Comparative Study of Graphene Oxides from Wyoming Powder River Basin Coal and Commercial Source on Concrete

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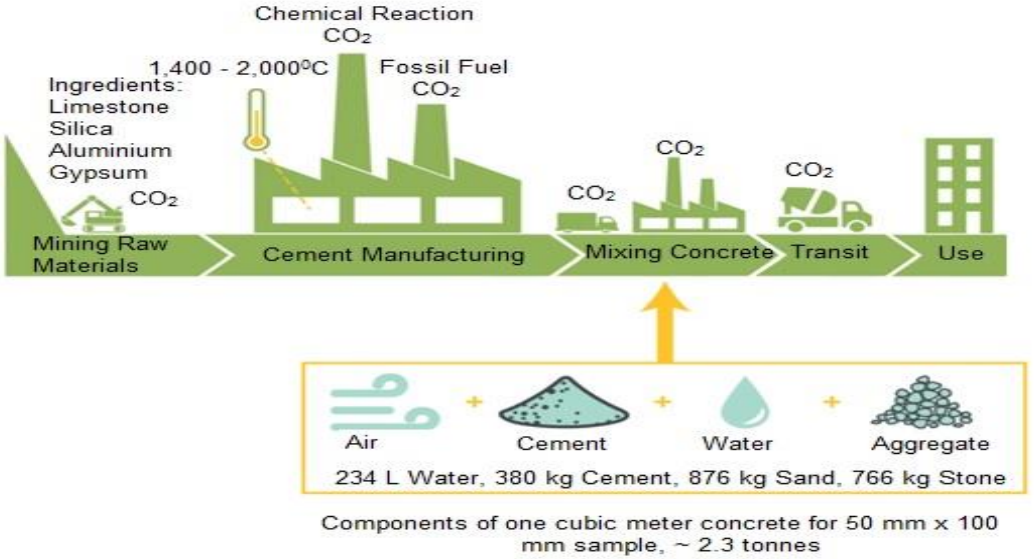
Outline of This Presentation

- Background
- Introduction to Graphene oxide (GO) and Reduced GO (rGO)
- Literature Review
- Current Research Gap
- Coal-derived GO and rGO in Concrete and Compare with Commercial GO
- Summary and Future Work

Background

- Cement industry accounts for around 8% of global CO_2 emissions [1].
- In 2023, cement production to an estimated 88 million tons in U.S., where the global production was 4.5 billion tons [2] .



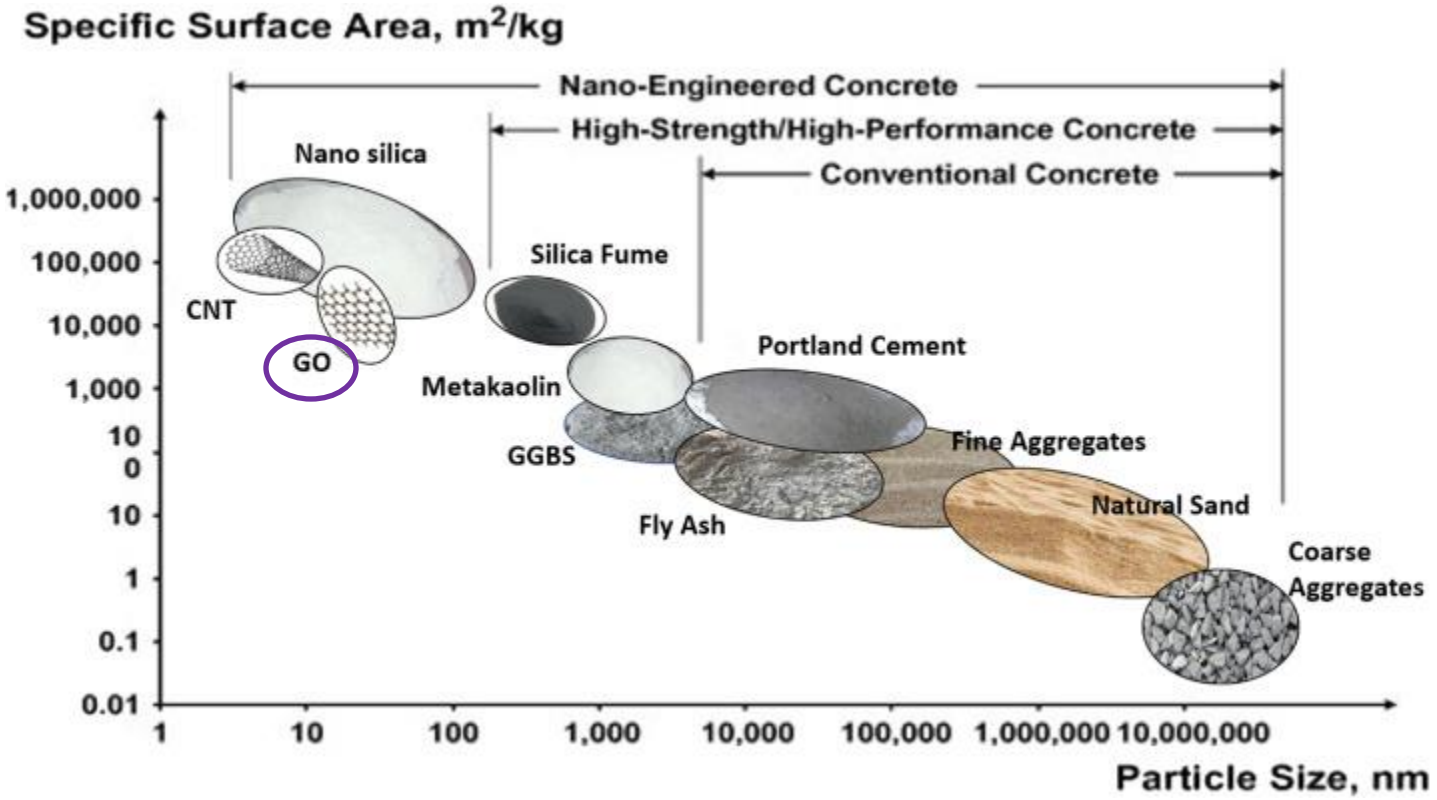
https://www.materialspalette.org/concrete/

https://tinyurl.com/53hkz2h5

As per data from the Portland Cement Association:

- For every ton of cement produced, approximately 900 kg of CO_2 are produced.

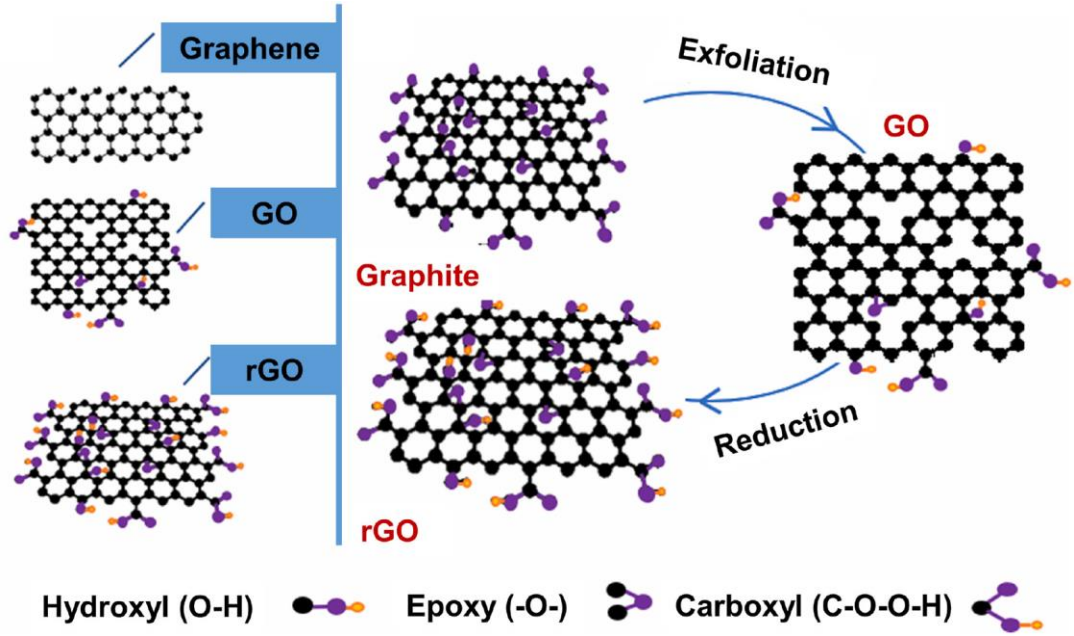
Use of Additives in Concrete



Paruthi, S., Rahman, I., Husain, A., Khan, A.H., Manea-Saghin, A.-M., Sabi, E., 2023. A comprehensive review of nano materials in geopolymer concrete: Impact on properties and performance. Developments in the Built Environment 16, 100287. https://doi.org/10.1016/j.dibe.2023.100287

