D/CARB GROUP

Transforming Agricultural Residues into High-Performance SCMs through High-Energy Ball Milling

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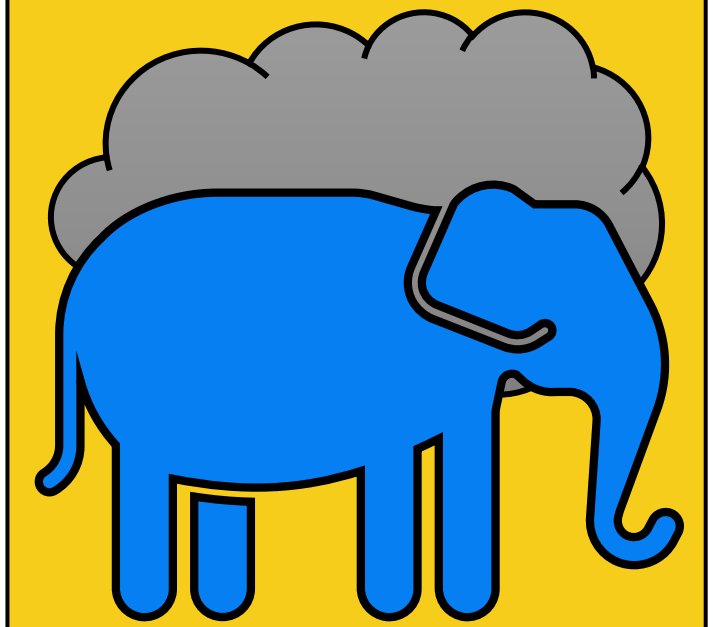
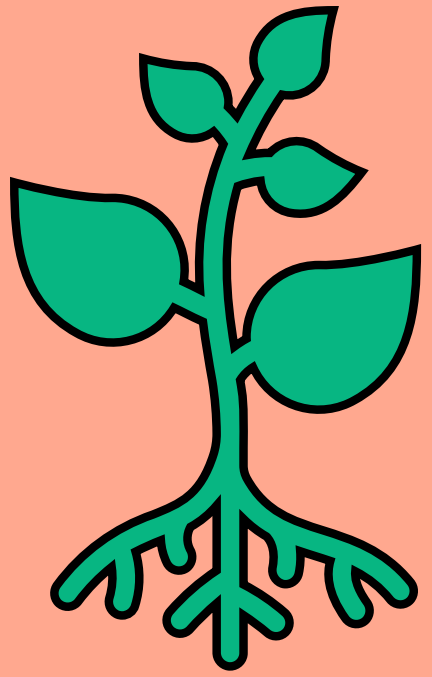
Architectural Engineering Department | The Pennsylvania State University

Why use less cement?



Why use Supplementary Cementitious Materials (SCMs)?

Why use cereal crops as SCMs?



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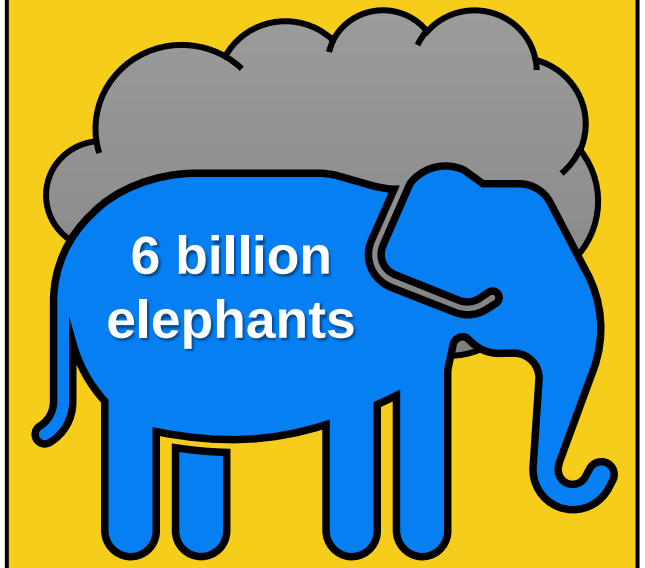

37 gigatons of CO_2 emissions a year globally

IEA (2023), *CO2 Emissions in 2022*, IEA, Paris https://www.iea.org/reports/co2-emissions-in-2022, Licence: CC BY 4.0

Our top 10 facts about elephants | *WWF*. (2024, January 31). https://www.wwf.org.uk/learn/fascinating-facts/elephants

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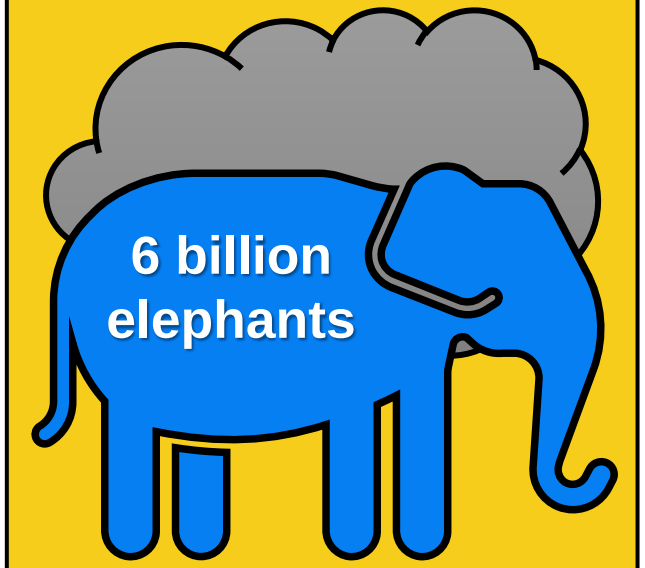

