Low-Carbon Biochar-Incorporated Concrete

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Introduction and Objectives

Biochar is an organic material produced as a result of the pyrolysis of carbon-based biomass and organic waste. It is a sustainable material obtained by heating biomass i.e., plant materials, agricultural residues, biomass from wood, solid wastes, etc. Objectives of the study:

- Feasibility of biochar application in concrete
- Mechanical properties
- Cost and environmental analysis

Parameters Evaluated

- Cement content reduction
- Biochar addition levels

Experimental Program

Mixture Design

Mixture ID	Cement (pcy)	Water (pcy)	Coarse Aggregate (CA) (pcy)	Fine Aggregate (FA) (pcy)	Biochar (pcy)	Water Reducer (WR) (fl oz/cwt)
C632	632	260	1136*	1631	--	--
C601	601	247	1163*	1699	--	3.4
C569	569	234	1195*	1724	--	6.8
C537	537	221	1231*	1767	--	7.2
C632-B5	632	260	1136*	1631	32	8.8
C601-B5	601	247	1163*	1699	32	16
C569-B5	569	234	1195*	1724	32	22
C537-B5	537	221	1231*	1767	32	18
RCA-B0	632	260	1190**	1452	--	--
RCA-B5	632	260	1190**	1452	32	8.8
RCA-B10	632	260	1190**	1452	64	26.4
RCA-B15	632	260	1190**	1452	96	40

* Natural Aggregates

C601-B5: C601 → Cement Content (in pcy); B5 → Biochar addition of 5% by wt of cement

** Recycled Concrete Aggregates (RCA)

RCA-B5: RCA → Recycled Concrete Aggregates; B5 → Biochar addition of 5% by wt of cement

Concrete Mixing Procedure (ASTM C192)

1. CA+30% water w/ WR (if needed), **mix for 30 sec**
2. Biochar, **mix for 30 sec**
3. FA, cement, and 70% water, **mix for 3 min**
4. **3 min rest**, followed by final **mix for 2 min**