Introduction to Graphene

- Thinnest imaginable material
  - Two dimensional
  - Single layer carbon atom
- Strongest material ever measured (theoretical limit)
  - Young's modulus of 1 TPa
  - Tensile strength of 130 GPa
- Record thermal conductivity (outperforming diamond)
- Stretchable crystal (up to 20% elasticity)

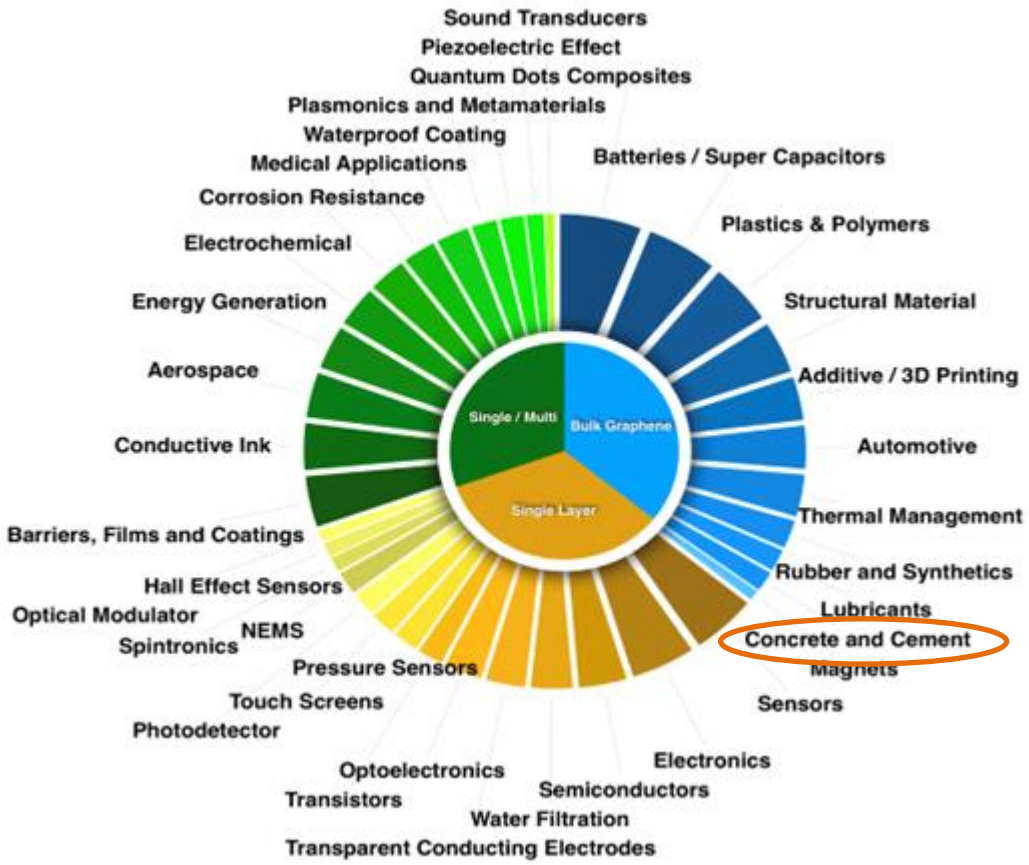


GO- Graphene oxide; rGO – Reduced graphene oxide

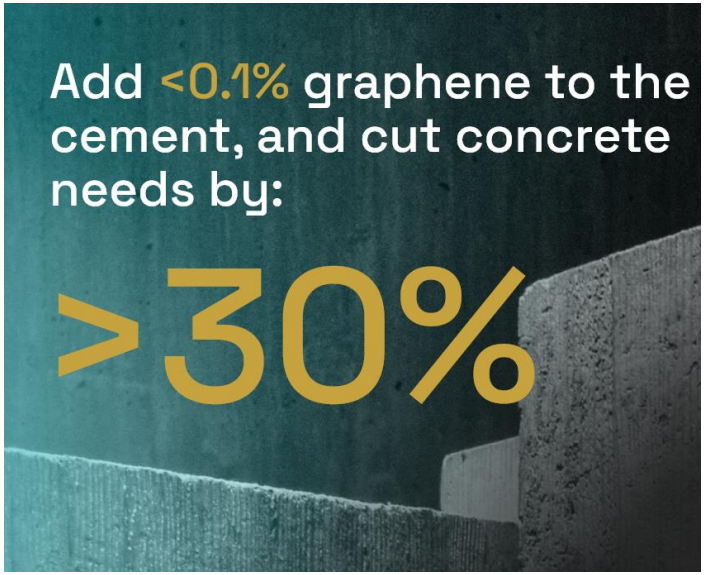
Xu, Y., Zeng, J., Chen, W., Jin, R., Li, B., Pan, Z., 2018. A holistic review of cement composites reinforced with graphene oxide. Construction and Building Materials 171, 291–302.

Barkan, T. (2019, March 8). Graphene nanomaterials unlocking new possibilities.

Graphene Oxide in Concrete

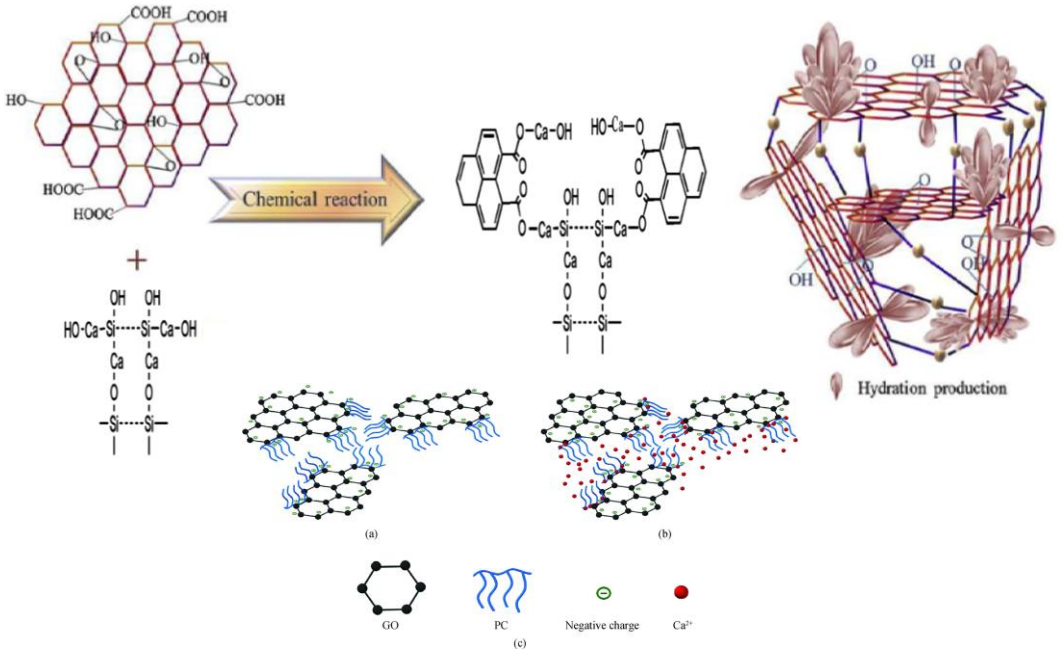


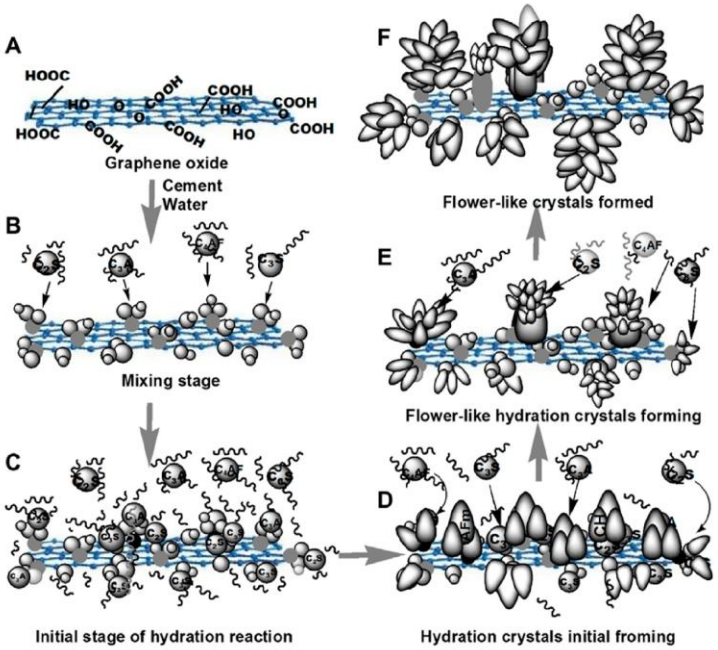
Barkan, T. (2019, March 8). Graphene nanomaterials unlocking new possibilities.