Cement is 3rd largest source of human made CO_2 Emissions

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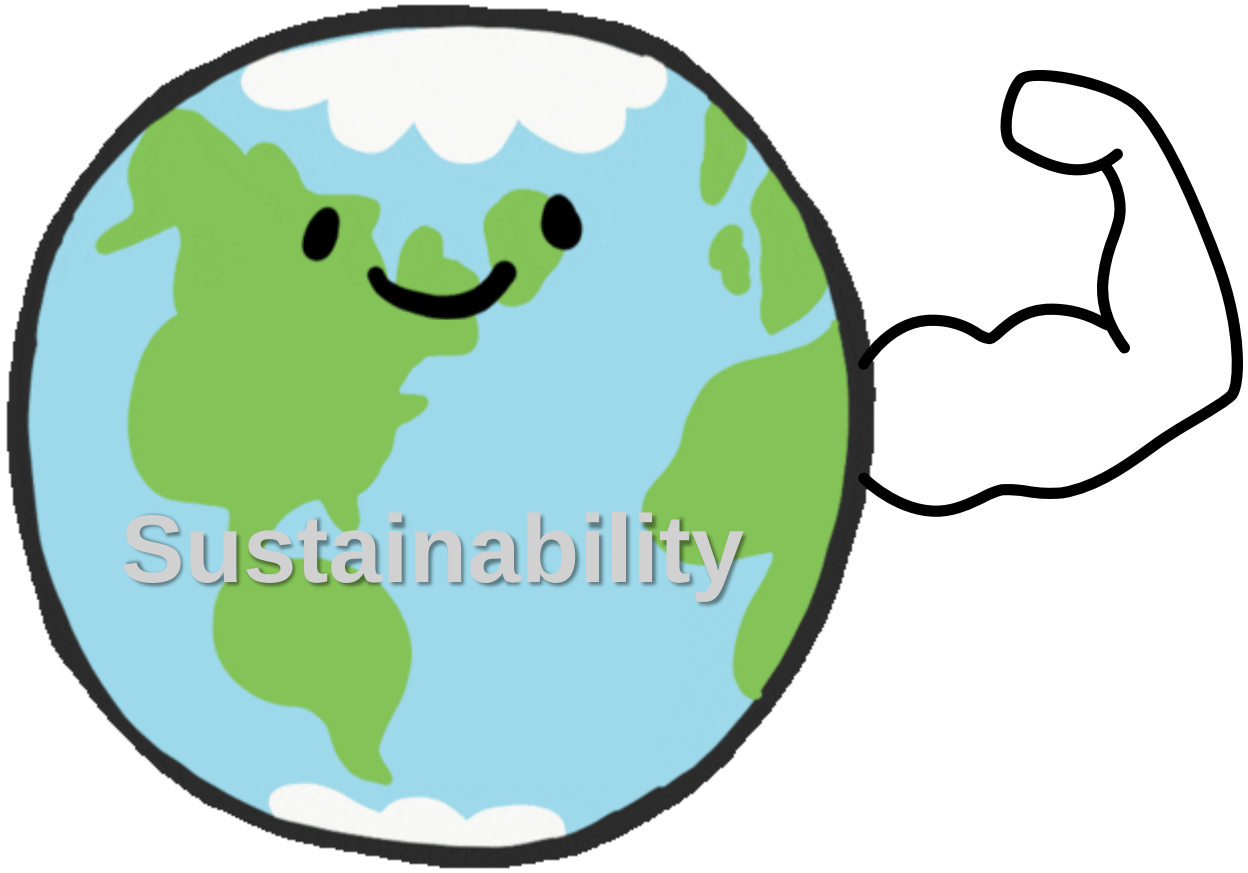
Andrew, R. M. (2018). Global CO_2 emissions from cement production. *Earth System Science Data*, *10*(1), 195–217. https://doi.org/10.5194/essd-10-195-2018

Why use Supplementary Cementitious Materials (SCMs)?

01/ SCOPE OF WORK



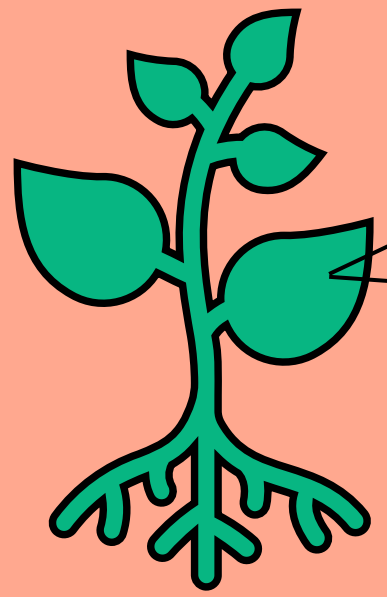
Why use Supplementary Cementitious Materials (SCMs)?

