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Title: Suitability of biochar as supplementary cementitious material (SCM) or filler: waste revalorization, a critical review

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Introduction

0.81kgCO2-eq to 0.90kgCO2-eq per kg

SCMs

300 to 1000°C

Calcinated Biomasses

Biochar

Selection criteria and screening

379 items

20 items

Biochar as a functional material

Physical and morphological properties

Porosity, particle shape, surface area and density

Transport properties

Workability

Filler effect

Chemical properties

Elemental and chemical composition

Pozzolanic reaction

pH

Porosity, particle shape, surface area and density

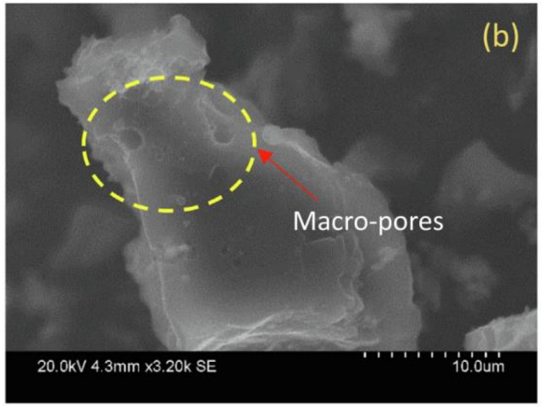
Porous nature

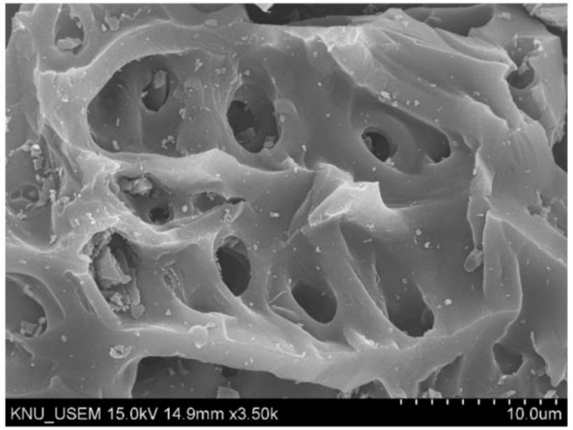
Low bulk density

High absorption

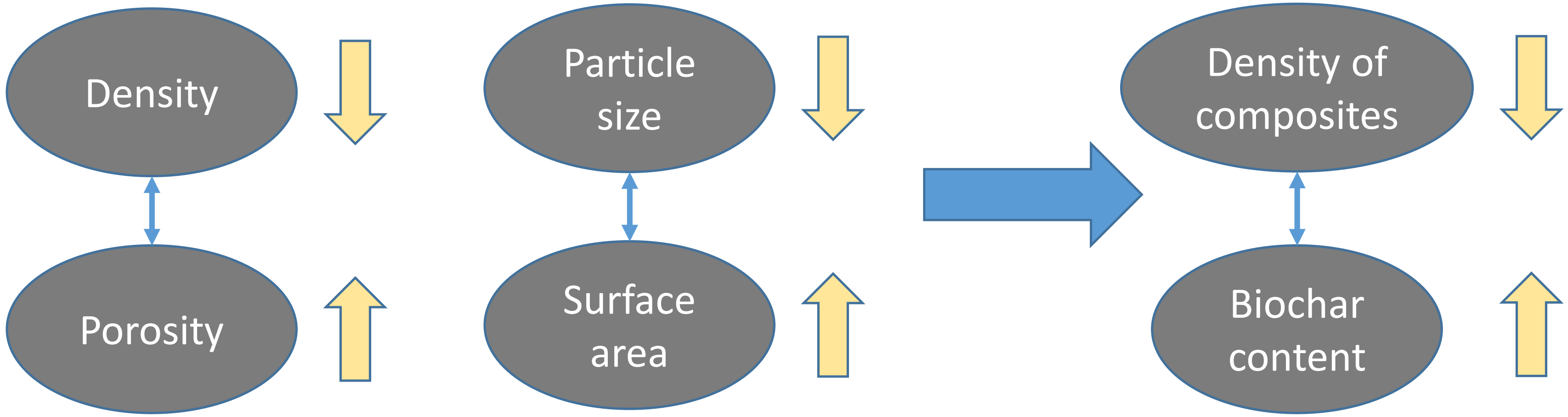
Complex pore network

Internal curing agent





Potential applications as lightweight energy-efficient composites



Micrographs from: Gupta et al. (2021) and Yang & Wang (2021).