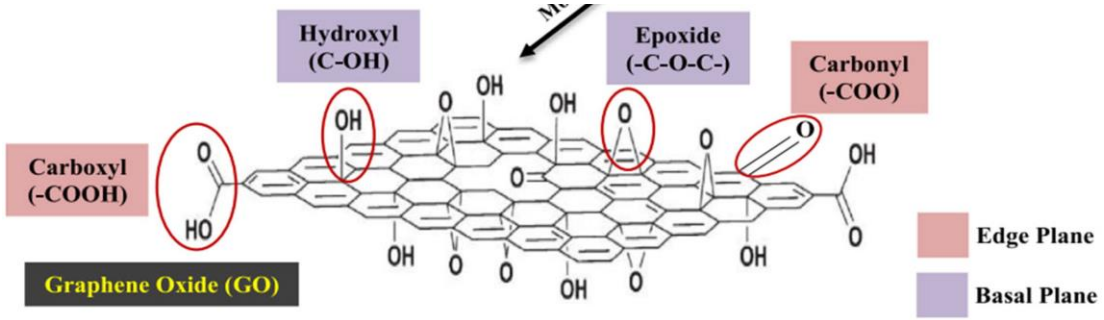


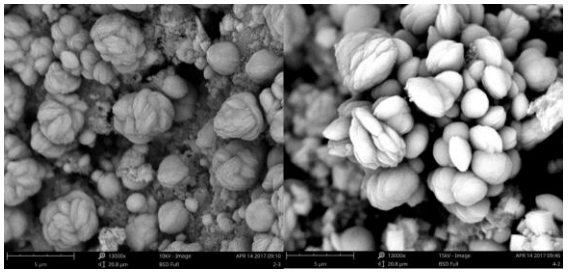
Devi, S.C., Khan, R.A. "Effect of graphene oxide on mechanical and durability performance of concrete". J. Build. Eng. 27 (2020)

Graphene Oxide in Concrete









https://doi.org/10.1016/j.conbuildmat.2018.03.147

https://doi.org/10.1080/01932691.2024.2334861

Graphene Oxide in Concrete

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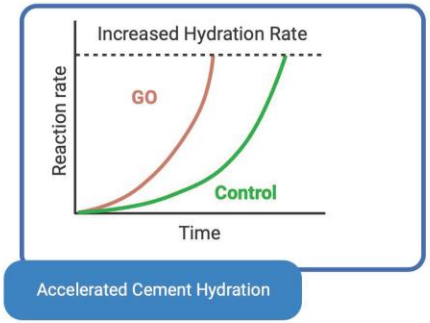
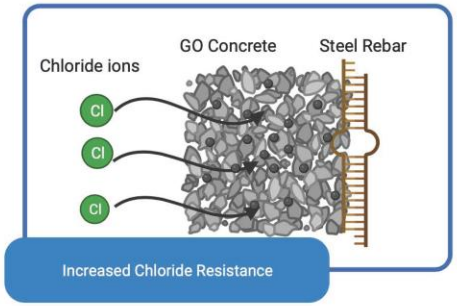
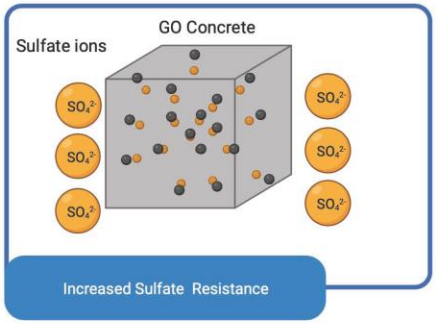
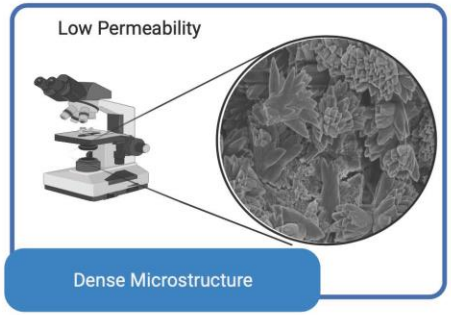
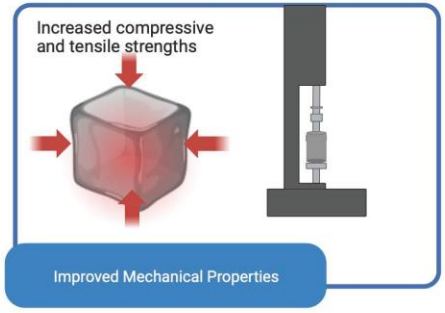
Benefits











https://tinyurl.com/5hc4s7yc

Problems associated with GO-concrete

Problems
Impact on workability
Dispersion issues
Optimization of dosage
Cost and Scalability

Purpose of This Research

- Understand how to reduce CO_2 that results from the production of cement by using coal-derived GO and rGO.

- Compare the performance of coal derived GO and rGO concrete with that of commercially available graphite-derived GO in terms of key concrete properties.

Coal-derived GO

Commercial GO

Wyoming Coal Reserves

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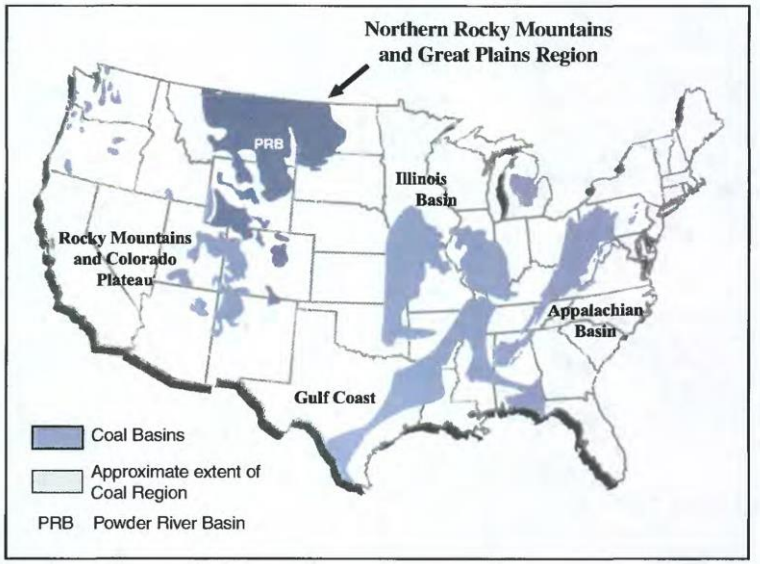
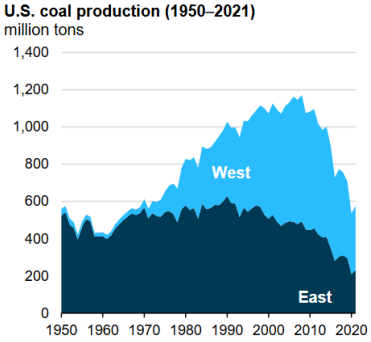
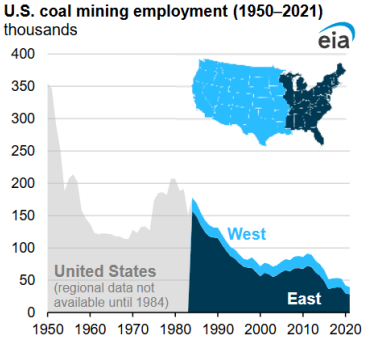
Price Barrier

Precursor and Products	Price [$/kg]
Graphene, Monolayer graphene film	320,000
Industrial Graphene Oxide Bulk Powder products	14,000
Reduced Graphene Oxide Powder	3,000
Graphite Flake	850
Wyoming subbituminous PRB coal	0.016
Coal-derived GO/rGO (UW Lab scale production)	3 ~ 4

Data cited from: https://www.acsmaterial.com







Data cited from: U.S. Energy Information Administration, Annual Coal Report; U.S. Department of Labor, Mine Health and Safety Administration

GO and rGO from PRB coal

[3]

US 20210214231A1

(19) **United States**

(12) **Patent Application Publication**

JOHNSON et al.