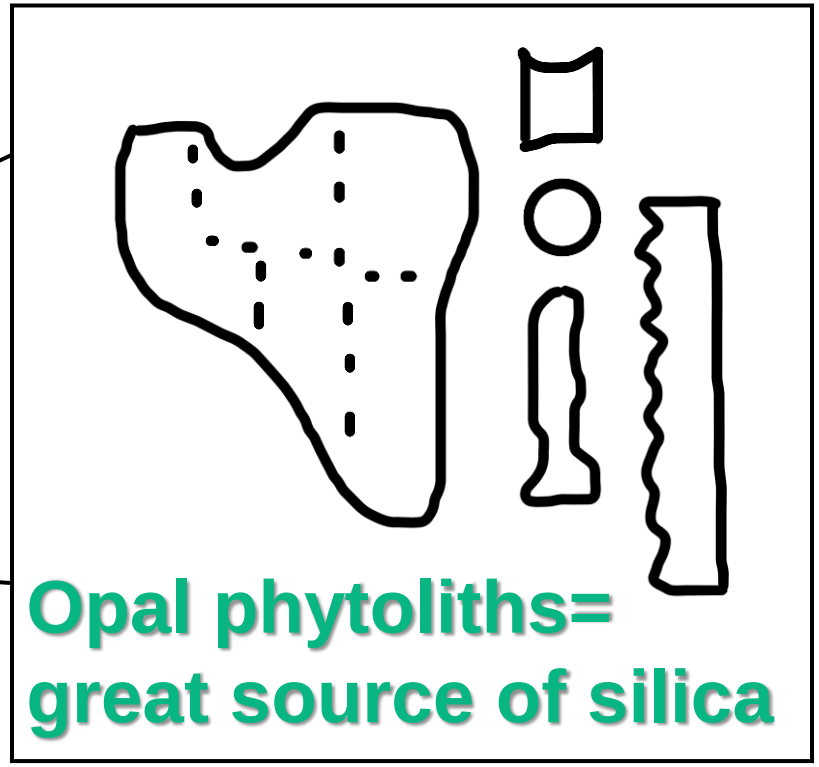
- Strength
- Cost
- ASR Mitigation
- Other durability factors

Duchesne, J. (2021). Alternative supplementary cementitious materials for sustainable concrete structures: A review on characterization and properties. *Waste and Biomass Valorization*, *12*(3), 1219–1236. https://doi.org/10.1007/s12649-020-01068-4

Wang, Y., Ramanathan, S., Chopperla, K. S. T., Ideker, J. H., & Suraneni, P. (2022). Estimation of non-traditional supplementary cementitious materials potential to prevent alkali-silica reaction using pozzolanic reactivity and bulk resistivity. *Cement and Concrete Composites*, *133*, 104723. https://doi.org/10.1016/j.cemconcomp.2022.104723

Why use cereal crops as SCMs?





Opal phytoliths= great source of silica

Clarke, J. (2003). The occurrence and significance of biogenic opal in the regolith. *Earth-Science Reviews*, *60*(3), 175–194. https://doi.org/10.1016/S0012-8252(02)00092-2

Rice Hull Ash (RHA) is a great SCM candidate but has challenges in its physical and chemical properties.

Question

How do we improve the physical and chemical properties of RHA for incorporation into cement?

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Hypothesis

Wet milling RHA via attrition milling will modify the ash and make it a more viable partial cement replacement.

RHA from an energy plant was tested and characterized as received and from attrition milling.