Transport properties and workability

Water absorption, permeability, thermal conductivity, electrical resistivity, sulfate resistance and chloride diffusion

Complicated pore network + high porosity

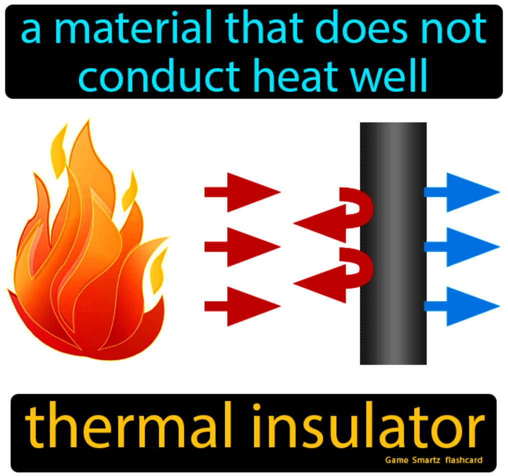
Great thermal insulator

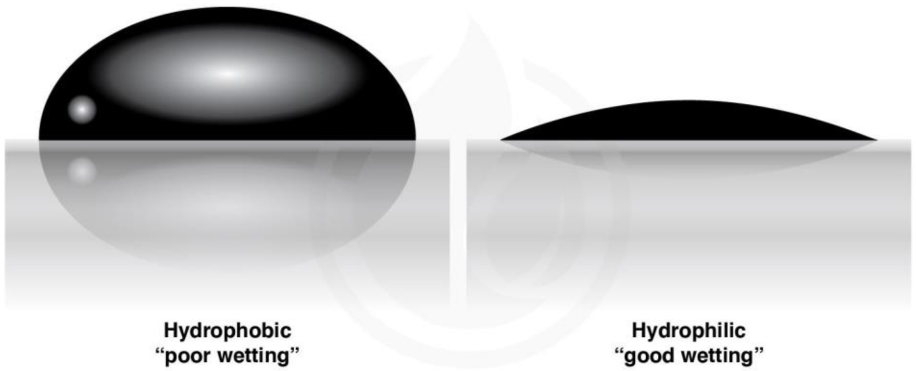
Energy savings, thermal efficiency

Hydrophilicity

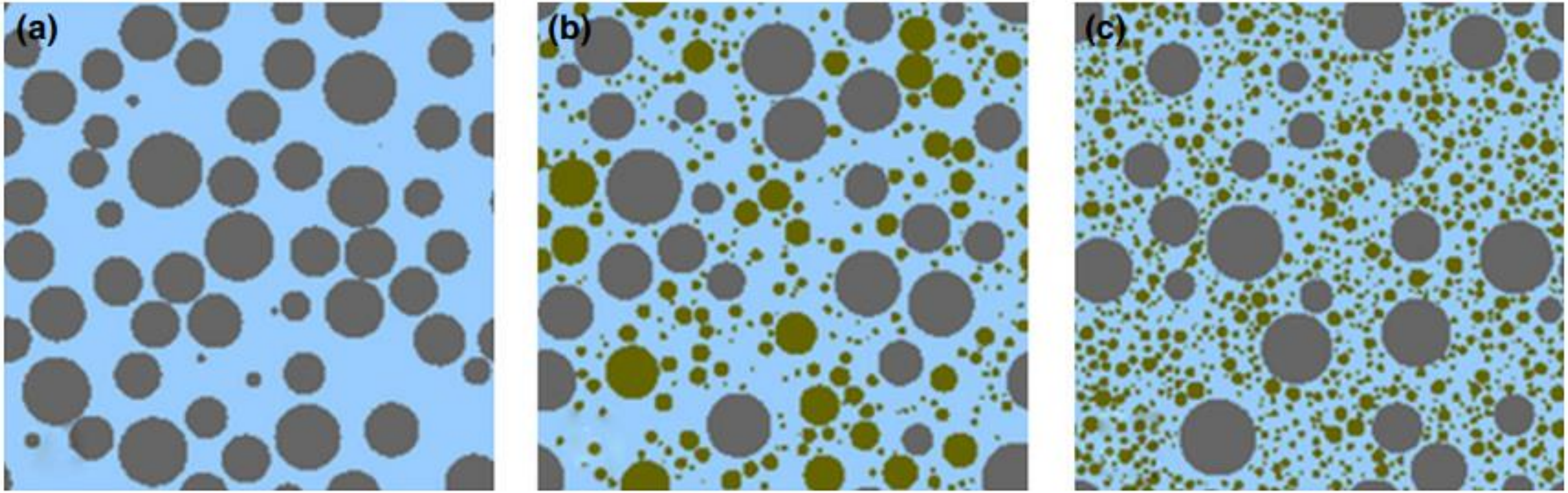
Voids ↑

Workability ↓

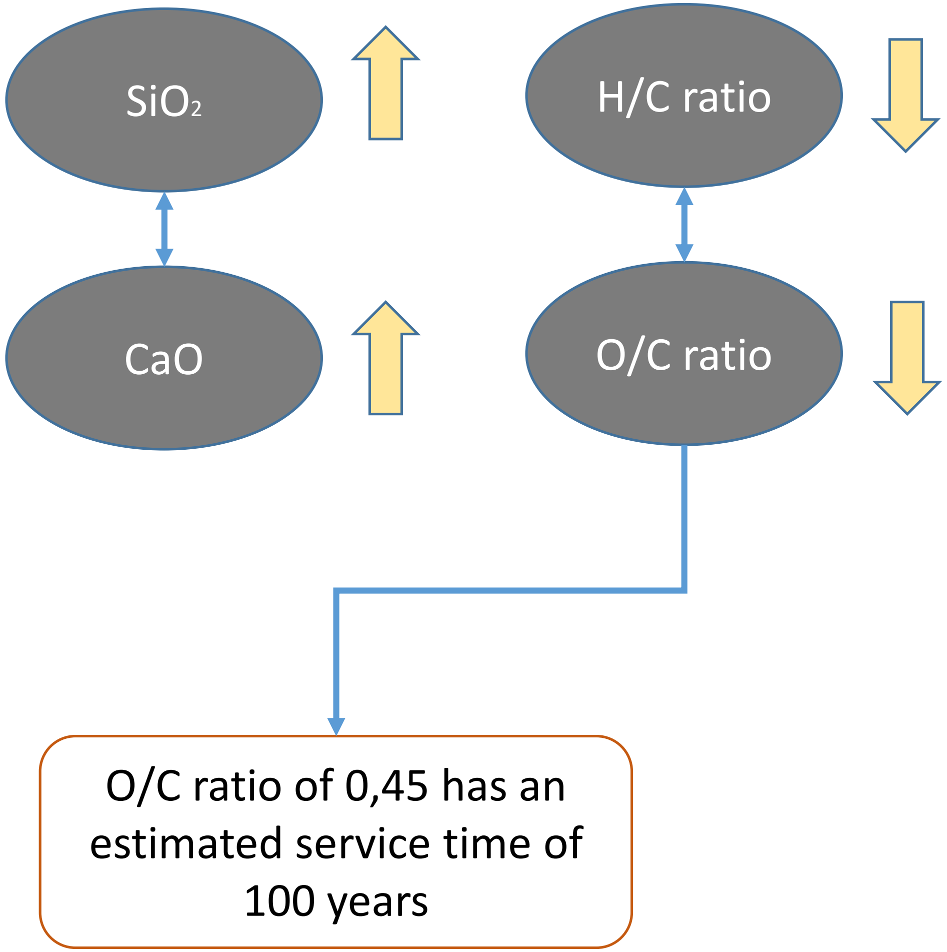




Filler effect

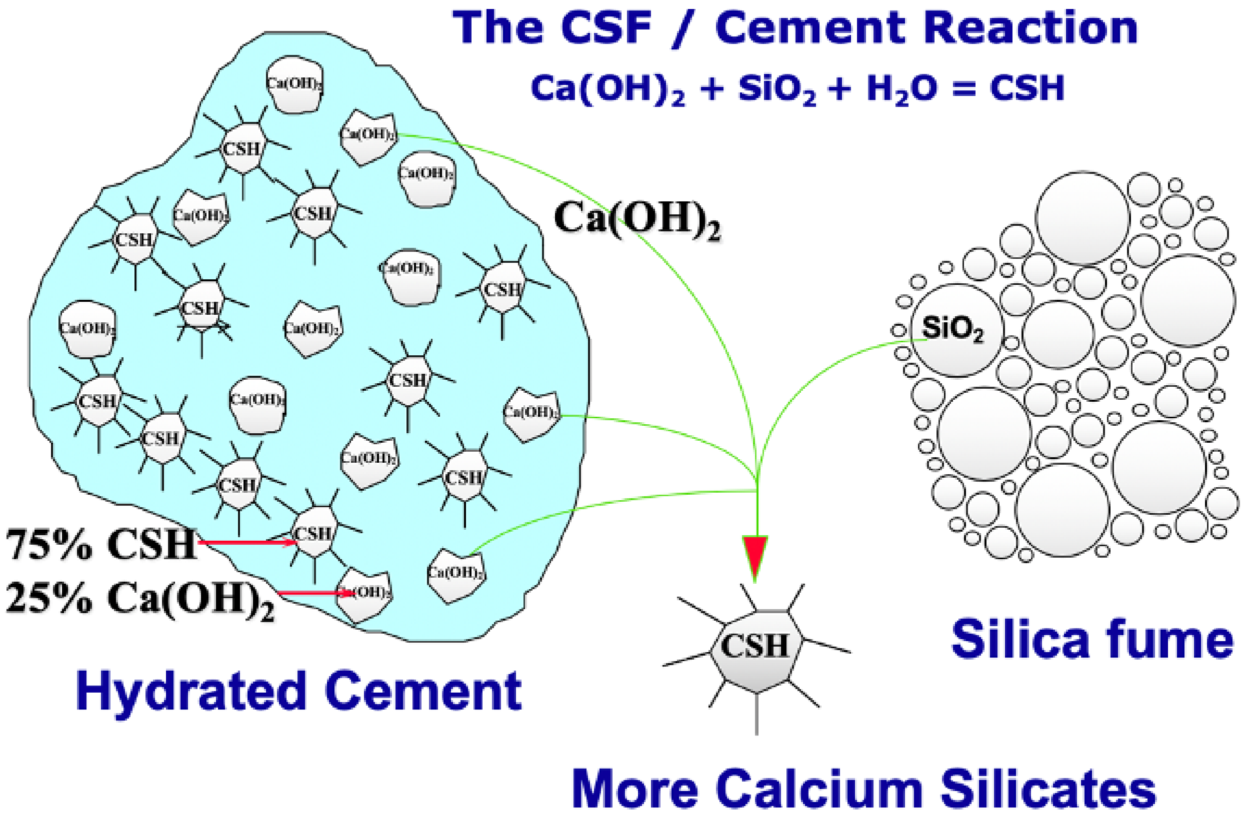


Elemental and chemical composition



Biochar	O/C	H/C
MWW300 (Gupta & Kua, 2018)	0.41	--
MWW500 (Gupta & Kua, 2018)	0.08	--
MWW500 (Dixit et al., 2019)	--	0.03
CS500 (Gupta, Krishnan, et al., 2020)	0.27	0.05
MWW500 (Gupta, Krishnan, et al., 2020)	1.27	0.05
SOR500 (Gupta, Palansooriya, et al., 2020)	0.28	0.06
SOR600 (Gupta, Palansooriya, et al., 2020)	0.21	0.05
AL500 (Gupta, Palansooriya, et al., 2020)	0.46	0.05
CST210 (Gupta, Palansooriya, et al., 2020)	1.23	0.12
CST250 (Gupta, Palansooriya, et al., 2020)	1.04	0.11
CST290 (Gupta, Palansooriya, et al., 2020)	1.00	0.12
DM600 (Gupta, Palansooriya, et al., 2020)	0.88	0.08
MS300 (X. Chen et al., 2020)	1.22	0.13
MS500 (X. Chen et al., 2020)	1.96	0.05
