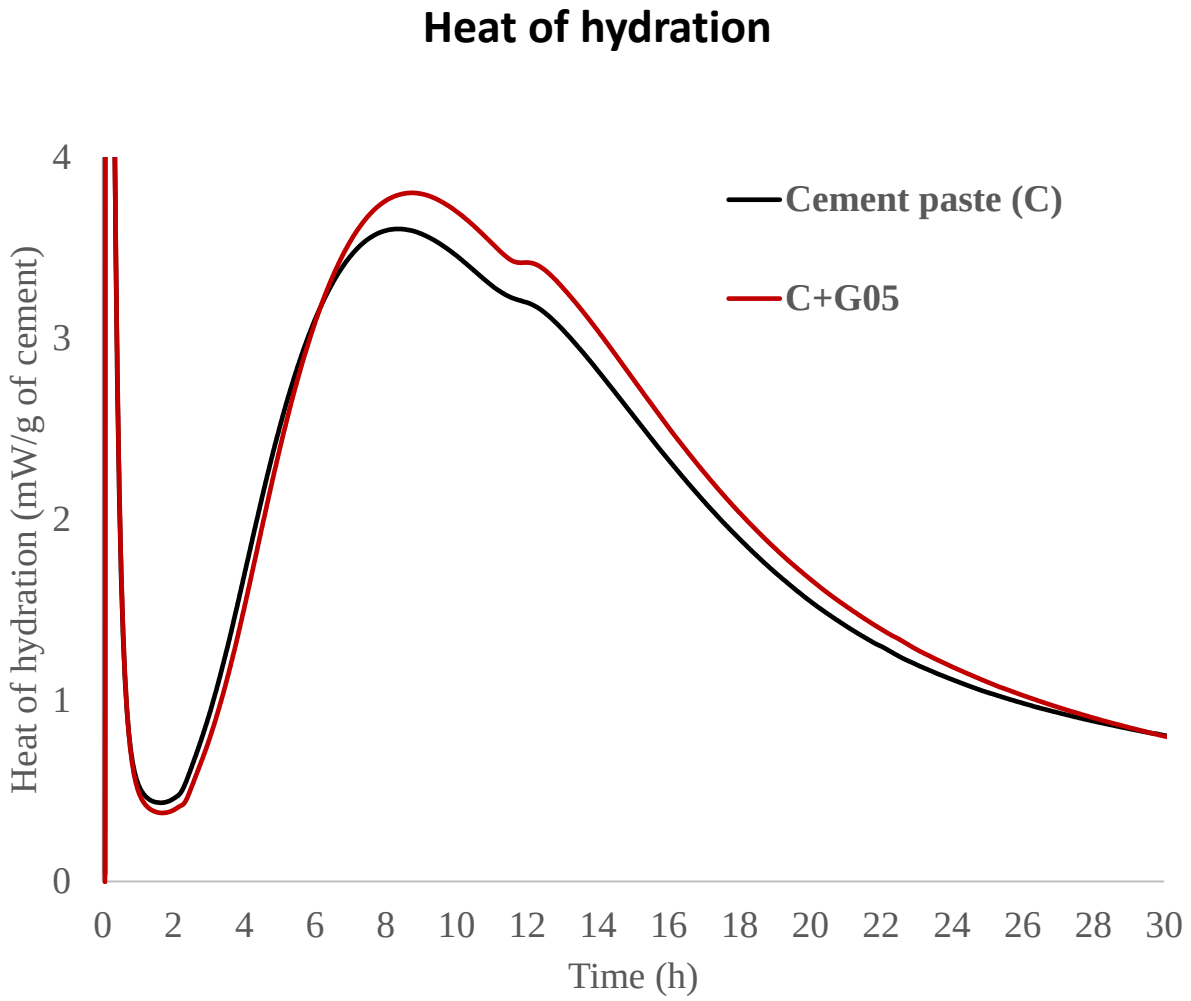




Cement particle surface at 15 min. of hydration

Meng et.al, Nanotechnology Reviews, 2021

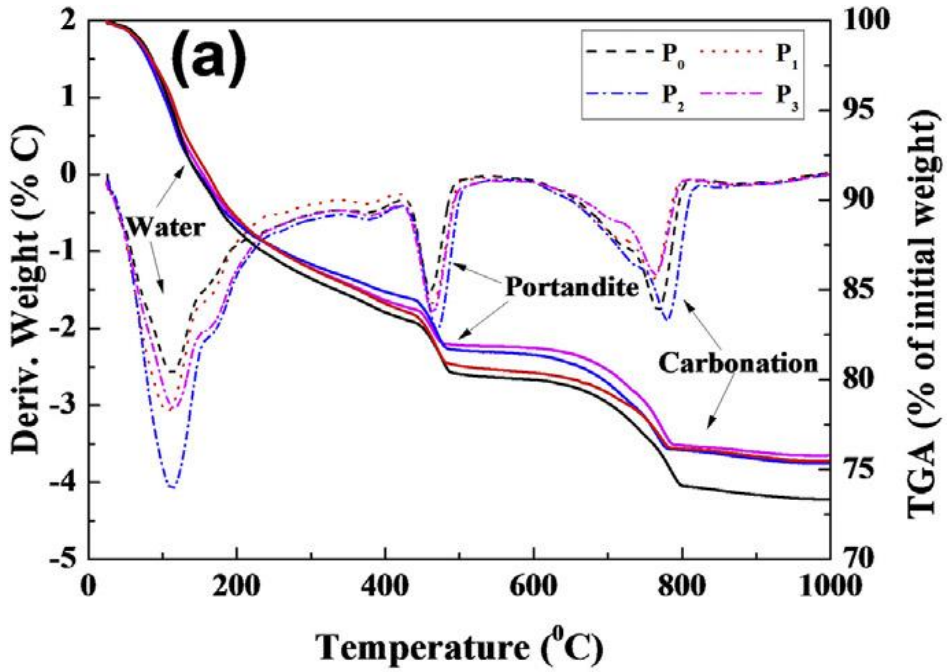
Effect of GO on cement paste hydration



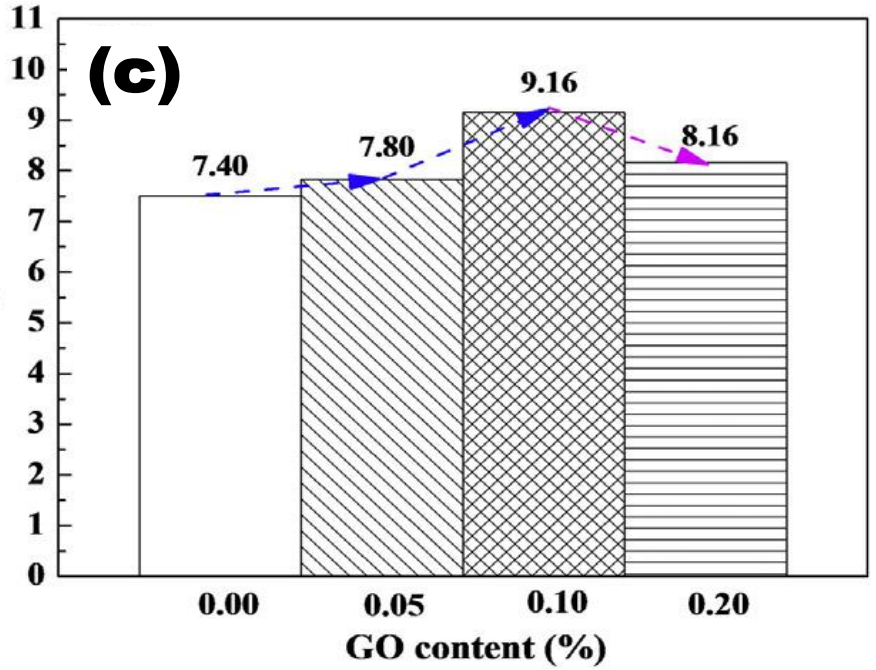
Mishra et. al. Journal of Building Engineering, 2022

Effect of GO on cement paste hydration

Thermogravimetric analysis (TGA)



$Ca(OH)_2$ formation (%)



Effect of GO on cement paste – NMR spectroscopy

Integrated area percentage of de-convoluted Si-NMR spectrum components

	OPC	OPC + GO
Q^4	1.8	3.5