Milling conditions

- 400 rpm
- 5:1 liquid: solid
- 10:1 ball: powder
- 3-hour milling

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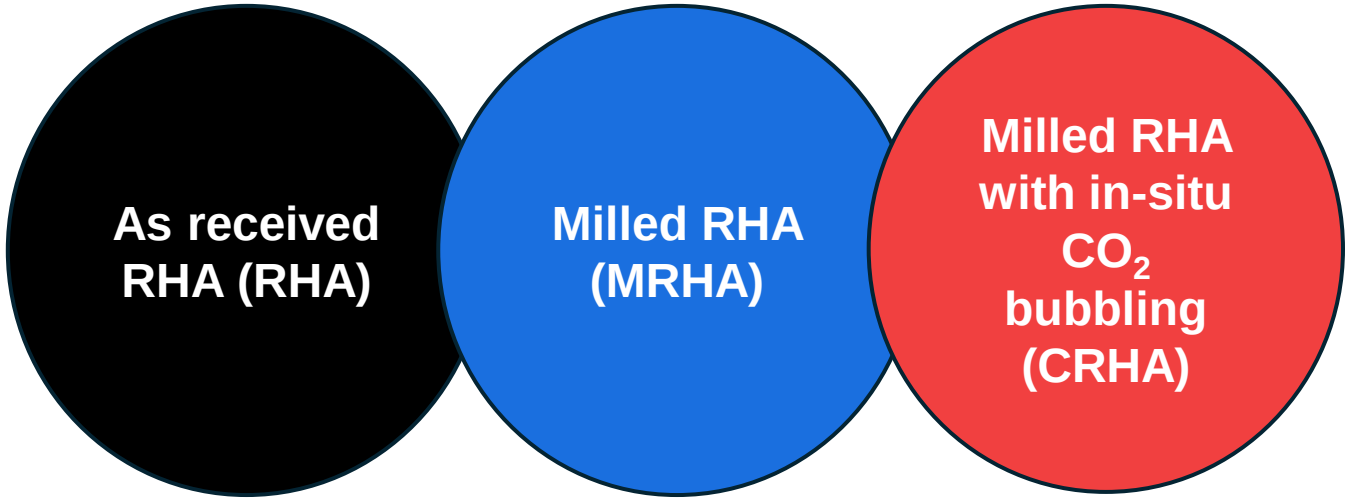
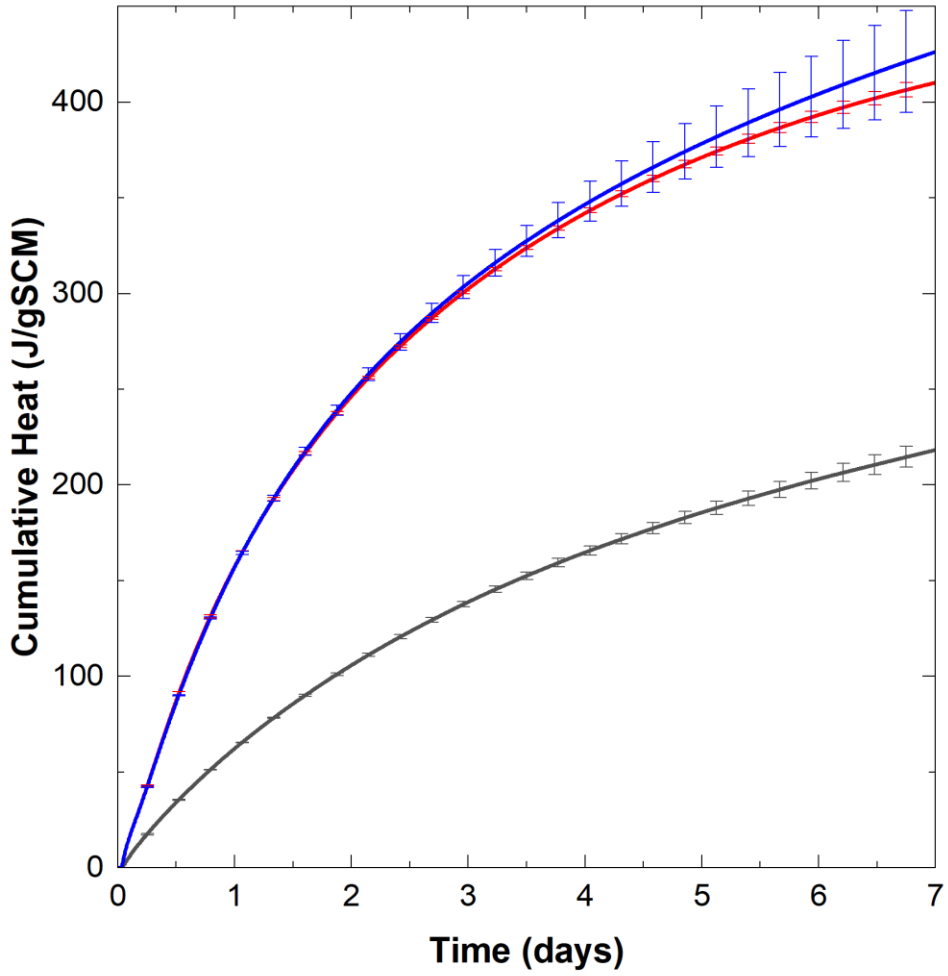
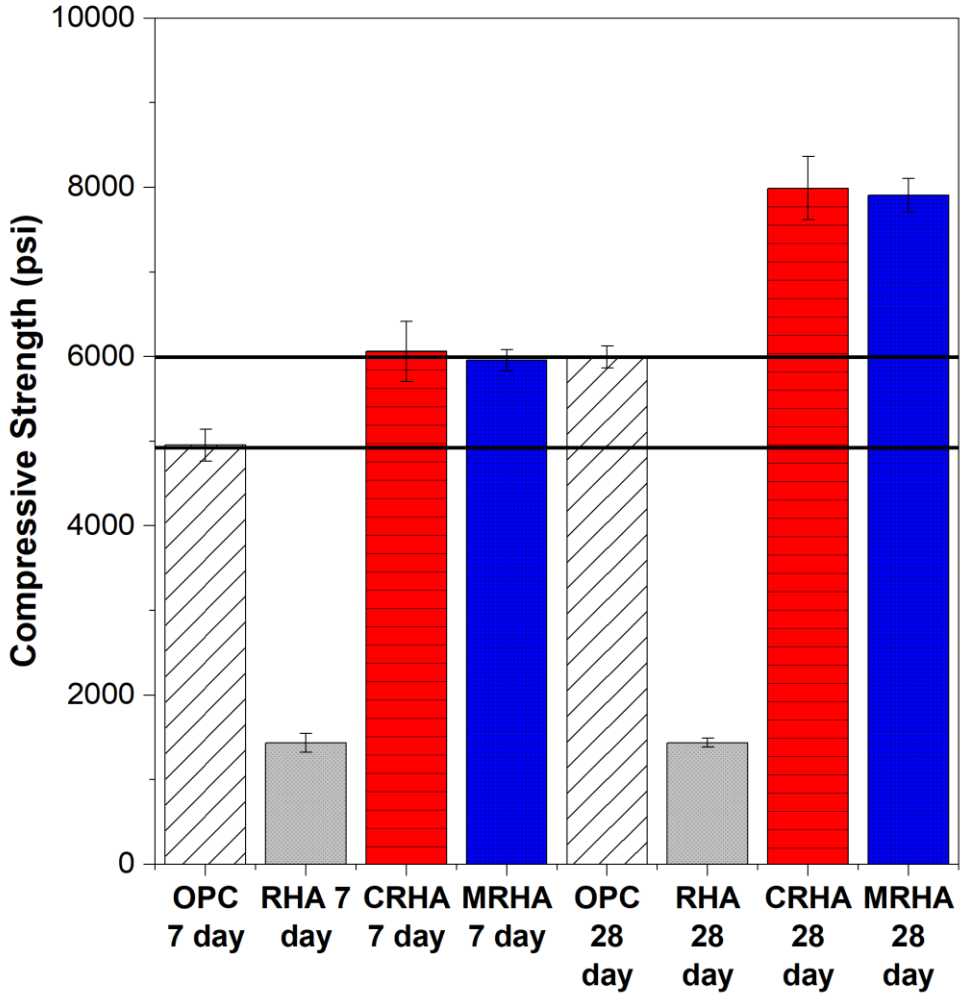


RHA, MRHA, and CRHA were tested for their reactivity and compressive strength.