MS600 (X. Chen et al., 2020)	1.92	0.01
RH (Gupta, Muthukrishnan, et al., 2021)	1.37	0.05
MWW (Gupta, Muthukrishnan, et al., 2021)	0.21	0.03
PS (Gupta, Kashani, et al., 2021)	0.64	0.05
PL (Praneeth et al., 2021)	1.70	0.05
OS (Maljaee et al., 2021)	0.27	0.03
MWW (Maljaee et al., 2021)	0.25	0.04
RH (Maljaee et al., 2021)	0.82	0.05
MWW (Dixit et al., 2021)		0.04

Pozzolanic reaction and mechanical properties



Density ↑

Hydrated products ↑

Strength development ↑

RHA, SCBA, PLA → Replacement ratios from 1% up to 20% (w/w)

Discussion and research opportunities

- Biochar **dosage** and parent biomass feedstock played a critical role in the overall **properties and strength** development of the resultant composite.
- Dosages of over **10-20% (w/w)** demonstrated to **increase compressive and flexural strengths**.
- Incorporation of biochar **reduced the composite density**; however, it acted as **an internal curing agent**.
- **Dosage 2-8%** cement replacement enhanced water absorption, increased capillary porosity and decreased water penetration due to **saturation**.
- Biochar incorporation to cementitious blends resulted in an **abatement of GHG emissions** for 59 to 65 kg CO2-eq for each tonne of produced composite.

Discussion and research opportunities

- To the best of our knowledge there are no studies which statistically correlate the thermochemical conversion parameters such as temperature, heating rate and residence time with certain properties of biochar related to durability in cementitious composites such as elemental/chemical composition, O/C and H/C ratios, pH, density, porosity, surface area and mechanical properties to establish the statistical significance of these properties in relation to long-term expectation of biochar cementitious composites in terms of durability and as carbon sinks.

- Notwithstanding the lack of research about this particular subject, it can be inferred that biochar-amended composites pose as promising materials for the development of novel cement-based materials, such as pervious concrete, water purification, heavy metal removal, soil stabilization, bacteria carriers, heat and sound insulator, among others; while simultaneously acting as carbon footprint reduction agents. Assuredly, further investigations are needed to provide more precision and certainty over biochar-containing composites performance.

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