Q^2	36.6	40.4
Q^1	53.7	55.9
Q^0	7.9	0.2
Total Q^n sum	100	100

Xu et. al, Carbon, 2019

Effect of GO on Compressive strength

Samples	At 28 day	
	Compressive strength (MPa)	% increase rate
GO-0	82.3	-
GO-1 (0.01%)	87.5	+6.3%
GO-3 (0.03%)	91.2	+10.8%

Wang et.al, Construction and Building Materials, 2019

CO_2 uptake and storage in Concrete

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CNN BUSINESS Markets Tech Media Success Perspectives Videos

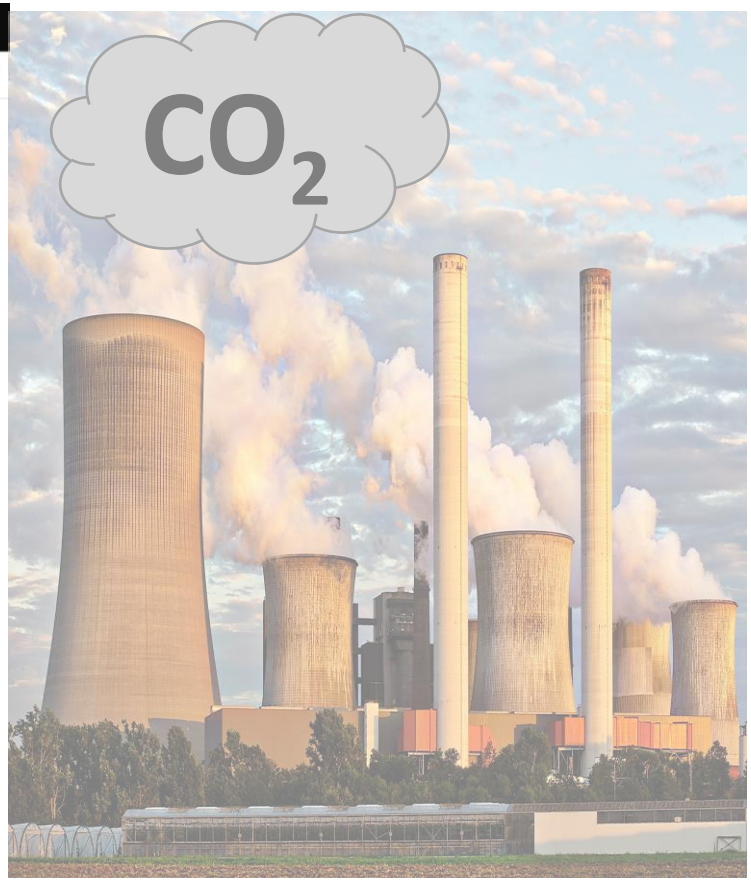
DOW -0.26% S&P 500 -0.08% NASDAQ +0.41% | FEATURED Crypto 101 | LATEST