There is a substantial jump in strength and reactivity after attrition milling.





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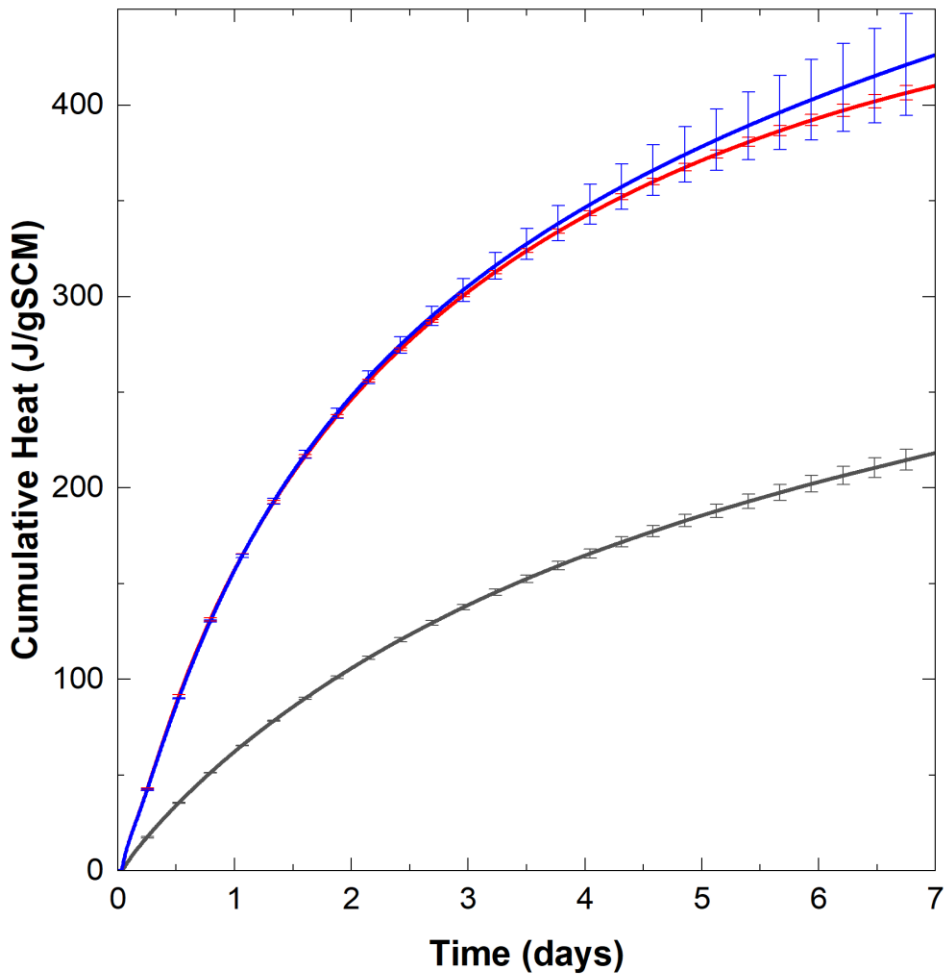