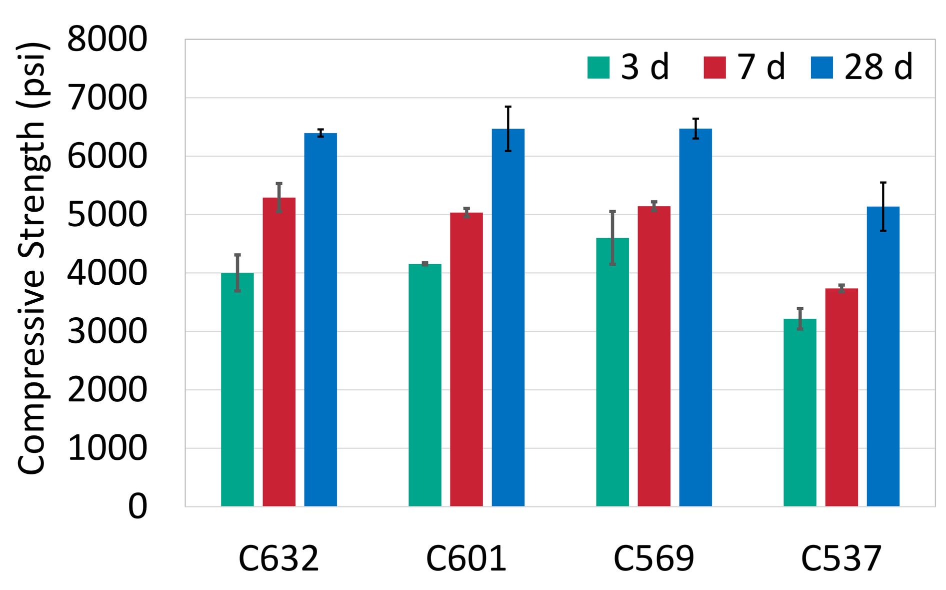
Properties

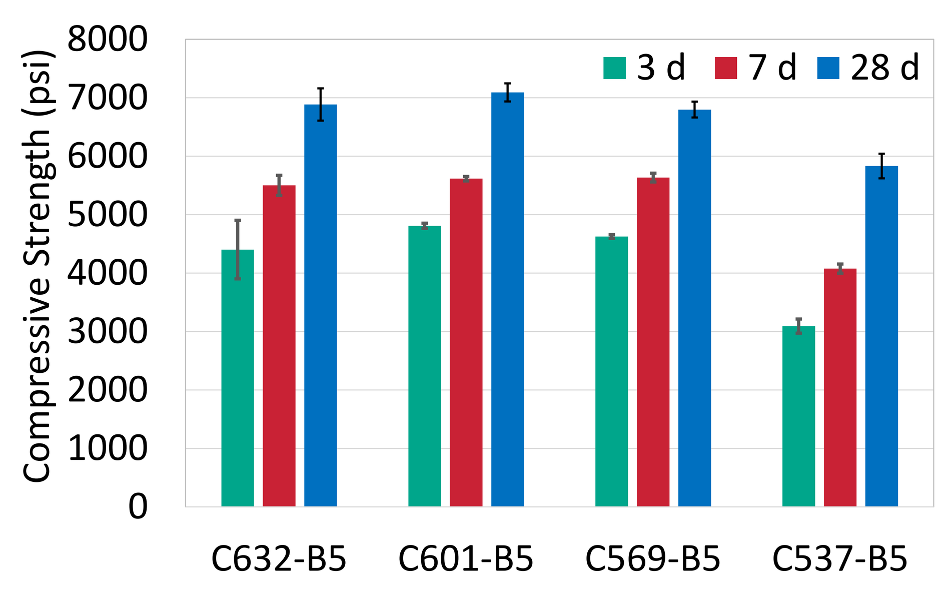
- Workability (ASTM C143)
- Compressive strength (ASTM C39)
- Splitting tensile strength (ASTM C496)
- Modulus of Elasticity (ASTM C469)
- Microstructure (SEM)
- Chloride ion penetration (AASHTO TP 95-14)
- Drying shrinkage (ASTM C157)
- Freezing -Thawing resistance (ASTM C666)