The 'living concrete' that can heal itself

By Andrew Stewart, for CNN
Updated 12:15 PM EST, Mon March 7, 2016

Concrete Cancer : Alkali-silica reaction

SP-302-11
Putting Concrete to Sleep and Waking It Up with Chemical Admixtures



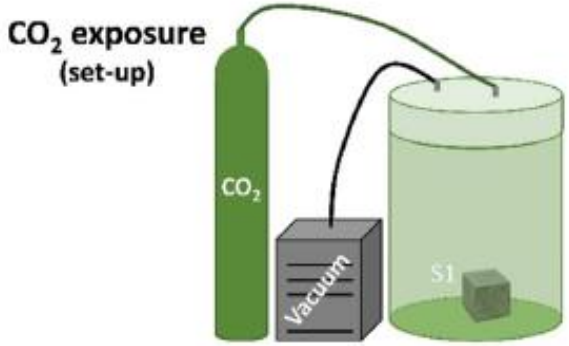
Can concrete breathe?

Is concrete alive?

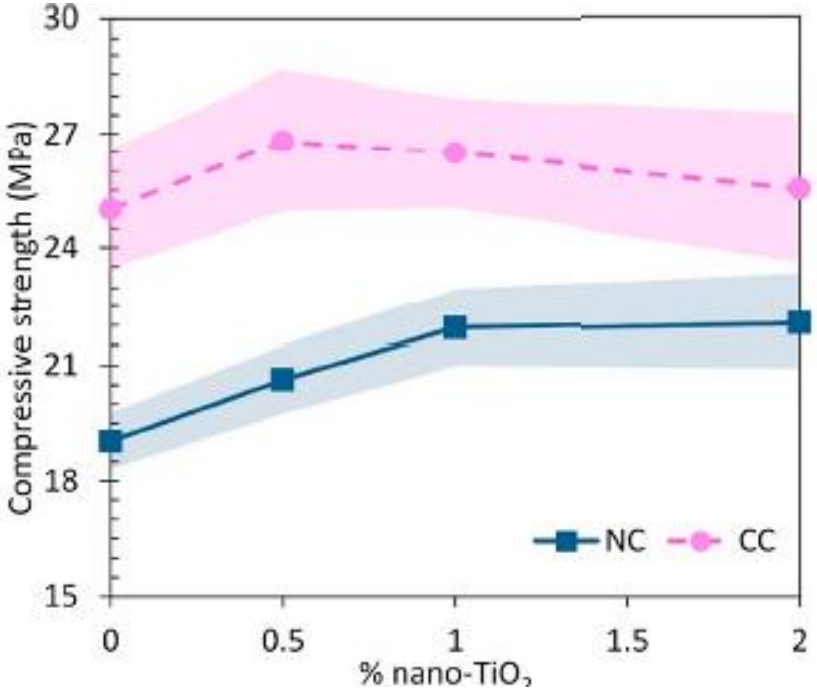
What does it inhale?

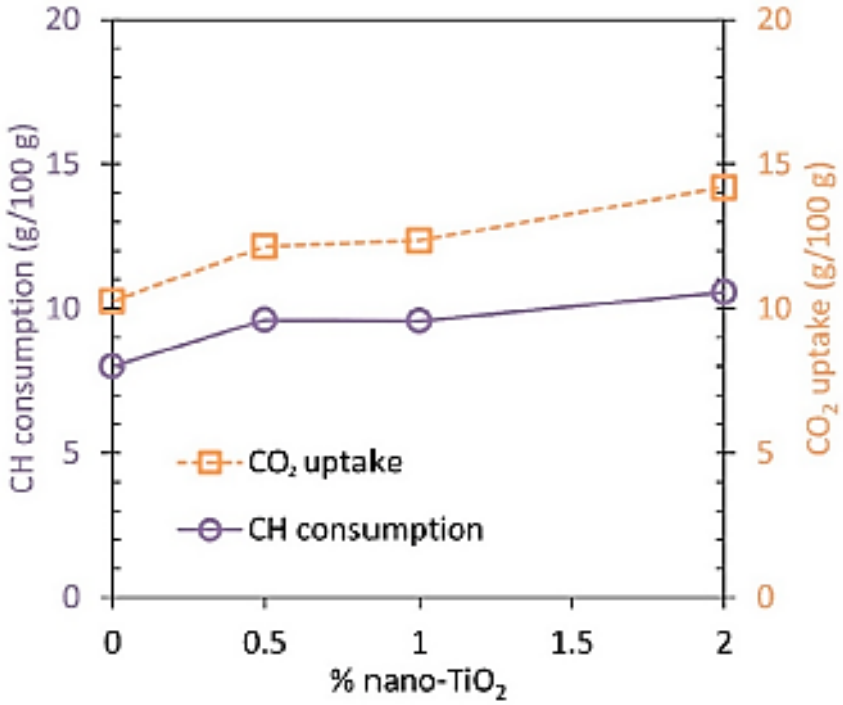
YES!