Doubled the reactivity

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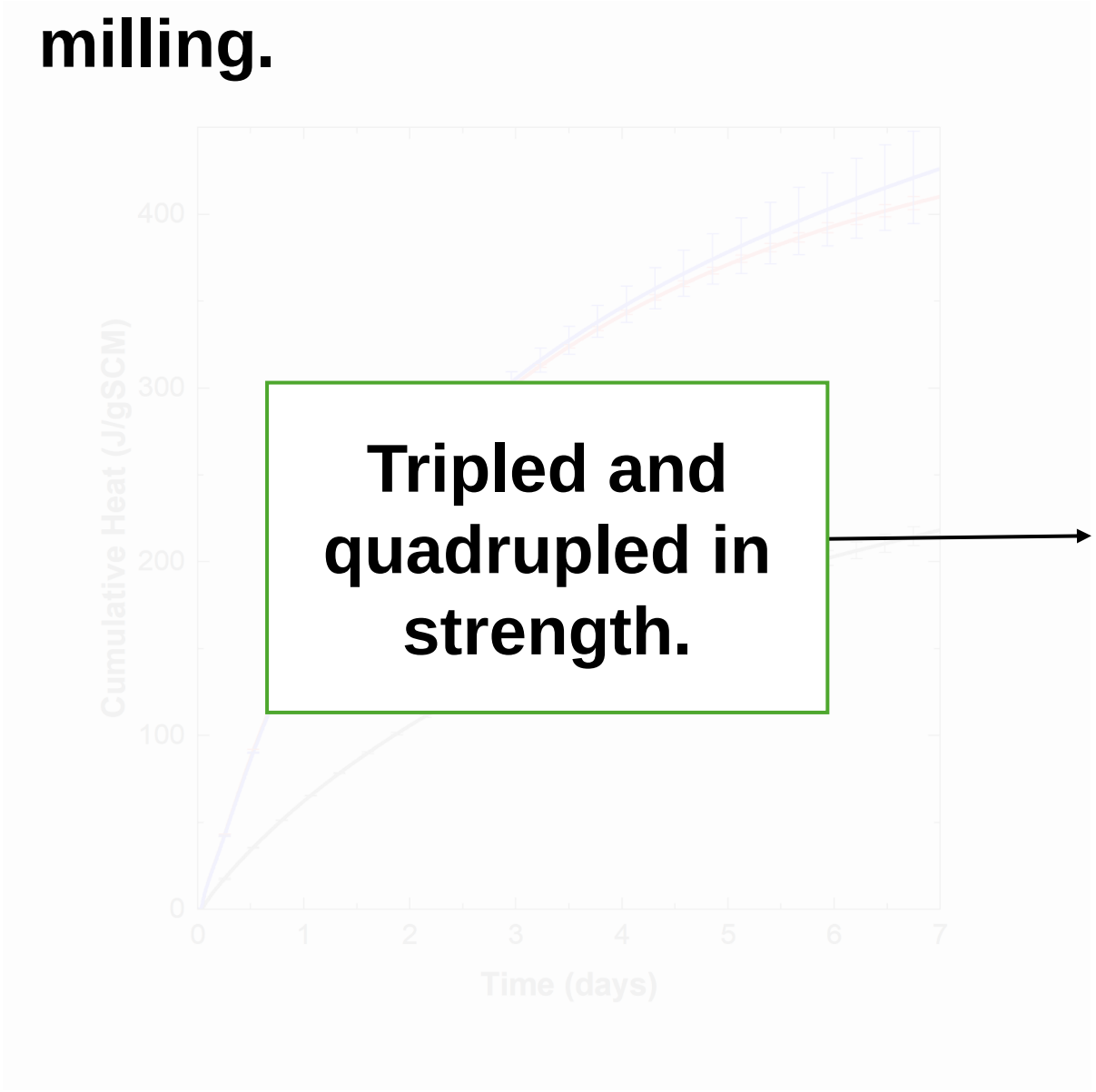
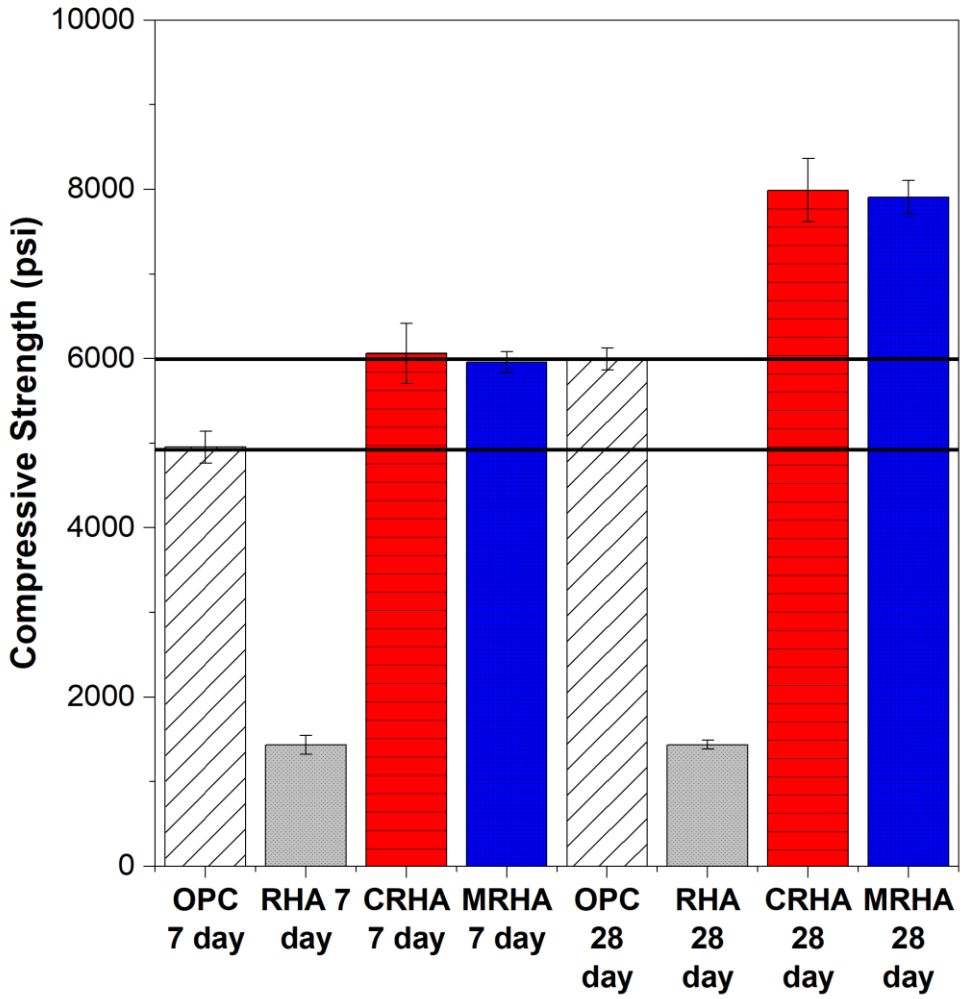
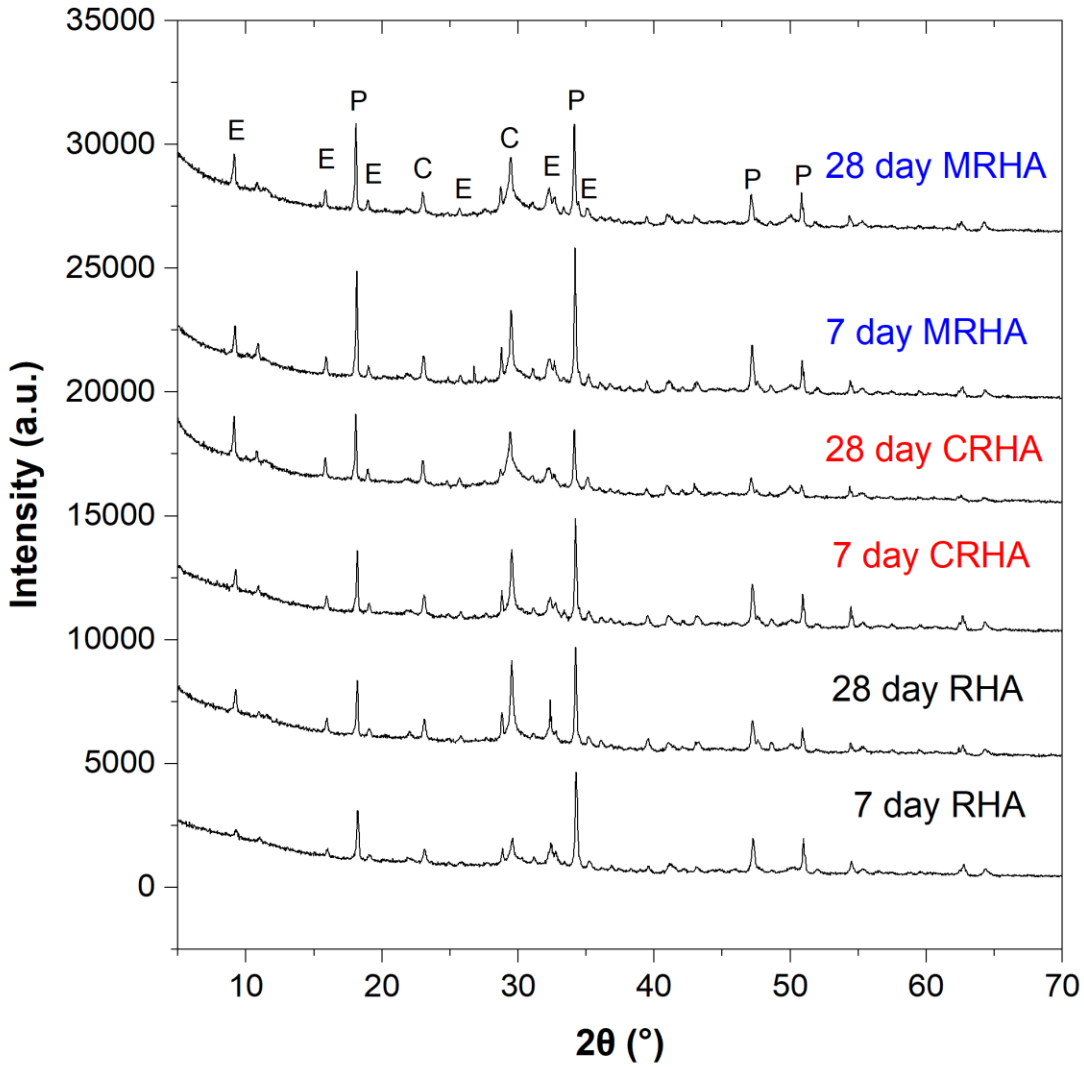


