

Reducing the Carbon Footprint of Concrete and Masonry Structures

PI-Jennifer Tanner, Co-PI TeYu Chien, April 19, 2024

Carbon capture, utilization, and storage technologies can and must be implemented to combat climate change. Burning fossil fuels is the largest contributor to climate change, namely carbon dioxide (CO₂) emissions generated by these processes. The global average temperature rose 1.8 °F (1 °C) over the period from 1901 to 2016. (EPA, 2023)

Producing cement is the number one source of CO₂ released into the atmosphere. Furthermore, concrete and masonry are the main building materials for structures worldwide. These contrasting statements create an opportunity for developing procedures to improve our construction materials on a global scale. It is not surprising that the Portland Cement Association (PCA at www.cement.org/) and American Concrete institute (ACI at www.concrete.org/) are actively pushing for carbon neutral concrete by 2050. ACI has developed a Center of Excellence for Carbon Neutral Concrete (neu at www.neuconcrete.org/).

The proposal herein builds upon previous work at the University of Wyoming to replace cement with mineralized fly ash. Mineralization of carbon dioxide using fly ash was successfully used to develop a cement replacement material for use concrete. Our results show that the mineralized material sequesters 45% of its mass. Cement replacement levels of 15% shows negligible decrease in strength and 30% replacement levels of mineralized fly ash has a decrease of approximately 18%. Both mineralized fly ash materials reached the strength of concrete using just a 15% fly ash replacement, indicating potential for continuing this work.

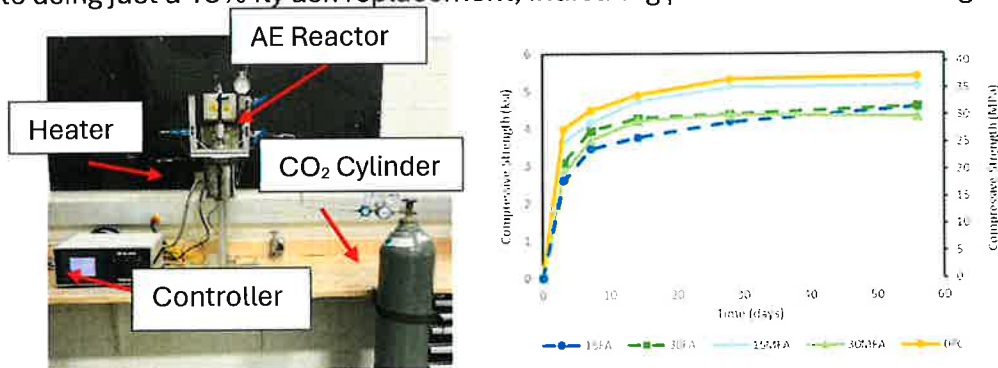


Figure 1: a) Controller, stirred tank reactor, and carbon dioxide cylinder b) test results.

This proposed project evaluates a suite of design mixtures for masonry grout. Grout in masonry is essentially a more fluid concrete and there are no mechanical differences in the material performance. Both compressive and tensile testing will be conducted to most accurately evaluate the material strength performance. This work will be completed in the robust structure's laboratory. Specifically, **PI Tanner** will advise a MS student to continue evaluating the material properties of grout materials. **Co-PI TeYu Chien** serves as a co-advisor and guide for designing and interpreting scanning electronic microscope (SEM) and x-ray diffraction (XRD) results to quantify the degree of carbon sequestration. He will utilize a novel metal-

assisted microwave treatment [Masi 2021] applied to fly ash under CO₂ environment as an alternative method to induce the mineralization, Figure 2. The high temperature creates a spark from the fork-shaped metal foils. The metal melting point directly determines the achievable temperature. Copper (~1050 °C), Nickel (~1450 °C) or tungsten (more than 3000 °C) can be tested for the best outcome. Fly ash or other materials from coal production by-products can be used as feedstock to produce graphite for being used to additive to cement. The advisors will have students participate in a competition to see what method is most technically effective versus cost of implementation. Creating a team that combines building fundamentals, masonry production knowledge with materials science improves the **interdisciplinary nature** of this project and success for future work.

These results will form the basis for a proposal to the CMU CheckOFF program, a new federally funded opportunity for research projects through the Department of Commerce with additional information available at

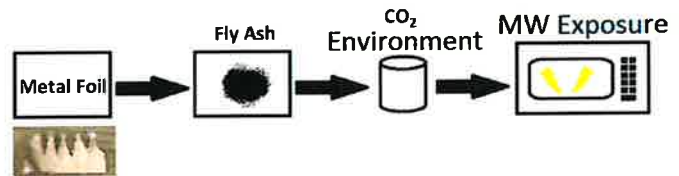


Figure 2. Metal-assisted microwave treatment

<https://concretemasonrycheckoff.org/programs/education-research>. Proposals are solicited by regions and Wyoming is part of region 5 that includes Washington (WA), Oregon (OR), Idaho (ID), Montana (MT), Wyoming (WY), Utah (UT), Colorado (CO), California (CA), Nevada (NV), Alaska (AK), Hawaii (HI). As an example, region 5 had a budget of roughly \$400,000 in the year 2023. The research advisory committee (RAC) solicits proposals from qualified investigators. In March 2024, I presented the idea of reducing the carbon footprint of masonry and the team members were very interested in pursuing this topic. Two of the states in our region require reducing the carbon footprint of all public work projects (Colorado and California). On the other side of the equation, my expertise includes masonry and there are not many faculty members with this skill set within our region. Because I have served on the masonry code committee, regularly complete experimental work in masonry materials and have published in the area, **funding is highly likely**. The key deliverable from this proposal will be a proposal submitted to the CMU CheckOFF program to reduce CO₂ emissions in grout or concrete blocks.