CO_2 sequestration using Nano-TiO_2



- Nano-TiO_2 improves CO_2 uptake and reduce CH crystal size during carbonation



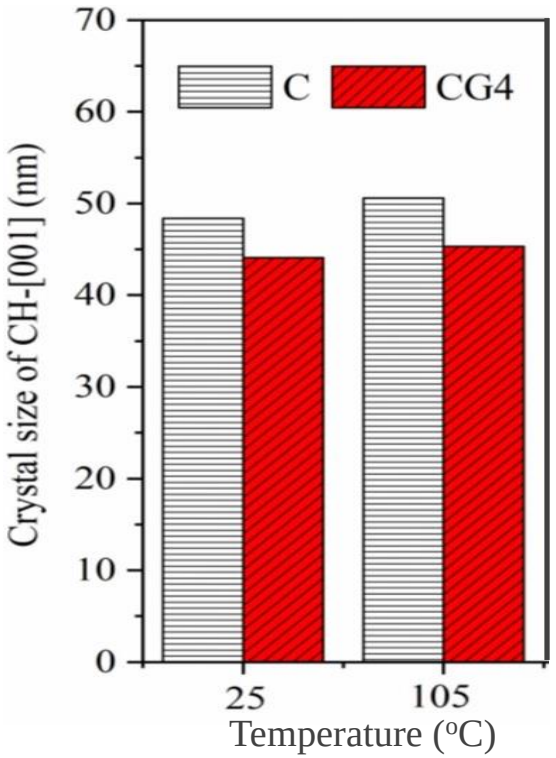


Source: Carlos Moro et.al. Construction and Building Materials, 2021

Change in CH crystal size

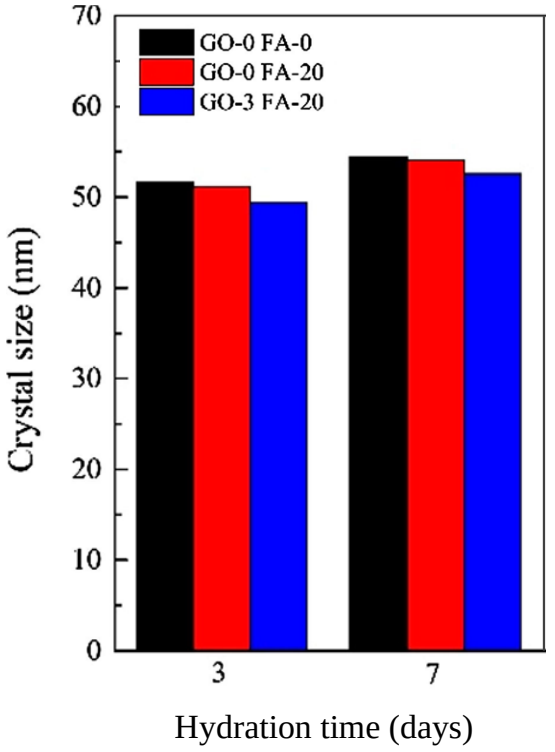
Graphene oxide (GO)

CG4 : C+ GO (0.04%)



Source: Chen et.al. Construction and Building Materials, 2022

GO (0.03%)+FA(20%)



Source: Wang et.al. Construction and Building Materials, 2019

Sample preparation and carbonation curing

1. Sample preparation

Graphene oxide(GO)

water

Shear mixing (1h at 1000rpm)