Tripled and quadrupled in strength.

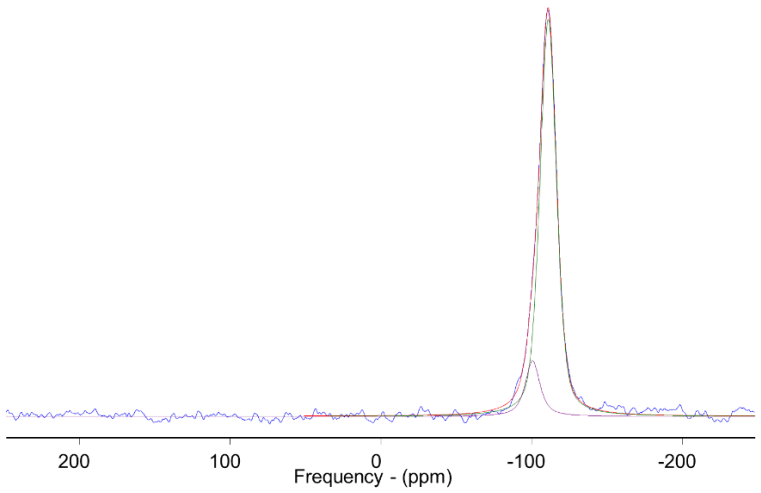


Only minimal changes in phases were present at 7 and 28 days.