(10) **Pub. No.: US 2021/0214231 A1**

(43) **Pub. Date: Jul. 15, 2021**

(54) **METHODS FOR PRODUCTION OF GRAPHENE OXIDE**

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(72) Inventors: **Patrick JOHNSON**, Laramie, WY (US); **Ana Paula MARTINS LEANDRO**, Laramie, WY (US)

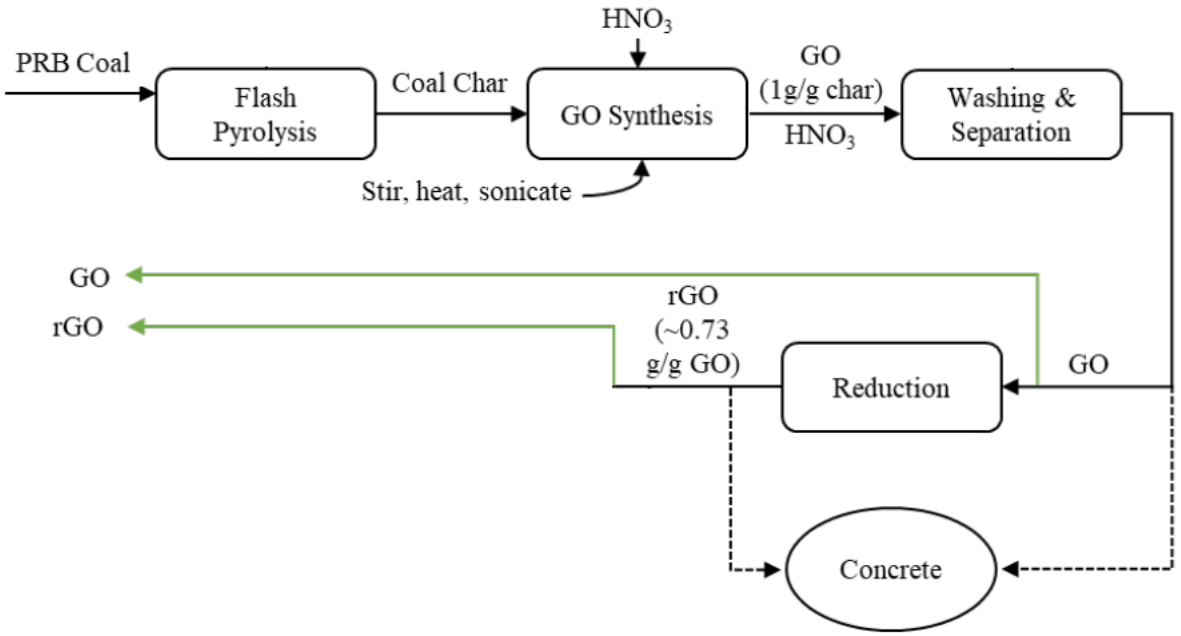
(73) Assignee: **UNIVERSITY OF WYOMING**, Laramie, WY (US)

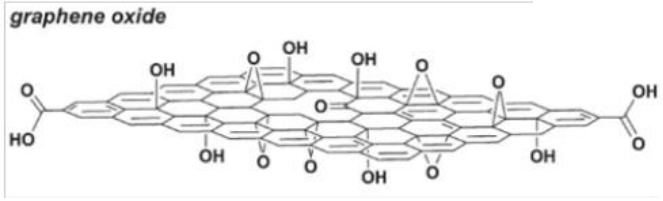
(21) Appl. No.: **17/149,242**

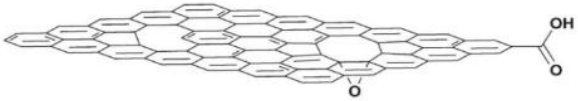
(22) Filed: **Jan. 14, 2021**

Related U.S. Application Data

(60) Provisional application No. 62/961,550, filed on Jan. 15, 2020.







reduced graphene oxide

[4] Leandro et al., 2021

Microstructure Analysis - SEM

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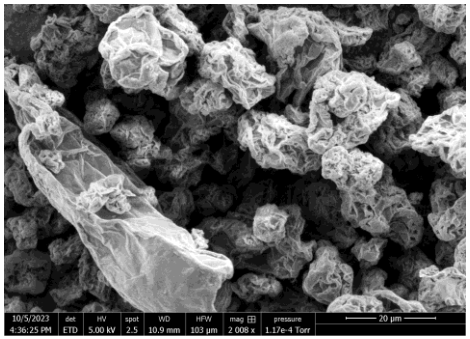
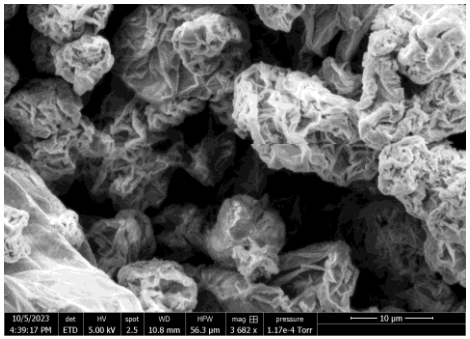
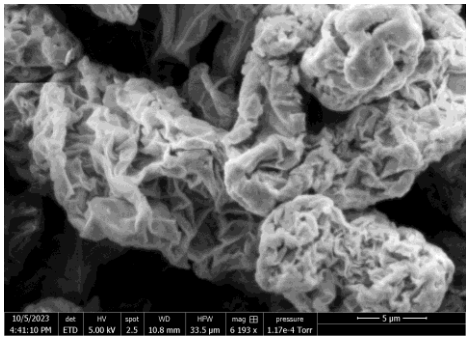
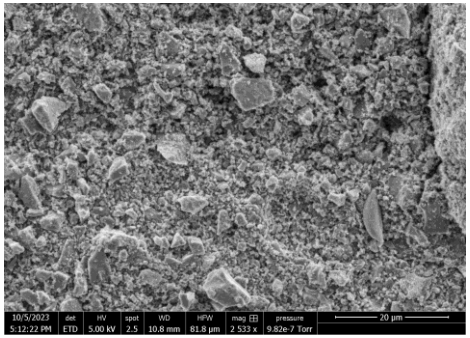
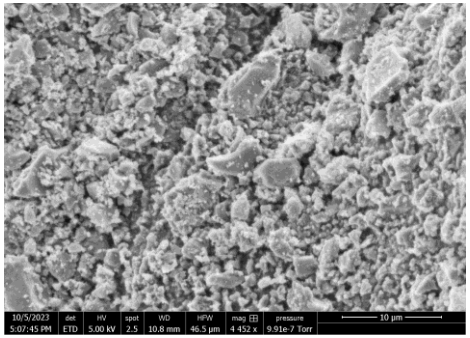
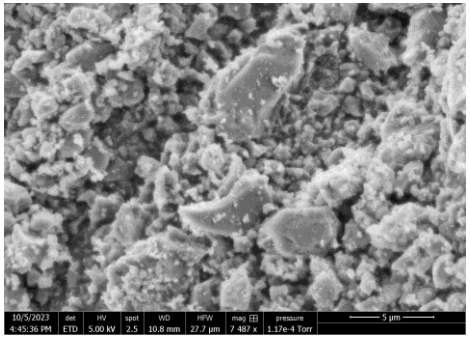
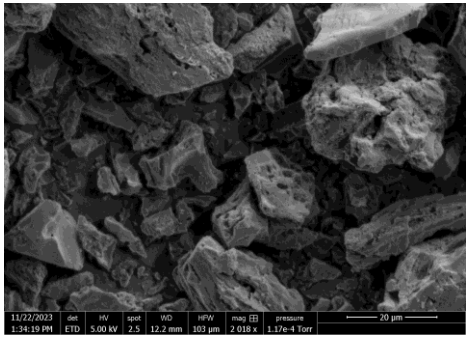
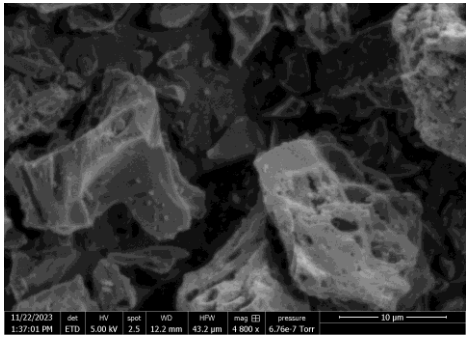
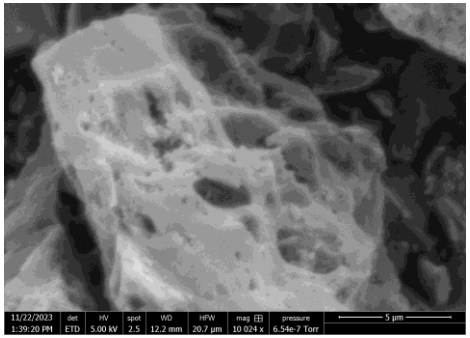
Scale: 20 µm | Scale: 10 µm | Scale: 5 µm