Dispersed GO solution

Specimens

2. Carbonation curing

Carbonation curing after 24h

Carbonation chamber

12% CO_2 concentration
65% RH
23°C

Mishra et. al. Journal of Building Engineering, 2022

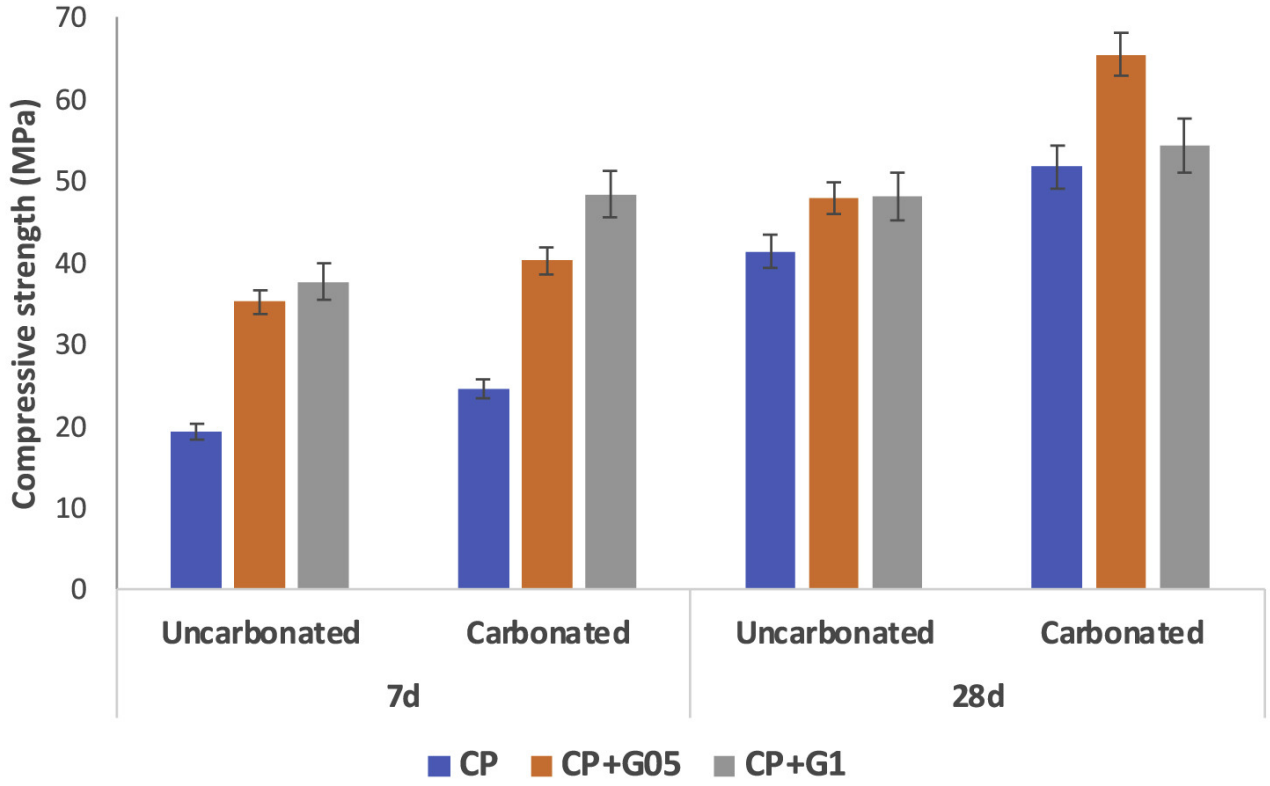
Mix composition and chemically bound water

S.No.	Mixes	Cement	GO	w/c
1	Cement paste	100%	0	0.5
2	C+G05	99.95%	0.05%	0.5
3	C+G1	99.90%	0.1%	0.5

Bound water in carbonated cement paste

Mixes	Chemically bound water (%)	
	7d-Carbonated	28d-Carbonated
Cement paste (CP)	15.66	15.91
CP+G05	16.18	16.86
CP+G1	16.21	16.18

Compressive strength



Compressive strength increased significantly with 0.05% of GO on carbonation

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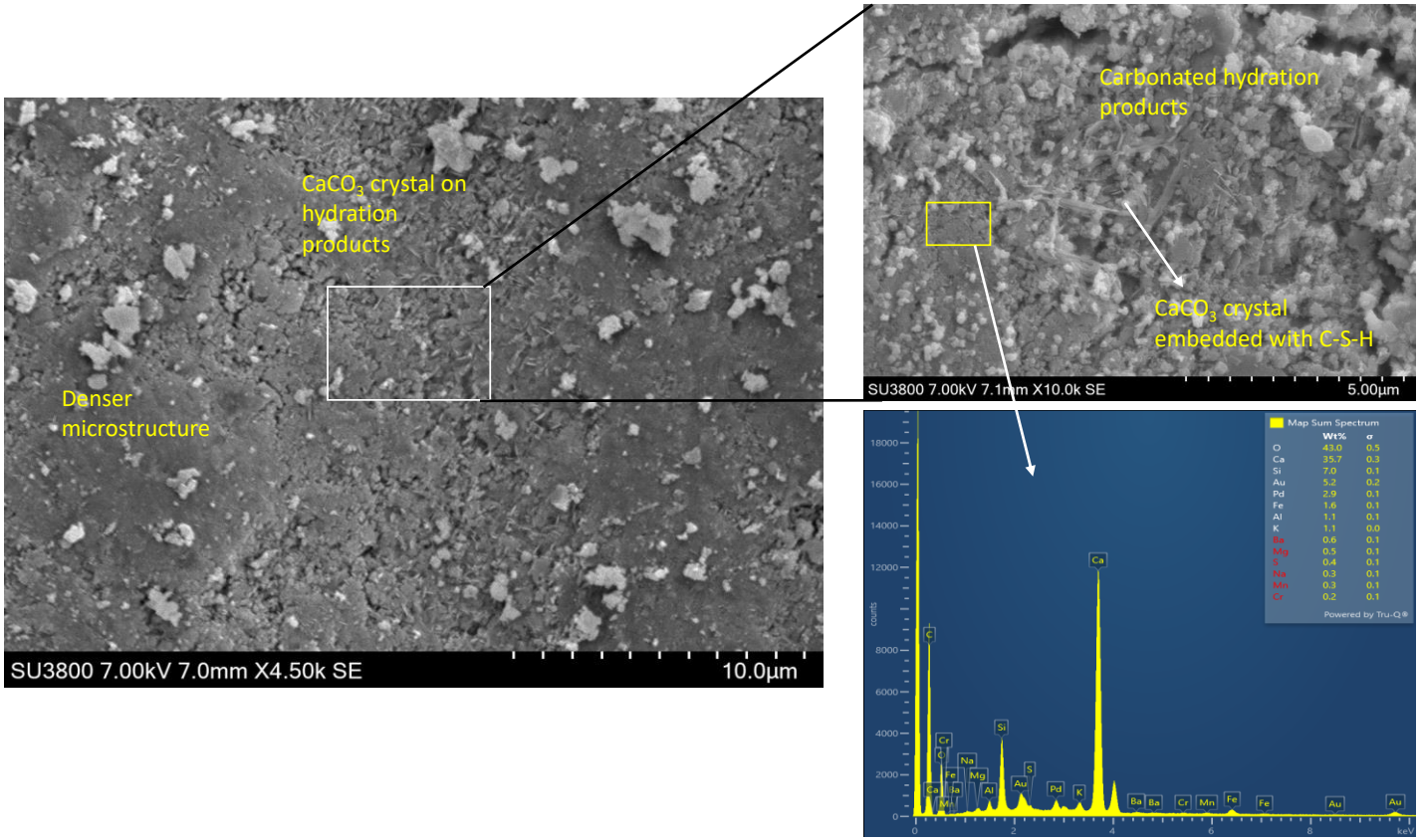
SEM micrographs