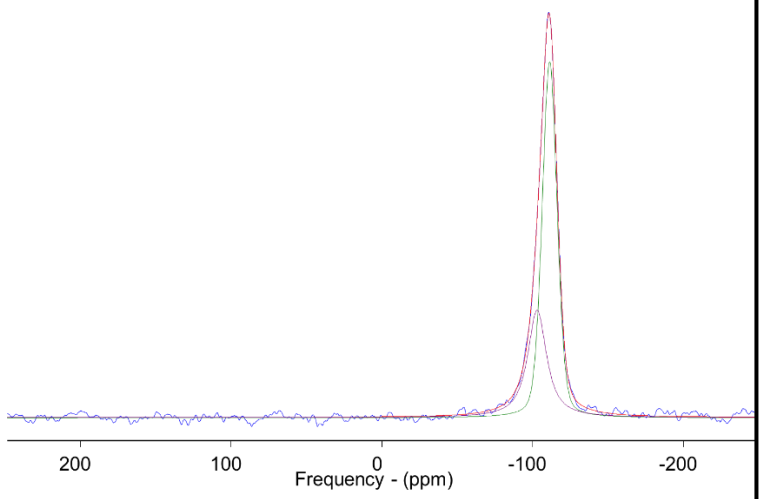


E= ettingite
P= portlandite
C= Calcite

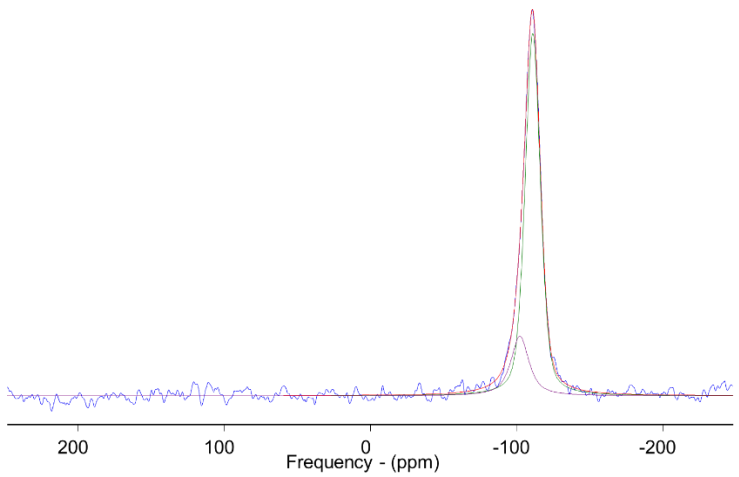
^{29}Si magic spinning NMR to investigate coordination showed only minor differences across samples.



MRHA



CRHA



RHA

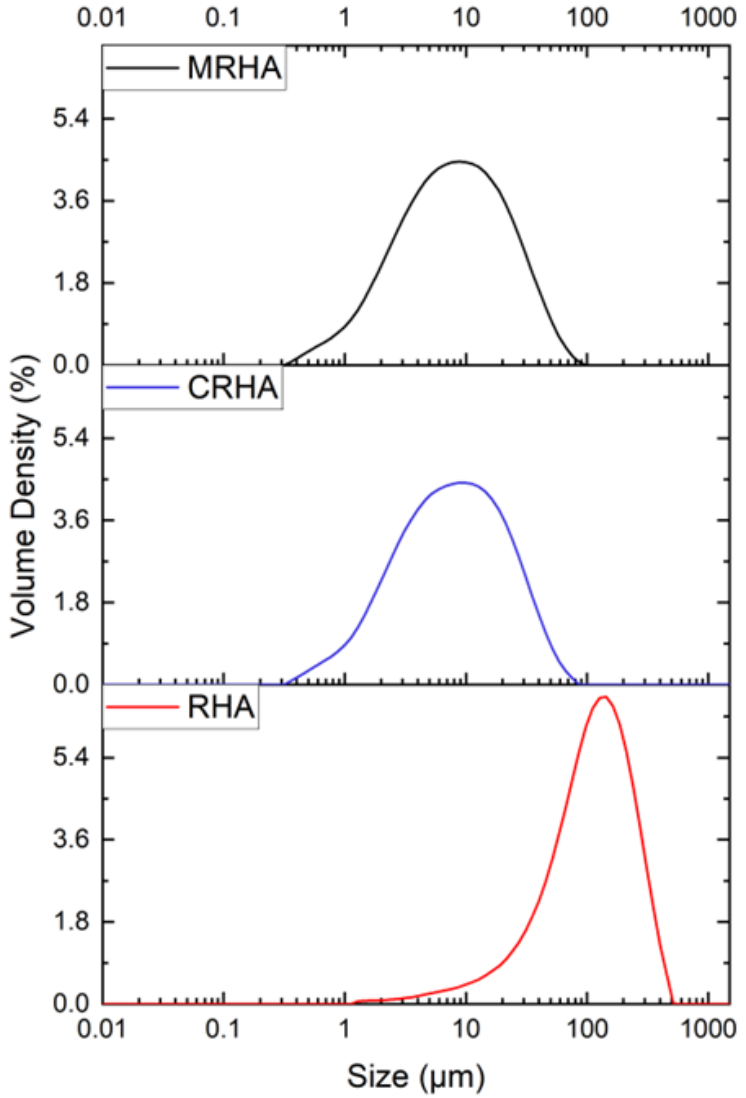
BET surface area nearly doubled between milled and plain rice husk ash.

RHA:
23.85 m^2/g

MRHA:
44.58 m^2/g

CRHA:
44.88 m^2/g

Shifting of particle size distribution also allows for better RHA incorporation.



Wet milling allows for reduction in potassium content.

Component	RHA (wt%)	CRHA (wt%)	MRHA (wt%)
CaO	0.73	0.22	0.23
SiO_2	94.20	94.20	93.60
Al_2O_3	0.24	1.28	1.33
Fe_2O_3	0.07	1.33	1.40
Na_2O	0.07	NA	0.04
K_2O	**2.33**	**0.16**	**0.18**
TiO_2	0.01	0.01	0.02
MgO	0.29	0.21	0.23
SO_3	0.24	0.11	0.15

Attrition Milling Technology is a Viable Option for Optimizing RHA for Cement Applications.

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Reactivity and compressive strength increase when after milling.

The surface area increases allowing for more space for interaction between the cement and RHA.

The potassium content is reduced which may reduce deleterious phases in later ages and influence early hydration.

Future work is needed to investigate potential homogenizing effects and workability.

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Questions?

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I would like to thank my advisor Dr. Juan Pablo Gevaudan for his guidance on this project. I would also like to thank the lab technicians at the Materials Research Institute (MRI) for their support and training. I also send my gratitude to the undergraduate researchers who have worked beside me on the experimental portions of this project. I would also like to thank my research group for there continual support and comradery.

References

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