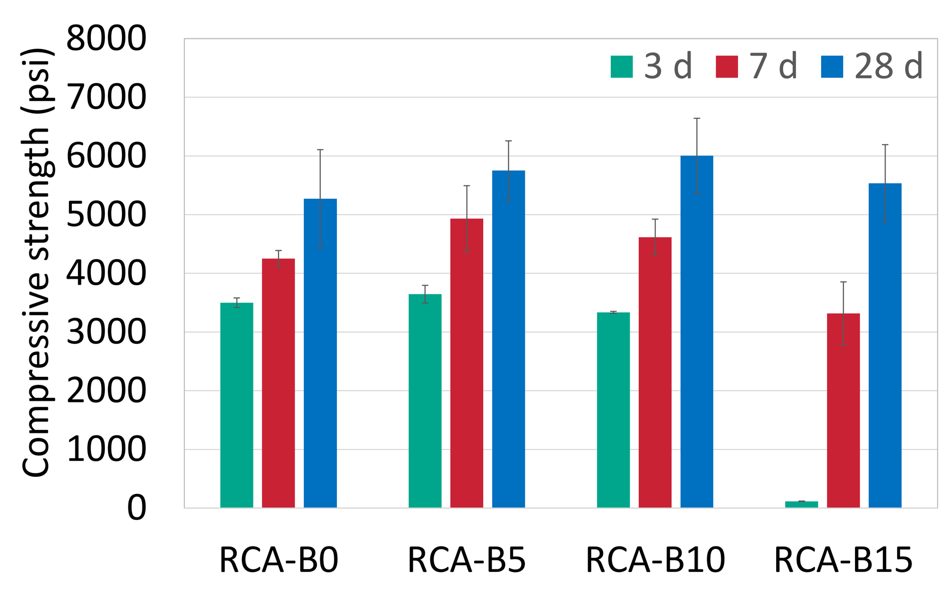
Production, Results and Discussion

Biochar Concrete Production

Compressive Strength

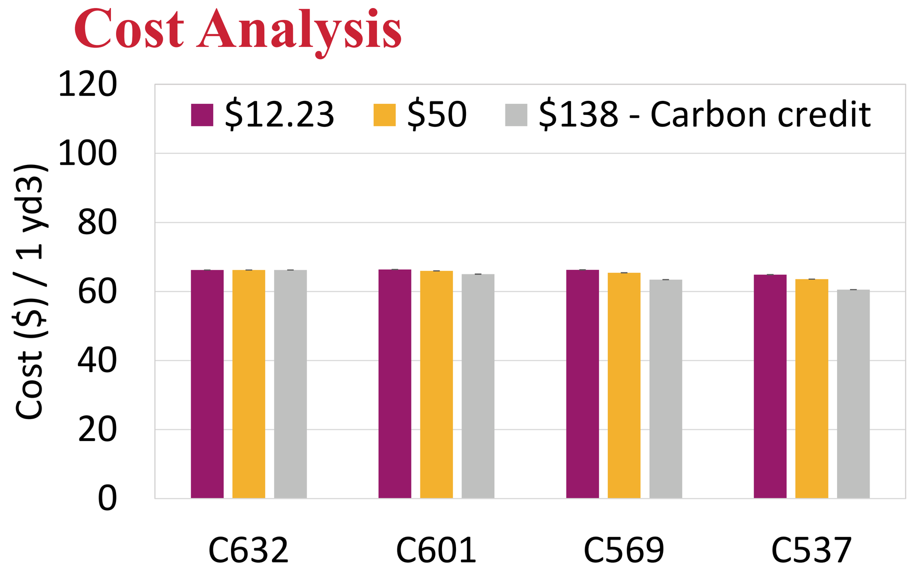


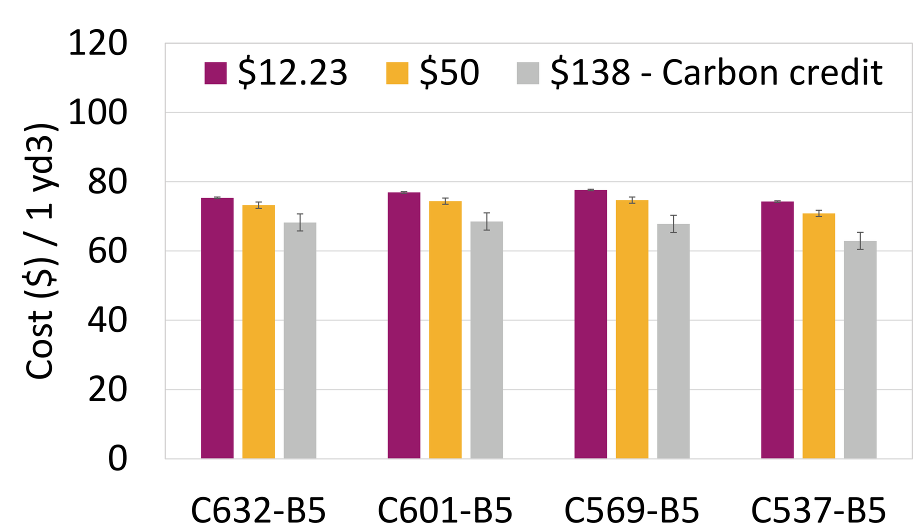


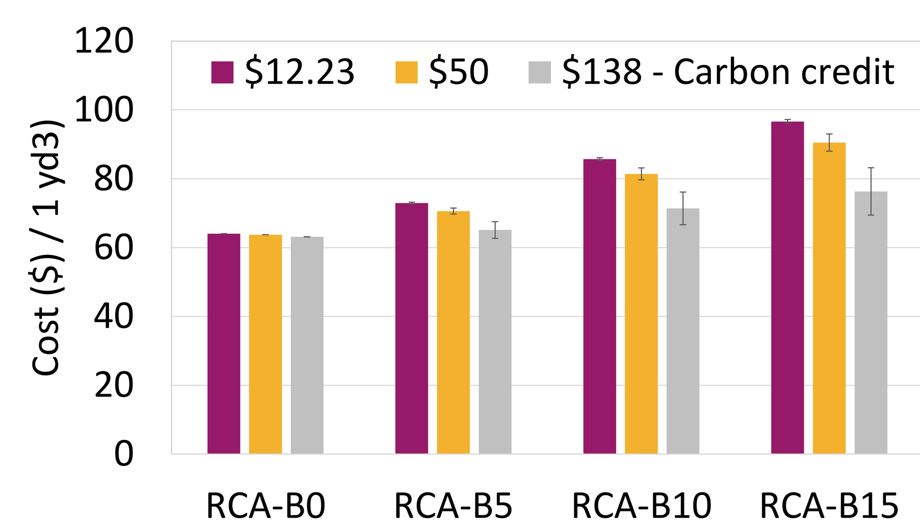


- Cement content reduction in concrete can be compensated by biochar addition at replacement levels of up to 15%.
- Biochar incorporation increases the strength by about 9% on average due to the nucleation effect and reduced effective water-to-cement ratio (w/c).
- Using biochar in high volume requires a high amount of WR, which leads to a decrease in early-age strength

