Low cost, Rapid and Scalable Microwave Coal Melt-Casting For Modular Carbon-Based Buildings

First Year Progress
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PI: Dr. Rouzbeh Savary

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Background & Motivations

Ordinary Portland Cement (OPC):

- ~4 bn/yr production of OPC in construction
- Mature industry with low cost (OPC sells for ~$100/ton)
- Its manufacturing is energy intensive (4-6 GJ/ton)
- Its manufacturing emits 7-10% of total CO2 emissions (~1500°C)

Coal:

- Its usage declining but it has a significant potential for construction
- Carbon-magnesia bricks (1500°C) → refractory lining
- Coal+polymer derived ceramic → roofing tiles
- Coal/OPC mixed products → but strength drops to 30% with addition of 65% coal.

Challenges: activators (cost), scalability, performance, industry acceptance

Objectives

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- Produce coal-based building prototype that has >70% wt% carbon (of which 51% is coal-derived) with physical, chemical and thermal properties on par with cement-based concrete

- Optimize fabrication protocol followed by various technical and environmental testings for representative building components

- Conduct conceptual design of a carbon-based building prototype, technoeconomic analysis, life-cycles analysis and technology gap analysis to demonstrate commercial feasibility

Our Key Value Propositions

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1) Direct Utilization of Coal (~70%)
2) High-Strength, Tough and Lightweight Properties
3) No external binder via melt-casting induced fusion
4) Curing in minutes/hours (vs. days in conventional curing)
5) Scalability and Ease of Implementation
6) Energy Efficient Processes (orders of magnitude lower)
7) Low Risk Technology
8) No concerns on heavy metals

Tasks Breakdown

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Task 1.0: Project Management and Planning

Task 2– Fabrication and Optimization of Coal-Based Building Products

Task 3– Technical and Environmental Standard Testing of Carbon-Based Building Materials

Task 4 – Conceptual Design and Modeling of Carbon-based Buildings

Success Criteria

Success Criteria: Identify top 2 refined recipe for at least two coal type (with >70% carbon content) with a complete product data sheet with

- Compressive strength >4000 psi,
- Flexural strength >300 psi,
- Excellent chemical resistivity (on par with OPC)
- At least >600 °C thermal stability,
- Meeting environmental testing for leaching

Compressive Strength ~6000 psi

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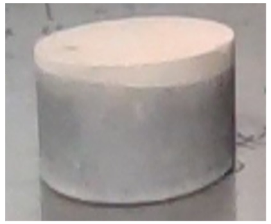
Sample #	**Mass ratio**	Sintered sample dimensions	Mass loss during sintering	Comp strength	Youngs Modulus	Toughness
1	**70/30**	D = 29 mm H = 35 mm	5%	6668 psi	9*10^6 psi	300 psi
2	**74/26**	D = 29 mm H = 33 mm	8%	7124 psi	1.1*10^7 psi	305 psi
3	**73/27**	D = 29 mm H = 33 mm	7%	5467 psi	1.0*10^7 psi	266 psi
4	**77/23**	D = 29 mm H = 35 mm	4%	7055 psi	8*10^6 psi	288 psi
5	**76/24**	D = 29 mm H = 34 mm	8%	5661 psi	9*10^6 psi	299 psi
6	**77/23**	D = 29 mm H = 36 mm	5%	6051 psi	1.3*10^7 psi	305 psi



>70% carbon from coal (bit, sub, anthracite, etc) in the product with ~6000 psi strength (OPC ~3500 psi)

Testing Lignite Coal

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Sample #	Mass ratio	Sintered sample dimensions	Comp strength	Youngs Modulus	Toughness
1	78/22	D = 29 mm H = 38 mm	**5855 psi**	8.2*10^6 psi	282 psi

Our technology is independent of the coal type

Oxidization resistance up to 1300 ° C

Heated sintered sample to 1300C. Sample melted and became glassy and very hard. Couldn't grind it flat for compression test

Alkali Resistance (pH=13)

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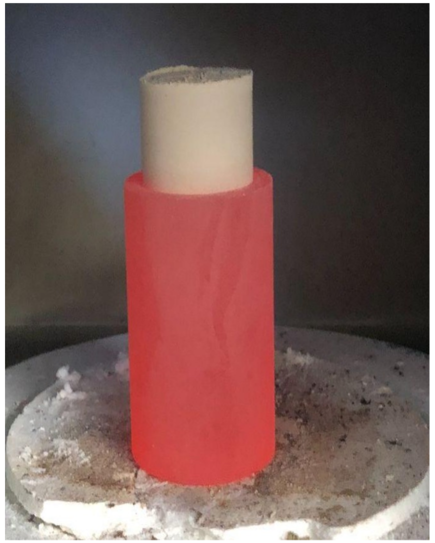
Sample #	Soak time (days)	Dimensions	Dimensions after soaking	% V change	% Mass change	Comp strength	Youngs Modulus	Toughness
1	3	D = 29.31 mm H = 24.25 mm	D = 29.30 mm H = 24.31 mm	+0.18%	+1.1%	5511 psi	9.2*10^6 psi	255 psi
2	3	D = 29.11 mm H = 23.98 mm	D = 29.13 mm H = 24.01 mm	+0.26%	+1.3%	4981 psi	1.0*10^7 psi	234 psi
3	7	D = 29.07 mm H = 22.97 mm	D = 29.10 mm H = 22.89 mm	-0.14%	+1.1%	5225 psi	8.2*10^6 psi	261 psi
4	7	D = 29.27 mm H = 24.12 mm	D = 29.24 mm H = 24.10 mm	-0.29%	+0.9%	5367 psi	1.1*10^7 psi	270 psi
5	28	D = 29.25 mm H = 23.42 mm	D = 29.26 mm H = 23.51 mm	+0.11%	+0.7%	5691 psi	9.0*10^6 psi	225 psi
6	28	D = 29.22 mm H = 23.36 mm	D = 29.20 mm H = 23.21 mm	-0.21%	+1.2%	5211 psi	9.9*10^6 psi	266 psi

Excellent resistance to Alkali solutions

Testing various molds



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Conclusion

- Fabricated coal-based construction materials that have >70% wt% coal with physical, chemical and thermal properties on par with cement-based concrete
- Compressive strengths >6000 psi with oxidization resistance up to 1300 ° C
- Excellent durability and resistance with respect to aggressive acid and basic solutions
- Direct utilization of coal (>70%)
- Champion use of coal as a sustainable material in construction

Acknowledgments

- NETL

(Michael Fasouletos, Jason Montgomery)