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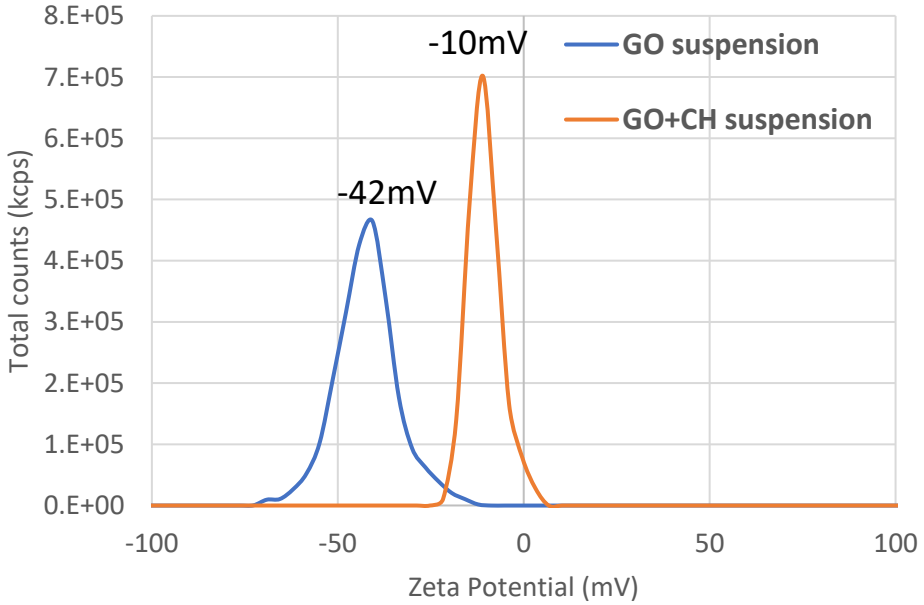
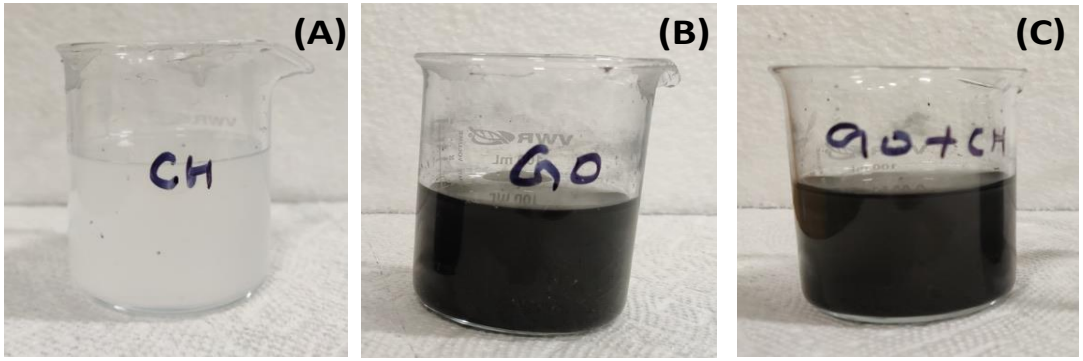
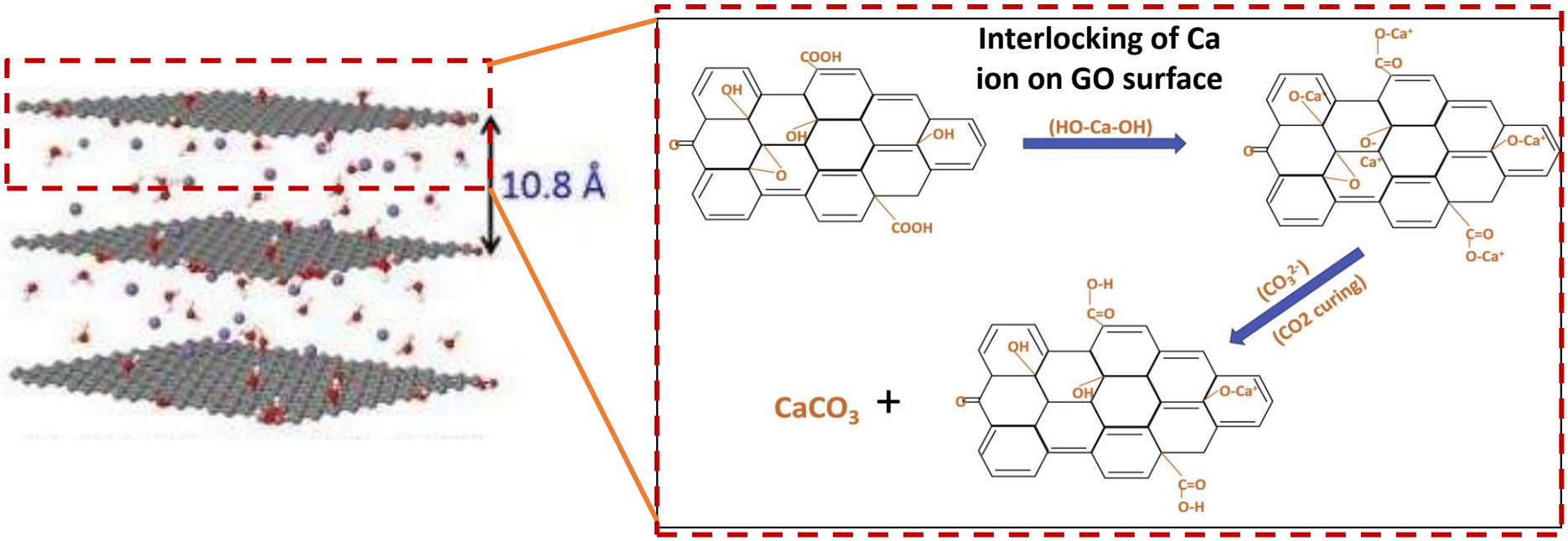
Zeta potential of GO and GO+CH solutions





