Asian Deans' Forum 2026

THE RISING STARS

Women in Engineering Workshop

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RESEARCH VISION

Engineering Biochar Interfaces for Low-Carbon, Climate-Resilient Construction

From molecular hydration to printable systems and fire-safe building elements

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A CIRCULAR MATERIALS VISION

Can waste-derived carbon be engineered to control how cementitious materials hydrate, flow, insulate and survive climate extremes?

Surface Chemistry

Direct Ca^{2+} adsorption and hydrate formation at carbon–cement interfaces

Internal Water

Buffer drying, support hydration and suppress microcracking

Pore Architecture

Regulate heat transfer, shrinkage, anisotropy and layer bonding

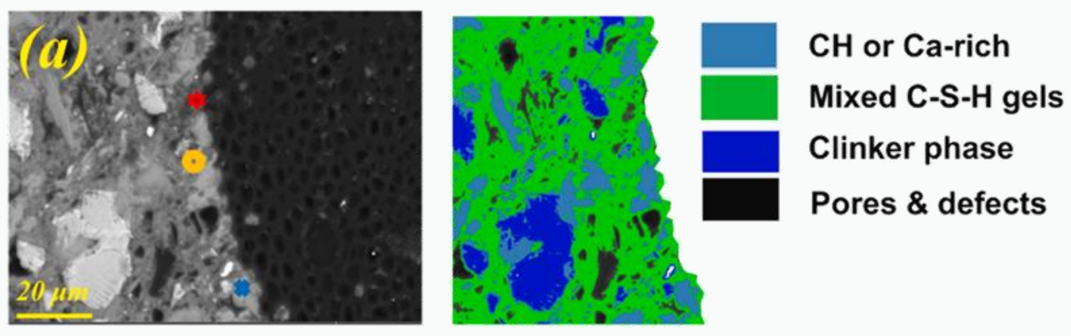
WASTE → ENGINEERED BIOCHAR → MULTIFUNCTIONAL MATERIALS → RESILIENT CITIES

A single carbon platform connects embodied-carbon reduction with thermal safety and digital construction