Cost Analysis

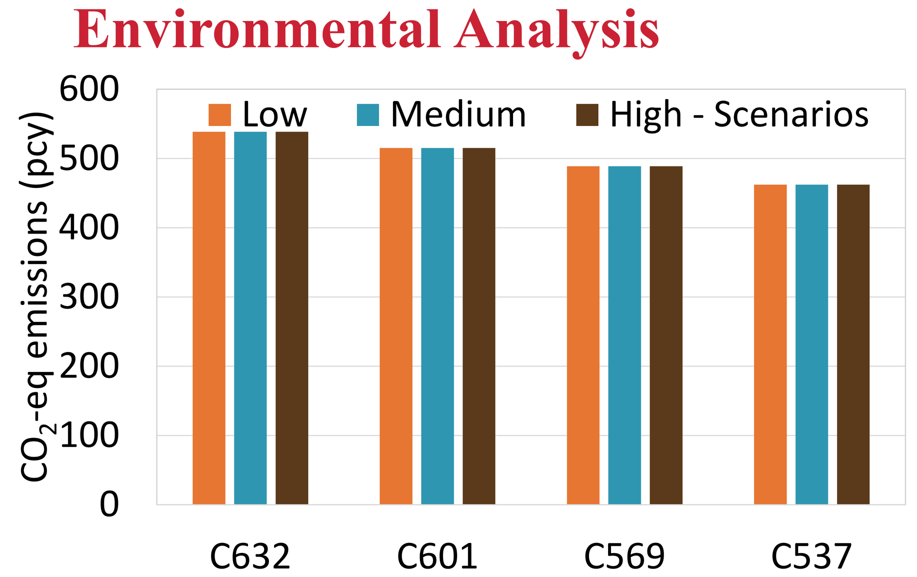


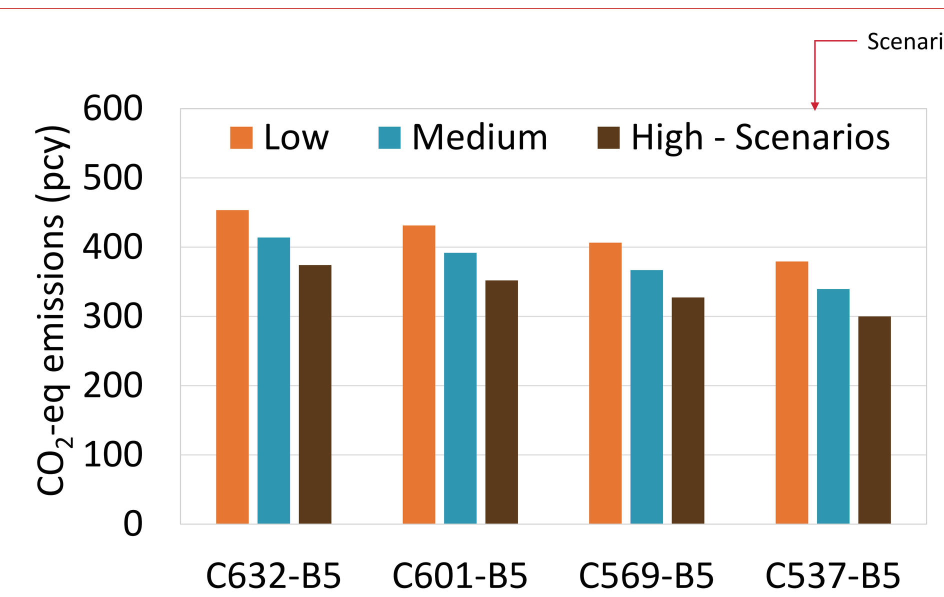


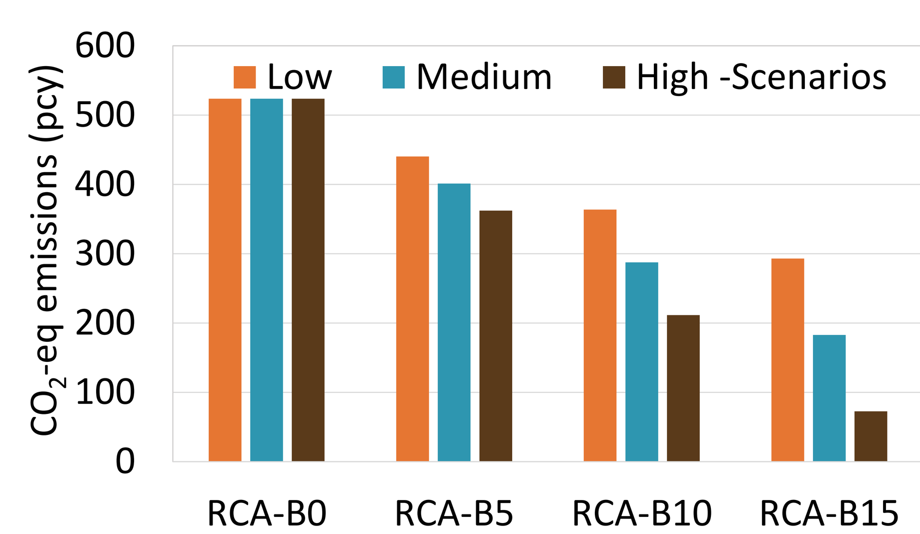


- Cement reduction reduces the cost of concrete slightly only due to the high demand for WR used to compensate for workability loss.
- Cost of biochar concrete is comparable at lower biochar addition levels and high carbon credit prices, but a high volume of biochar increases the cost of concrete due to the high unit cost of biochar and high demand on WR.

Environmental Analysis







- Cement reduction by 5%, 10, 15% can reduce CO_2-eq by roughly 4%, 9% and 14%, respectively.
- 5% of biochar addition into concrete with 5-15% cement reduction can reduce the CO_2-eq by 15.8-44.3%.
- Addition of biochar in 10-15% of the mass of cement can reduce the CO_2-eq by 30-84%.

Summary

- Addition of biochar can compensate for cement reduction in concrete and results in higher strength compared to the mixtures without biochar due to the nucleation effect and reduced effective w/c.
- A comparable cost at lower biochar incorporation can be obtained at 5% biochar content (mass of cement). However, higher biochar addition (10-15%) results in a higher cost of concrete due to the high unit cost of biochar and demand on WR.
- Biochar incorporation can significantly reduce the carbon footprint of concrete. 10-15% of biochar incorporation (by mass of cement) can reduce the CO_2-eq of concrete by 30-84%.

Acknowledgement

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