Zeta potential → +0.4mV -42mV -10mV

Mechanism of CO_2 sequestration using Graphene oxide



Graphene oxide (GO)

Mechanism of CO_2 capture

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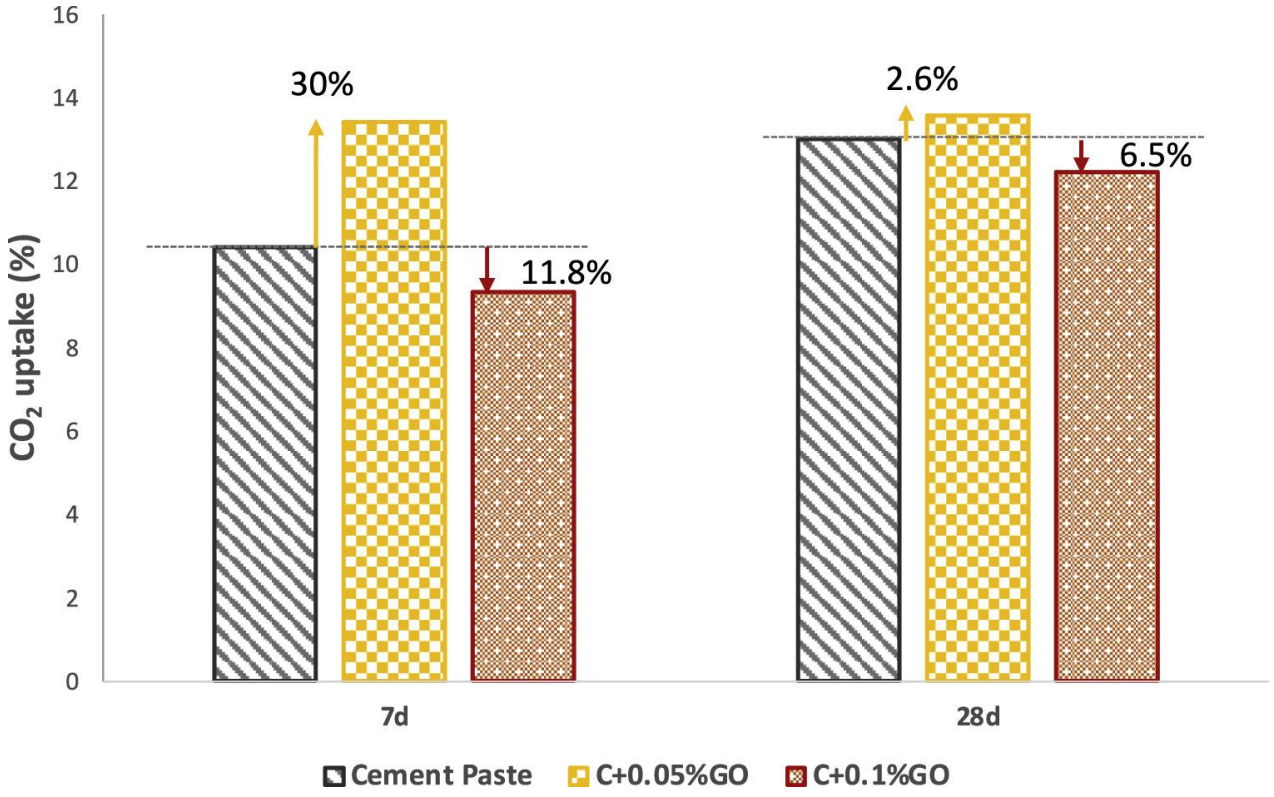
CO2 sequestration with graphene oxide – Thermogravimetric analysis



- 30% more CO_2 can be captured with a very small amount of GO (0.05%)
- Higher amounts densify the microstructure and restricted ingress of CO_2 in the matrix