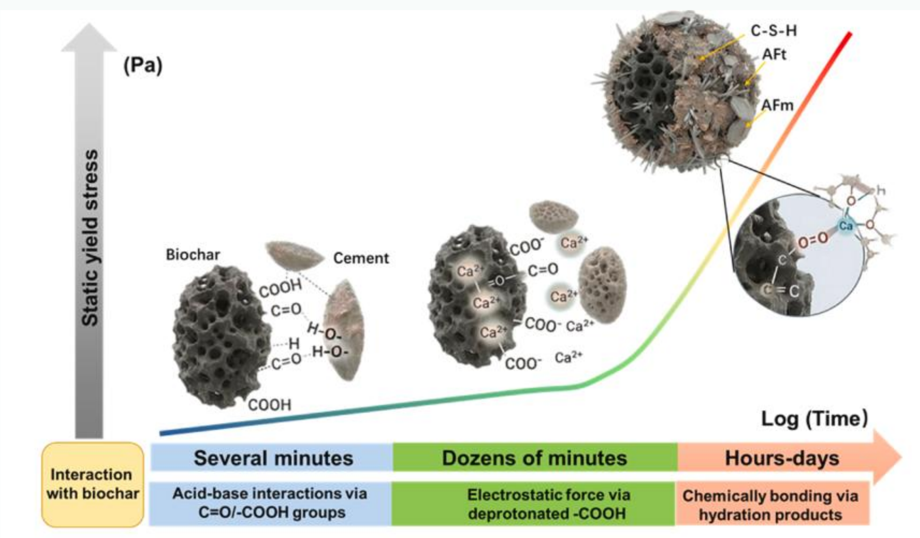
DESIGN LOGIC ACROSS SCALES

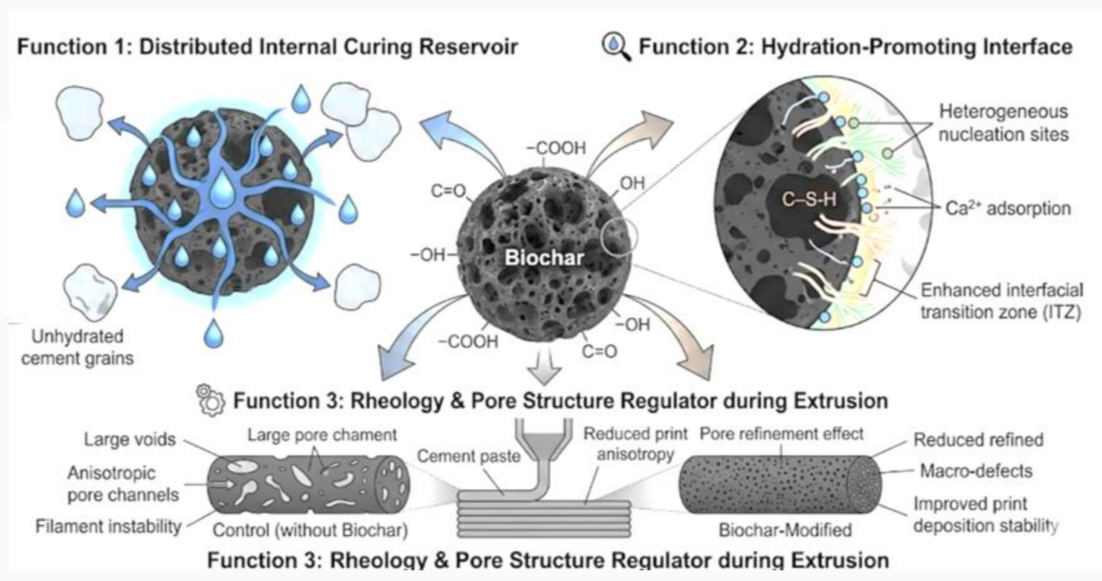
01	CHEMISTRY	Functional groups regulate ions and hydration products
02	PROCESSING	Porous carbon stores water and recovers structure after shear
03	PERFORMANCE	Interfaces and pores govern cracking, heat flow and anisotropy

INTERFACIAL CHEMISTRY



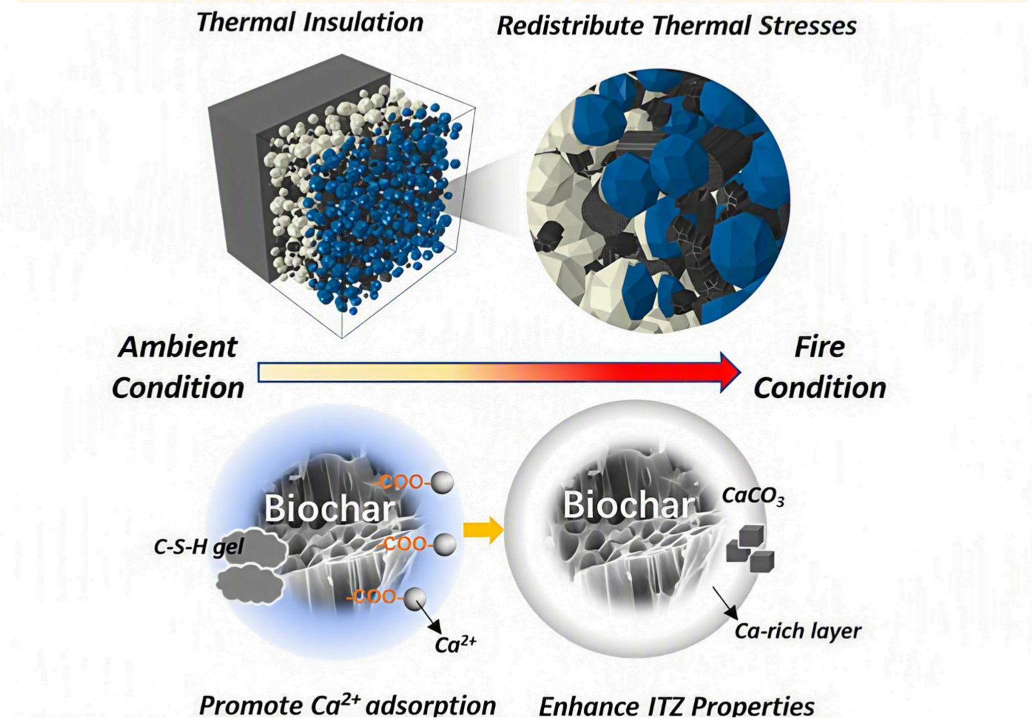
Biochar surfaces adsorb Ca^{2+} and support a Ca-rich layer that transforms into carbonate-rich reinforcement