Although beyond the scope of this project, future proposals could include submissions to either PCA or ACI which have annual competitions through their foundations for funding academic research.

This fall PI-Tanner is teaching masonry design, a combined undergraduate and graduate class, where graduate students complete an independent project. Graduate students will be strongly encouraged to select proposals related to CO₂ sequestration within masonry.

References

EPA. (2023). *Climate change science*. United States Environmental Protection Agency. Retrieved July 28, 2023, from <https://www.epa.gov/climatechange-science>.

Budget

The total budget is \$24,958. The MS student will be partially funded by a teaching assistantship with one month summer salary at \$1,710 plus tuition and fees. Supplemental salary of \$300 per month to bring the stipend up to the cost of living in Laramie and aid in recruiting international students. Hourly student help is included to assist with the process of mineralizing the fly ash.

Purchasing a second stirred autoclave reactor is budgeted at \$5,800 based on the attached quote. Securing materials is a total of \$3,600 is estimated to transport suitable aggregates, travel costs for securing required fly ash, purchasing cement, blocks, test molds and any other incidentals that arise for both methods of sequestering CO₂. Materials laboratory equipment rental is estimated at \$600.

A nominal amount of summer salary for the PI and Co-PI are estimated at roughly \$3,200 and \$3,000 respectively. These will be paid at the end of the project to ensure that the graduate student is fully funded throughout the duration of this project and through June 30th, 2025. The PIs are optimistic that future funding will be available after that date for continued student funding and expanding the scope of this overall work.

Table 1: Project budget

	Quantity	Cost/item	Summary cost
Jennifer Tanner			
PI salary (fraction of months)	0.25	\$ 9,250	\$ 2,313
Fringe benefits	0.409		\$946
Co-PI salary (fraction of month)	0.2	\$ 10,497	\$ 2,099
Fringe benefits	0.409		\$859
UW portion			
Hourly student salary	200	\$ 16	\$3,200
Graduate student salary	9	\$ 300	\$2,700
Summer salary	1	\$ 1,710	\$1,710
Tuition and fees			\$632
Materials and supplies			
Laboratory materials			\$ 3,600
Equipment purchase			\$5,800
Materials laboratory			\$600
Shop time	10	\$50	\$500
		UW subtotal	\$ 24,958



Trident Labortek
Science at work

MFGR'S & EXPORTERS OF: High — Autoclaves, Glass Autoclaves, Rotary Evaporators, Lab Chillers, Heating / Cooling Units, Multipurpose Pilot Plants in Glass & Stainless Steel SS 304 & SS 316.

Office & Works: Unit No 4-A, Ferrodie Industrial Premises, Road No. 22, Wagle Industrial Estate, Thane 400 604, INDIA
Mob. +91 93211 01515 / +91 93207 12008, **E-Mail :** tridentlabortek@gmail.com, **Web :** www.tridentlabortek.com

QUOTATION

Quotation No :20827

Date :16-04-2024

To M/s. University of Wyoming 1000 E University Ave AVE MS Sweden	
Contact Person: Jennifer Tanner	Designation: Scientist
Mobile No: 3077609788	Email Id: tannerj@uwyo.edu
Enquiry No: By Mail	Enquiry Date: 16-04-2024

Dear Sir,
Thanks for your Valued Enquiry. We wish to submit our Quotation for the same as follows.

Sr.	Item Description	HSN Code	Rate/E	Qty	U.O.M.	Amount
1	SS 316 Low Pressure Stirred Autoclave . Capacity 500 MI (0.5 L) Details as per attached specification sheet	84198910	4,268	1	USD \$	4,268.00
2	SS 316 Low Pressure Stirred Autoclave . Capacity 1000 MI (1 L) Details as per attached specification sheet	84198910	4,500	1	USD \$	4,500.00
3	SS 316 Low Pressure Stirred Autoclave . Capacity 1000 MI (1 L) SS 316 Low Pressure Stirred Autoclave . Capacity 3000 MI (3 L) Details as per attached specification sheet	84198910	5,860	1	USD \$	5,860.00
Grand Total						14,628.00

TERMS & CONDITIONS

Rates:	EX WORKS	GST:	NOT APPLICABLE FOR EXPORT
P & Fwdg:	EXPORT WORTHY PACKING , FUMIGATION, CUSTOM CLEARANCE & DOCUMENTATION CHARGES USD 600.00	Freight:	Estimated Sea Freight USD 1200
Delivery Period:	5- 6 WEEKS FROM RECEIPT OF PO & ADVANCE PAYMENT	Payment Terms:	50 % Advance, Balance on PI Before Despatch
Insurance	BY CLIENT	Validity:	60 DAYS
Installation Charges:	BY CLIENT - WE WILL PROVIDE VIDEO DEMO. IF INSTALLATION IS TO BE DONE BY US THEN RS 20,000/- EXTRA WILL BE CHARGEABLE		
Warranty:	12 Months from the Date of Despatch for Electrical & Electronic Components Only. Physical Damages, Damages due to Electrical Failure, Power Fluctuation or Natural Calamities will not be covered Under Warrantee. No Warantee for Glass Components		

Thanking You
For Trident Labortek

Marketing Team