Commercial GO

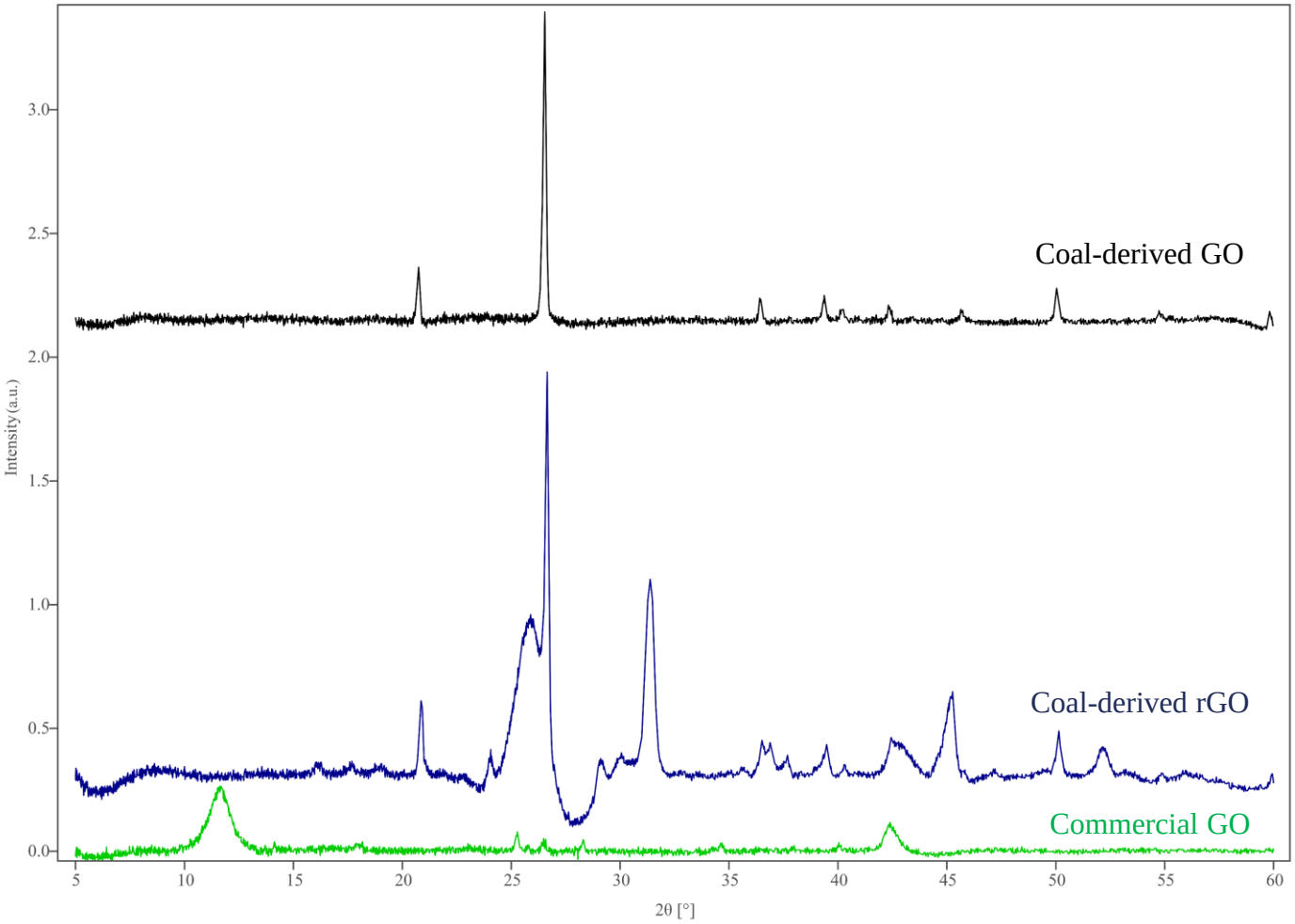
Lateral size (µm)	0.2-10
pH	~ 3.57
Carbon/Oxygen ratio	0.83