FIRE-RESILIENT BIOCHAR CONCRETE

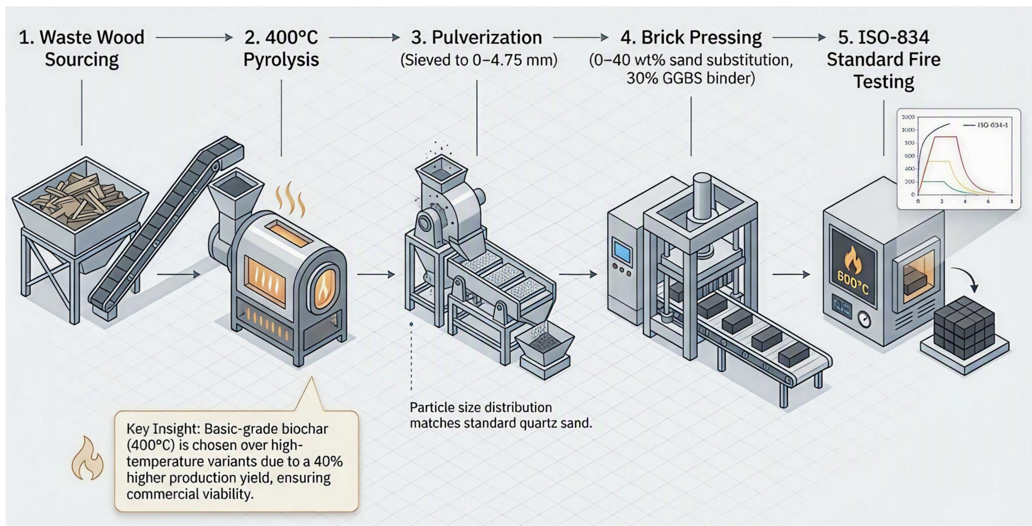
Oxygenated biochar interfaces concentrate Ca-rich hydrates and form a carbonate-reinforced shell during fire exposure.



66 → 52 °C	20–30 wt%	Class A1
mean rear-surface rise Ref → BC20	best-balanced sand replacement range	non-combustibility 5–40 wt%

Mechanistic Evidence

- Biochar –COO⁻ / –OH / C=O groups adsorb Ca^{2+} and support a localized Ca-rich shell
- After 500 °C exposure, >45 GPa $CaCO_3$-rich regions appear at the interface
- Protected internal regions show ~31% lower porosity and ~58% less hydrate decomposition



DESIGN PRINCIPLE

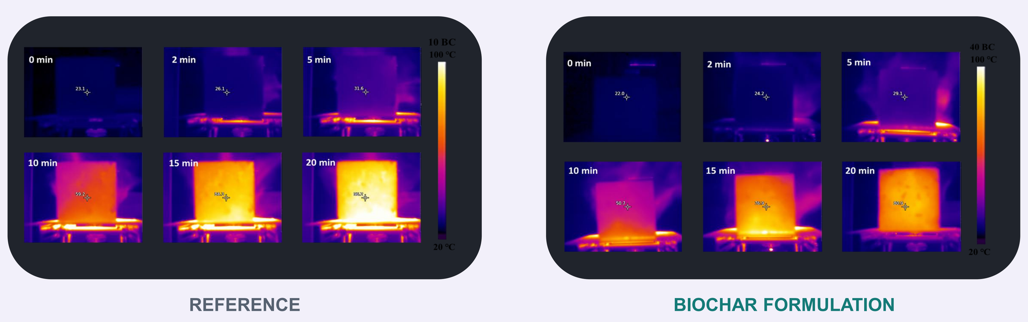
Tune surface oxygen groups to create Ca-rich interfaces, then select a dosage that preserves cementitious coverage and interrupts heat transfer.