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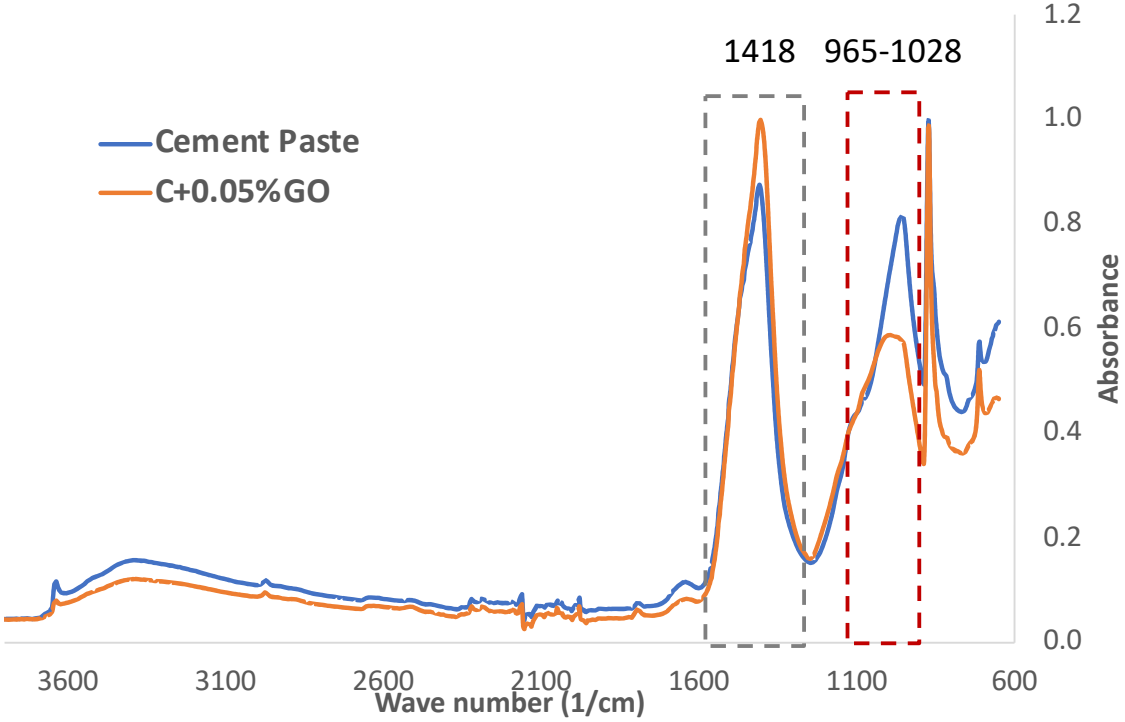
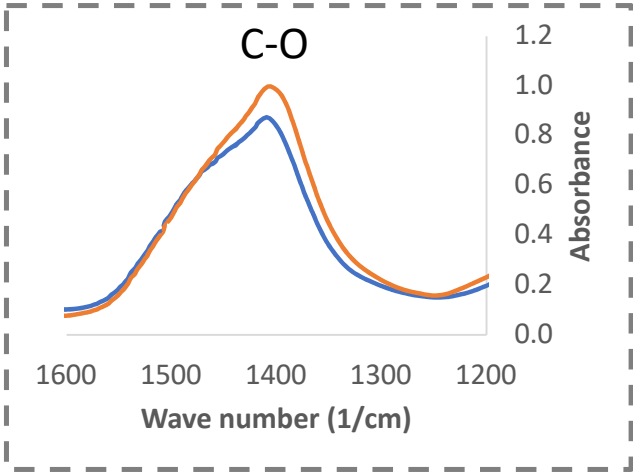
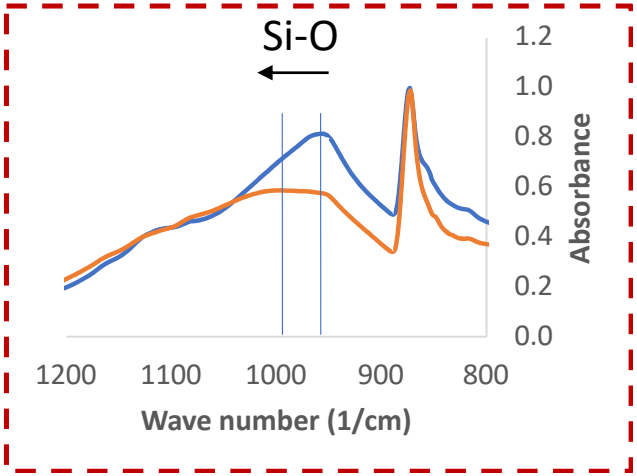
FTIR spectra showing C-S-H polymerization







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Conclusions

- Graphene based nanomaterials have the potential of increasing CO_2 uptake.
- Addition of graphene oxide change the orientation of $Ca(OH)_2$ and reduces the crystal size.
- Early age CO_2 curing accelerated the reaction kinetics and formed calcium carbonate, resulting improved compressive strength.
- Due to the presence of oxygen containing groups (-OH, -COOH), GO interlock the calcium ion (Ca^{2+}) and which reacts with the carbonates (CO_3^{2-}) obtained from the dissolution of CO_2 and promote the precipitation of $CaCO_3$.
- 30% more CO_2 can be captured with a very small amount of GO (0.05 wt%)

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Thank you!