Coal-derived GO

Lateral size (µm)	0.3-1
pH	~ 3.0
Carbon/Oxygen ratio	1.84

Coal-derived rGO

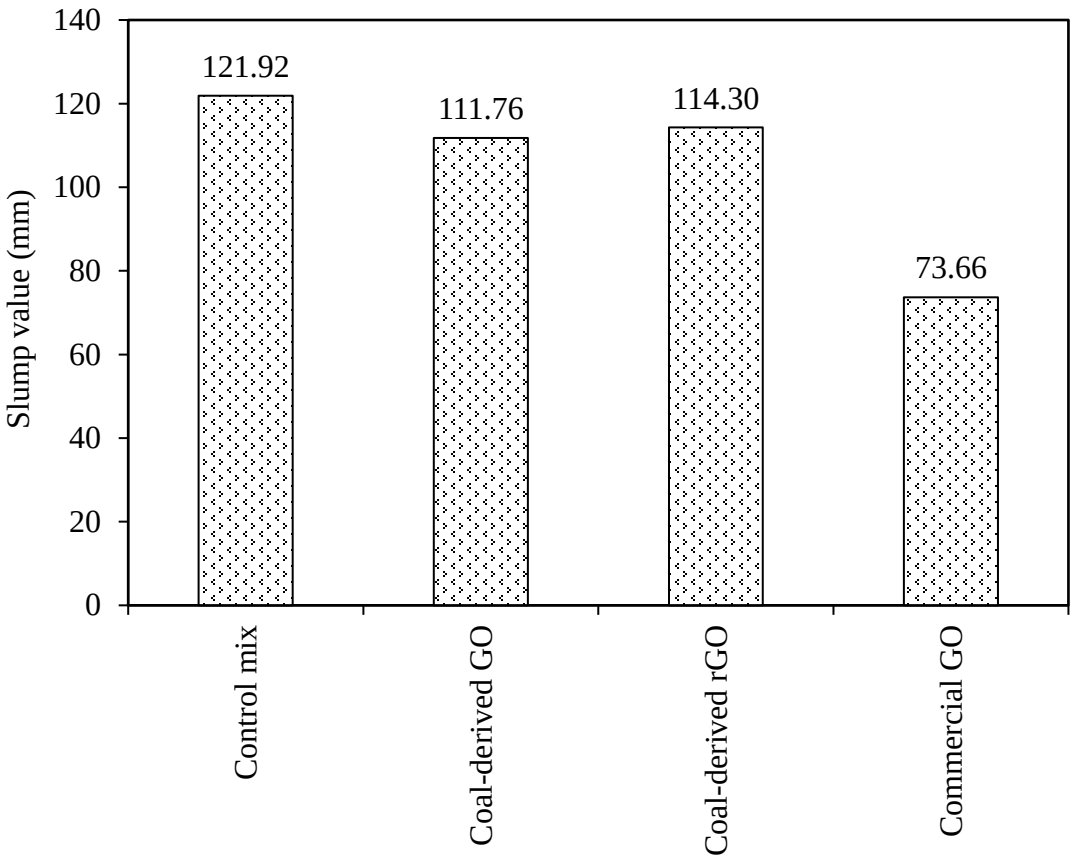
Microstructure Analysis - XRD

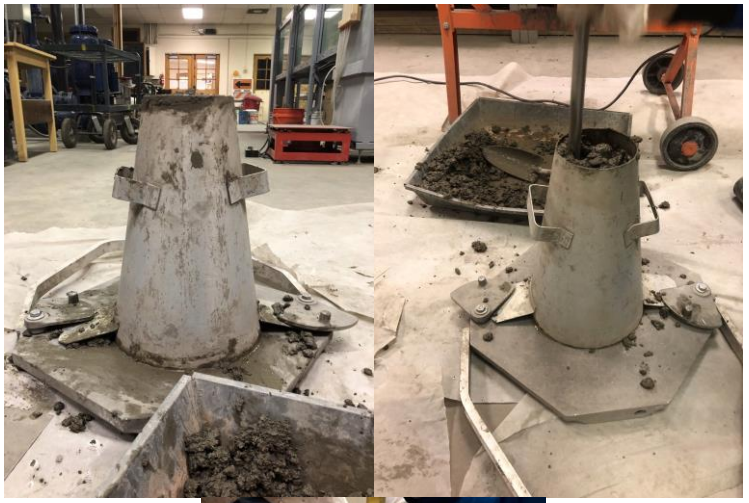


Workability of Concrete

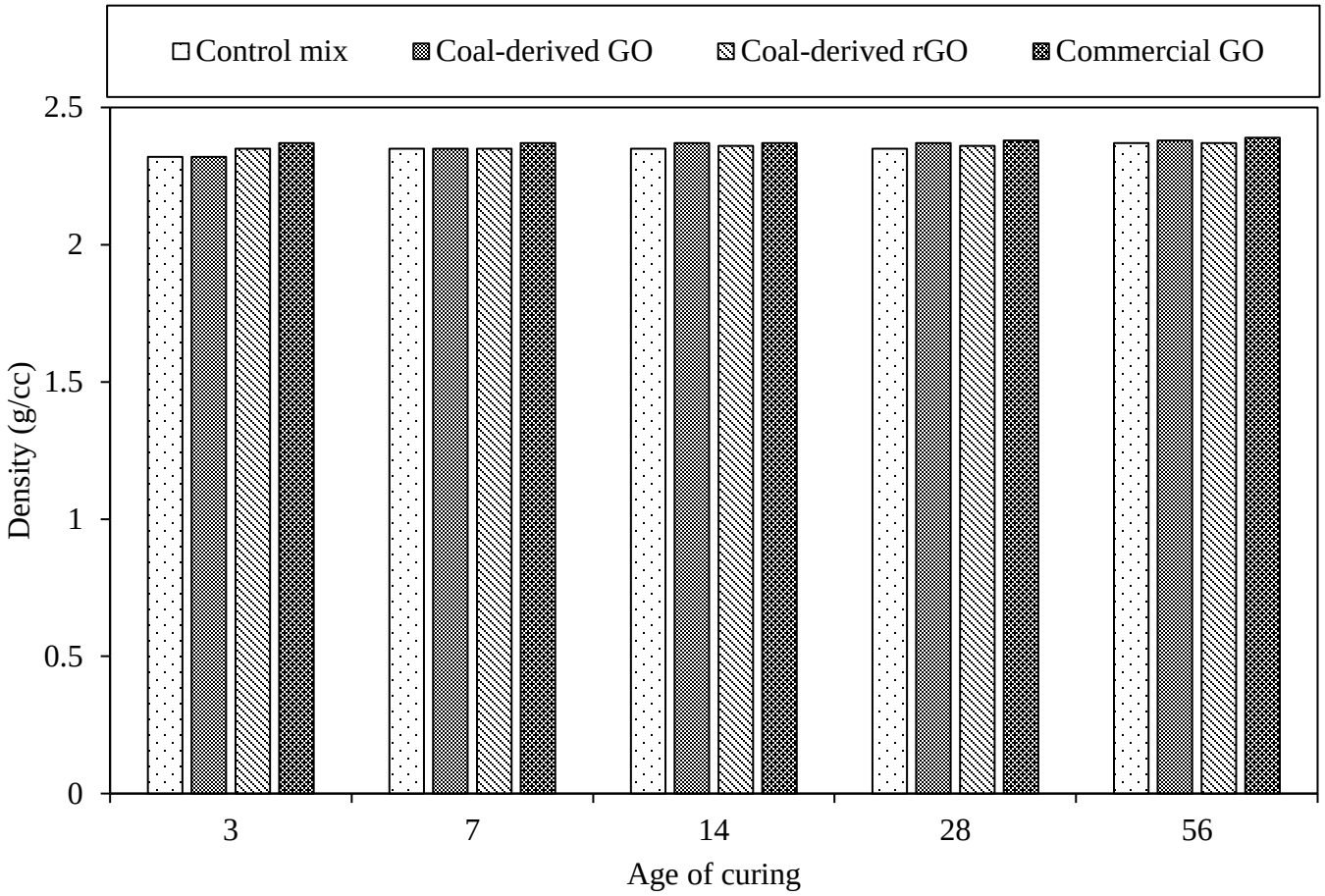
w/c – 0.6

Percentage of additives – 0.05% by weight of cement

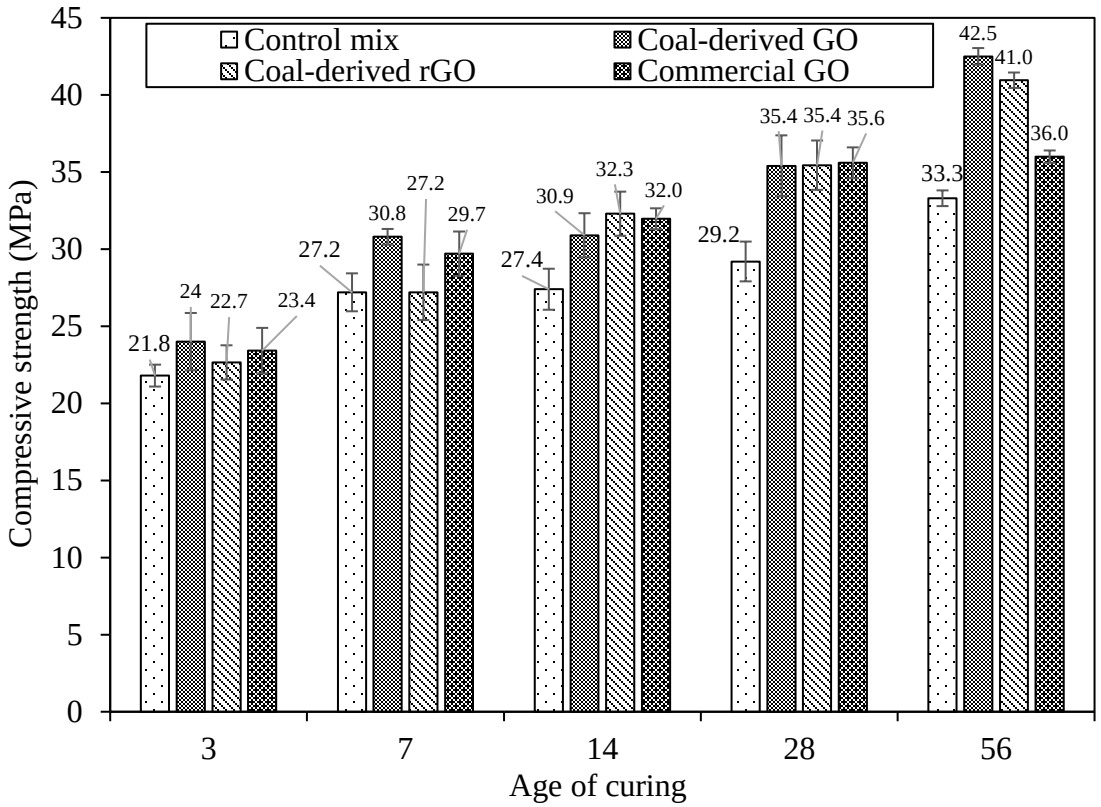




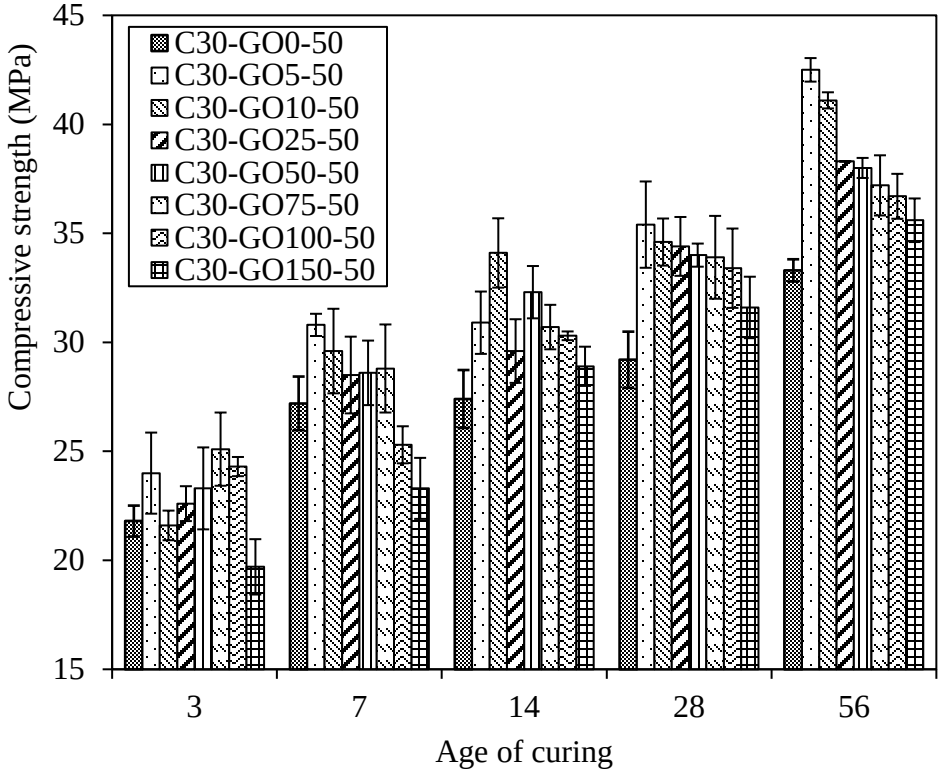
Density of Concrete

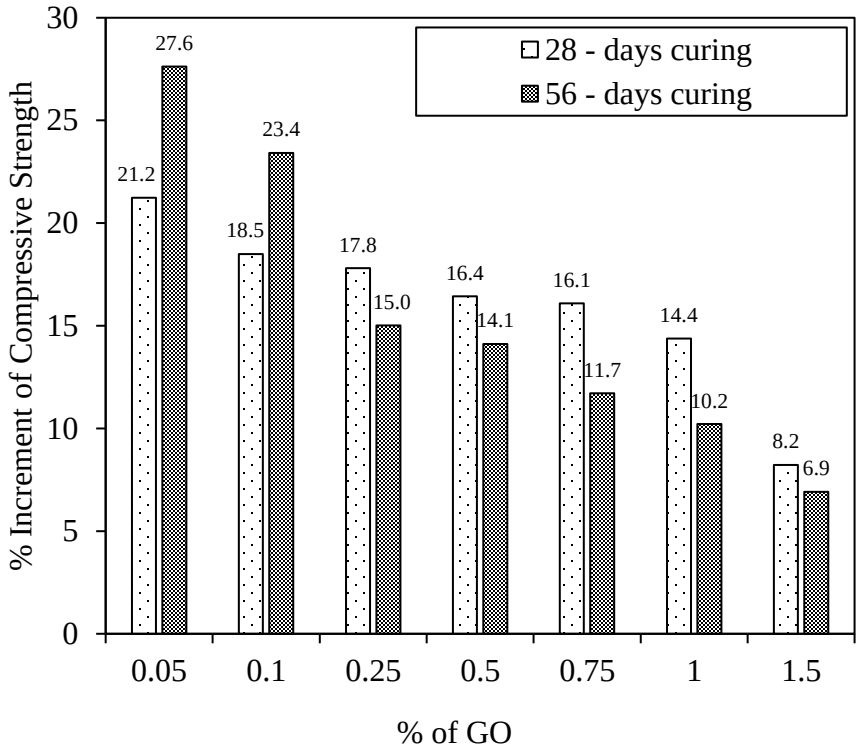


Compressive Strength of Concrete

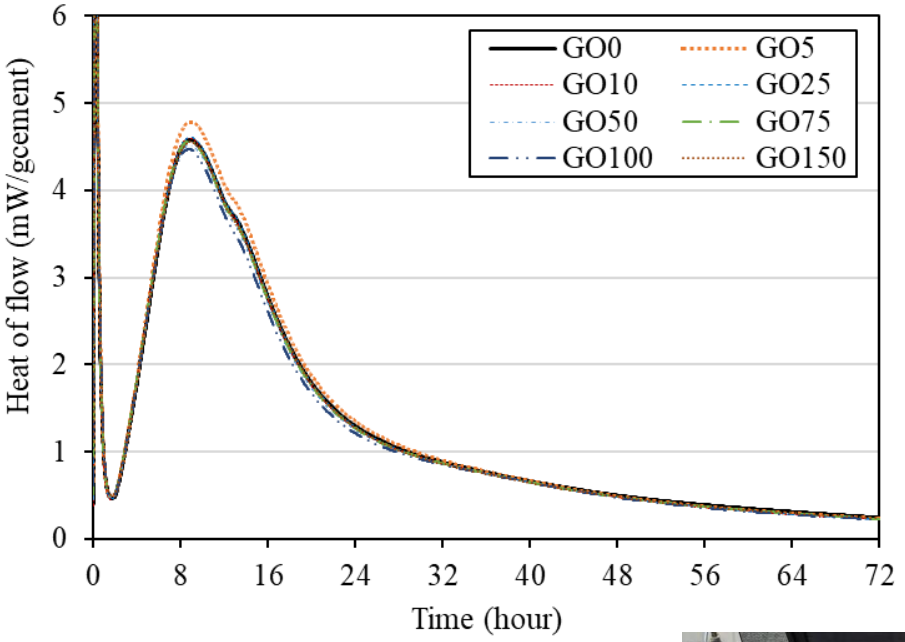


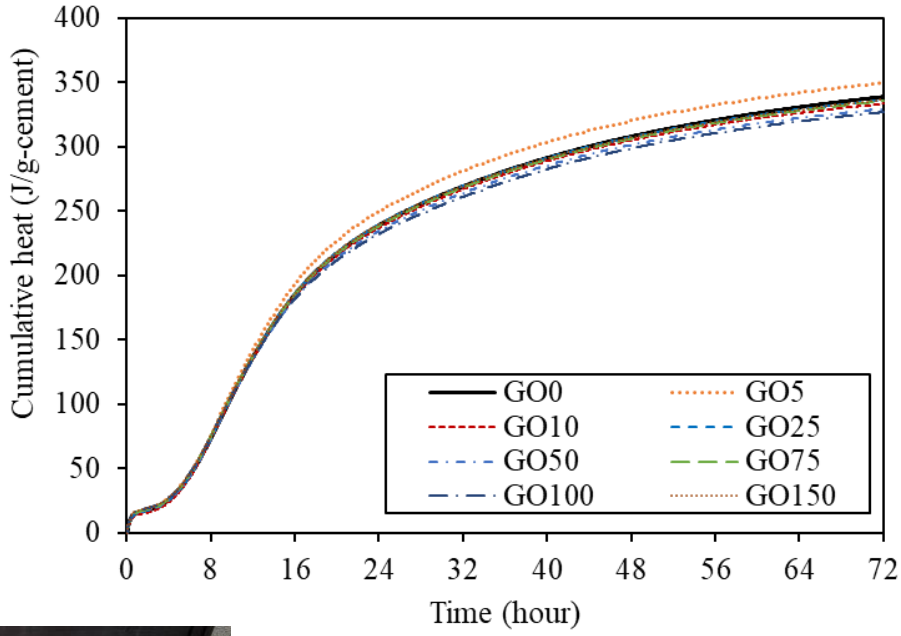
Compressive Strength of Concrete

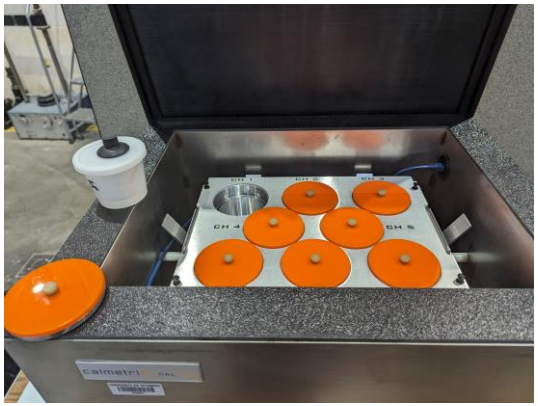




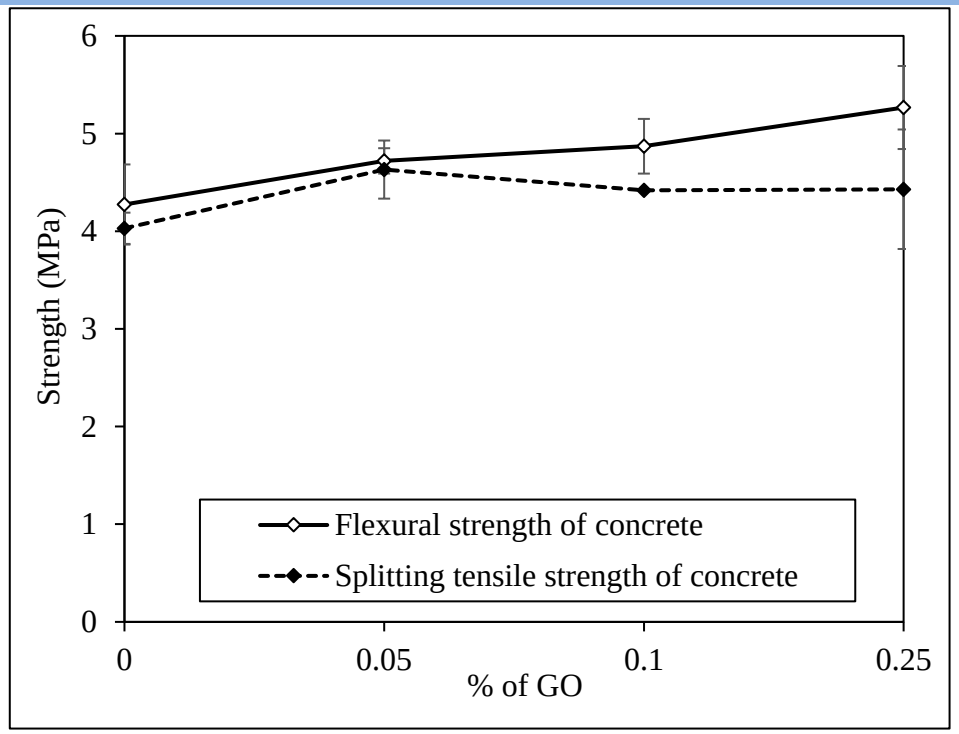
Calorimetric Analysis

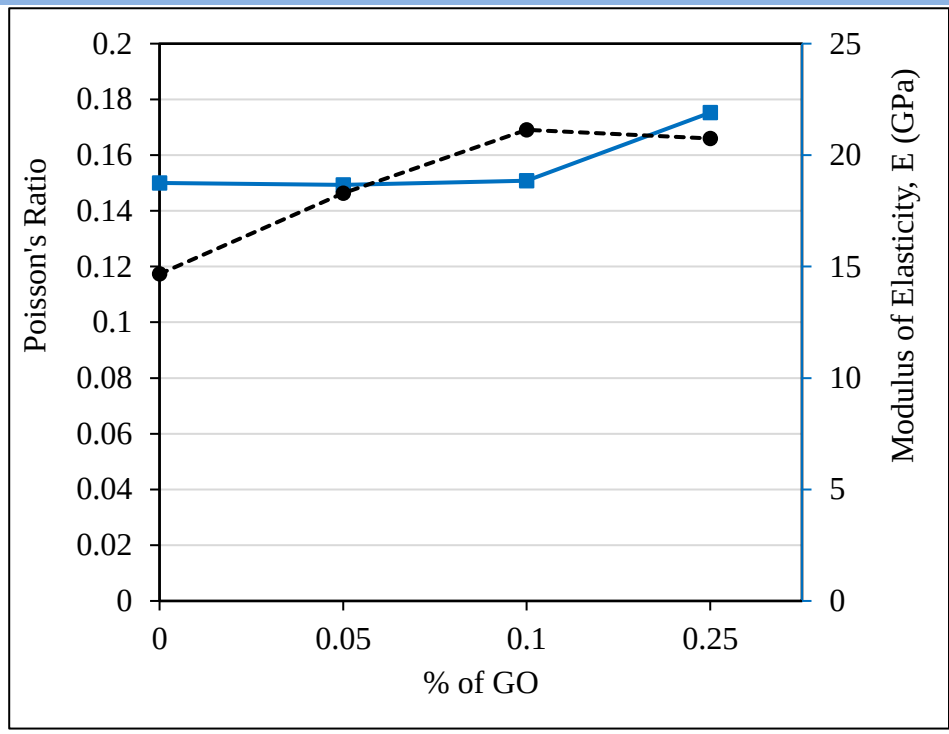


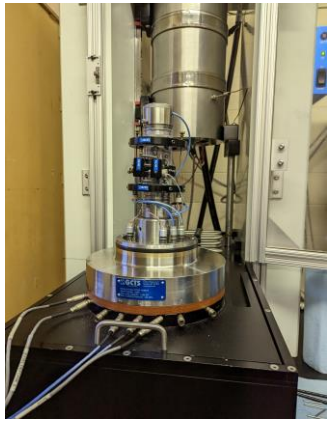




Other Properties in GO-Concrete



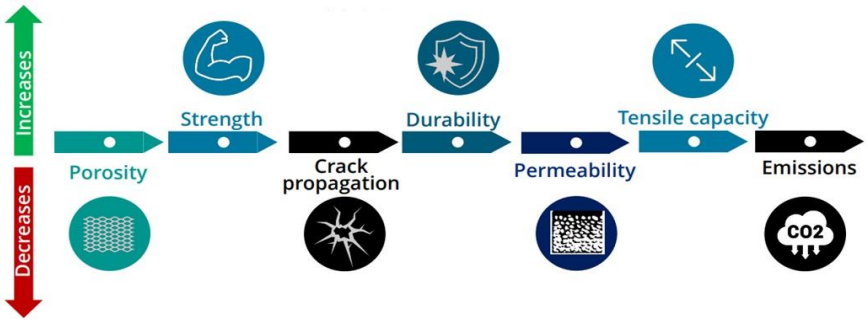