Caution: at 40 wt%, connected carbon/void pathways can increase heat release, porosity and crack susceptibility.

MULTISCALE WORKFLOW

1 BIOCHAR → 2 THERMAL EXPOSURE → 3 ITZ ANALYSIS → 4 WALL FIRE TEST

FULL-SCALE THERMAL RESPONSE



Compression · thermal expansion · MIP/μCT · XRD/TGA/SEM-EDS · nanoindentation · standardized wall testing

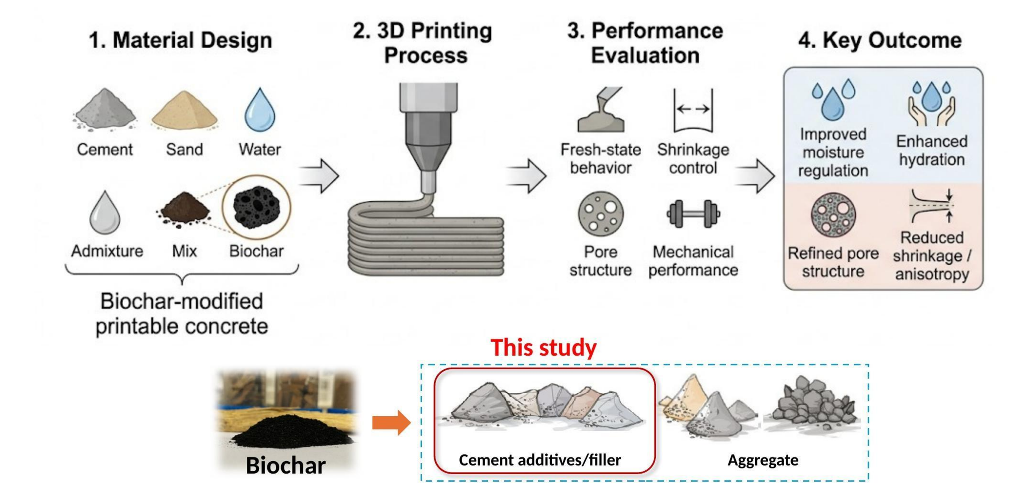
FULL-SCALE WALL TEST

1000 × 1000 × 115 mm wall · 60-min standard fire exposure · five-point unexposed-surface temperature monitoring

ENGINEERED BIOCHAR FOR 3D PRINTING

Engineered biochar couples moisture buffering, thixotropic recovery and pore-interface refinement to stabilize 3D printable concrete