Summary and Future Work

- Adding 0.05% by wt of cement of GO improves concrete strength by 27.6%, reducing cement use and carbon footprint.

- For future studies, we plan to
  - Expand further range of graphene oxide percentages to determine the optimal amount.
  - Evaluate the other mechanical, microstructural, and durability properties of concrete.



Patent and References

Patent:

Concrete using coal-derived graphene oxide and methods of making the same. Provisional patent application to the U.S. Patent and Trademark Office. (Patent application No. 63/439,529).

Journal Under Review:

Effect of coal-derived graphene oxide on the mechanical and microstructural characteristics of concrete.

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[1] Ellis, L.D., Badel, A.F., Chiang, M.L., Park, R.J. -y., Chiang, Y.-M., 2019. Toward electrochemical synthesis of cement—An electrolyzer-based process for decarbonating CaCO3 while producing useful gas streams. Proceedings of the National Academy of Sciences 117, 12584–12591. https://doi.org/10.1073/pnas.1821673116

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[4] Leandro, A.P.M., Seas, M.A., Vap, K., Tyrrell, A.S., Jain, V., Wahab, H., Johnson, P.A., 2021. Evolution of structural and electrical properties in coal-derived graphene oxide nanomaterials during high-temperature annealing. Diamond and Related Materials 112, 108244. https://doi.org/10.1016/j.diamond.2021.108244

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UW School of Energy Resources

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Thank you for your attention

Questions?

Comparative Study of Graphene Oxides from Wyoming Powder River Basin Coal and Commercial Source on Concrete Compressive Strength

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