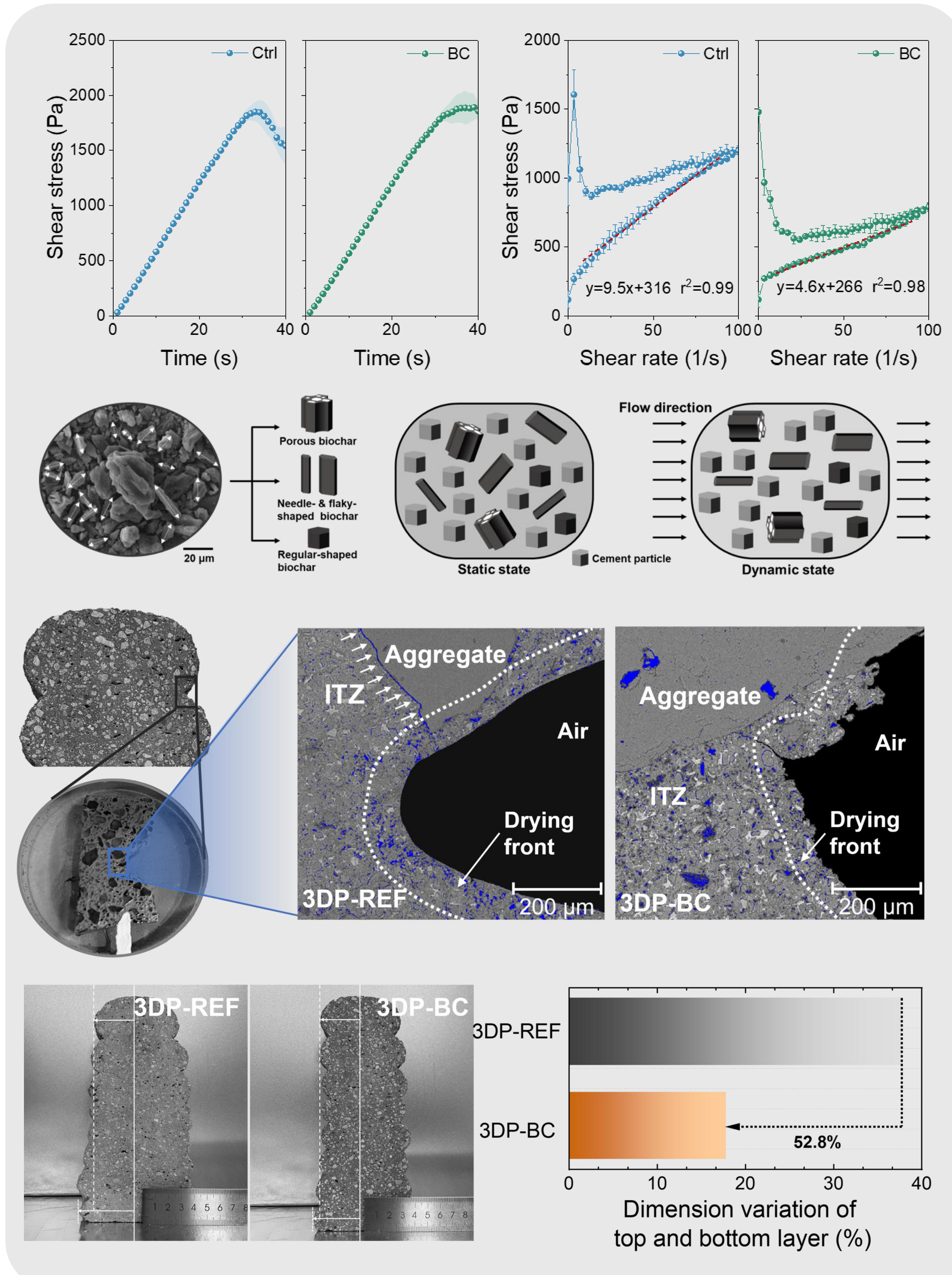
Comparing reference and biochar-enhanced 3DPC



↓16%	↓52%	↓43.6%
dynamic yield stress	plastic viscosity	drying shrinkage
↓64.4%	**43 → 74%**	**5.8 → 1.6%**
interfacial microcrack width	small pores <100 μm	anisotropy variation coefficient

THREE FUNCTIONS, ONE ADDITIVE

H_2O MOISTURE RESERVOIR	Ca^{2+} HYDRATION INTERFACE	3DP RHEOLOGY & PORES
Stores added water → delays surface drying	Adsorbs calcium → densifies the ITZ	Shear-thin → recover → stabilize filaments



SELECTED OUTPUTS

1. Zhang et al. Scaling biochar solutions for urban carbon dioxide removal. One Earth 7, 1481–1486 (2024).
2. Zhang et al. Enhanced thermal insulation of biochar–gypsum composites. Cem. Concr. Compos. 159, 106013 (2025).
3. Zhang et al. 3D printing technology in concrete construction. Nat. Rev. Clean Technol. 1, 288–303 (2025).

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