

8/3/25
Sunday
3:10pm - 4:41pm
91 minutes
46
2023

Carbon Capture & Storage Potential of Biochar-Enriched Cementitious Systems

Cement & Concrete Longevity
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12 pages

Abstract: \downarrow net-embodied GGE of CE infrastructure by vs BIOCHAR

- Carbon sink, improved performance of concrete
- 1% optimal amount, add mineral additives to boost porosity
- TGA shows 42% \uparrow CO₂ intake w/ just 1% Biochar, 92% \uparrow w/ 10% Class F FA
- Accelerated carbonation \rightarrow \uparrow pore, Tougher Finishes
- Morphology of Biochar promotes enhanced CO₂ absorption & in-situ mineralization of calcium carbonate \rightarrow \uparrow density \uparrow strength of cement matrix

Problem: Concrete Industry \rightarrow 7% of GGE

Soln: Mix w/ Biochar + FA / Nanosilica = \uparrow CO₂ uptake

superior pore structure

• Biochar
• CO₂ sequestration
• Mineralize
• Fly Ash
• Diffusion Kinetics
• CO₂ Uptake
• Hydrate Kinetics
• Crack propagation
• Synergistic

• Class C Fly Ash
• Powdered Nano Silica
• Biochar
• Carbonylate-based SP

M, M+BI, M+BI.S, M+BI+FA-C10, M+BI+NSI

W/C = 0.485
S/C = 2.75

Non-carbonated vs Carbonated

TGA: Calcite from 500-900°C weight loss

23°C / 45% RH for cure

@ 3 day, 12% CO₂ (100% purity) @ 15psi, 23°C, 65% RH

\uparrow + \rightarrow for 7-days, 10 day exposure to CO₂ under thermal power plant vents (Carbonate chamber)

ASTM C798 - Standard Sand
ASTM C618 - Fly Ash

Non-standard mix procedure: 30s, 30s, 90s @ 2-speed

ASTM C1679 - HOH Vortex-Mix for Vials

ASTM C1872 - TGA (on 7/28 day)

RILEM TC 162 - Size Independent Toughness Finishes

ASTM C349 - Compressive Strength

ASTM C109 M - MOD

TGA \rightarrow Find Bound water, CH, & CaCO₃

@ 7-day / 28-day

LEFM \rightarrow Load-CMOD @ 3, 7, 28, 0.001 mm/min crack propagation rate

Compressive \rightarrow Constant Velocity = 0.3 mm/s

HOH \rightarrow FA & Nanosilica \uparrow Hydrate mechanism

HOH \rightarrow CP+BI+FA10 RETARDED \uparrow HOH
CP+BI+NSI ACCELERATE \uparrow HOH \uparrow

TGA \rightarrow Bound water \uparrow for 15 weeks, to high surface which provides additional safe for precipitate of hydrate products

Comp Strength: CP+BI+FA/NSI TCS by differ particle sizes & shapes, better binary packing in matrix

Fill inter-particle spaces w/ \rightarrow hydrate products

Mech: Carbon-inert particles act as plasticizers in crack growth path

CO₂ is sequestered, stored in thermodynamically stable form of calcite

CP+BI+FA10 \rightarrow 92% CO₂ uptake thanks to added calcium from Class C promotes carbonate mineralization

SEM showed that porous shape of Biochar cases CO₂ absorption & in-situ mineralization of CaCO₃, results in \uparrow dense / strong matrix

BA+SEMS = \downarrow CO₂ emissions
 \uparrow CO₂ uptake & storage capacity
 \uparrow performance

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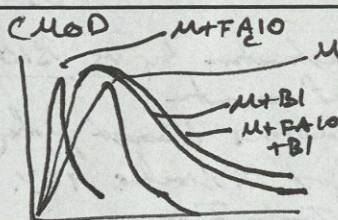
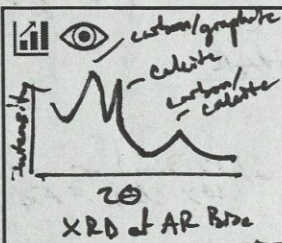


carbonate makes.
M+FA bottles
but M+BI = super
durable

Enhanced pore pH by hygro
products leads to pH in
much strength, then densit
of cementitious matrix

FA \rightarrow pozzolanic reaction
conversion of $\text{CH} \rightarrow \text{CSH}$
CSH = main hydro product
for strength during

"Polymorphs of calcite" \rightarrow CaCO_3 's polymorphs: ^{Aragonite} calcite



② Biochar: porous byproduct of biomass pyrolysis process,
thermochem conversion of biomass @ temps b/w 450-550°C
in absence of oxygen.

- Potential to offset 12% anthropogenic CO_2 emissions by 2050,
estimated request of 0.3-2 Gt CO_2 per year.
- pH in hydrate products \rightarrow carbonate mineralization sites
- Pyrolyzed biochar micro-particles in cement matrix
choiced by high strength & stiffness due to carbon content,
[crack tortuosity], thus promote tough mechanism.
- Highly porous, from local supplier. >90% Carbon, $\rho = 0.55 \text{ g/cm}^3$
- Particle size = 20-250 μm , irregular shapes = interlock, aggrs
- Surface micropores = 5-10 μm in size
formed due to conversion of volatiles & organic matter dur. pyrolysis,
which can absorb water & act as self-cur. agent in mortar/concrete.
- Semi-amorphous structure together w/ presence of calcite
- Tensile effect of carbon \downarrow H_2O , adds high inert filler content
 \downarrow reduces heat during curing, harden stage of
- Incorporation of just Biochar in cement does not pH \downarrow
- When mixed w/ NS or FA, micropores store. at biochar provides
sites for deposition of additional hydrates formed due to
pozzolanic reaction & rapid reaction.
- B1.5 causes significant loss in comp. strength. (from micropores
store at biochar)
- B+FA enhances bond strength & cohesivity of solid particles,
 \uparrow physicochemical props. of composites
- Continued exposure of specimens to CO_2 can generate dense membrane
of carbonates around interior anhydrous cement & hydrate products,
which hinders CO_2 diffusion & reaction
- Angular & fibrillar morphology of Biochar"
 \rightarrow contributes to effective stress redistribution into matrix
& drying of more tortuous & articulated crack paths

- Silica fume (pozzolanic active) can offset \downarrow in strength in
biochar mortars
- The pozzolanic active additives
varies w/ Δ in compo, particle size
or morphology
- Total pozzolanic additives
can \uparrow carbon sequestration capacity
by \uparrow CH from 20-60%.
- Only dust has been investigated.
Future work: Effect of CO_2
uptake capacity

For TGA: Weight loss occur
dur. decomp. of hydrated cement
From (105-400°C) = Bound water.
Where:
[105-400°C] = Dehydration of
 $\text{C-S-H}/\text{C-A-S-H}$, A-H , etc
[400-500°C] = Dehydration of CH
[550-900°C] = Decarbonation

Toughness Indices are size-independent
used to show interrelationships
to crack propagation when F_{10}
cracks coalesce to form a F_{10}
fracture zone @ post peak

$\text{H}_2\text{O} \rightarrow \text{CP} + \text{BI} + \text{NSI}$ works best
thanks to synergistic effect of
nano-silica & biochar.

\rightarrow acts as nucleation site for
faster dissolution of cement phases,
helps in moisture regulation dur.
the hydrate process

FA particles \rightarrow slow reaction,
dissolution/precipitation process
slows down @ early hydrate age
& causes extended dormant
period
However, w/ time even CP+BI+FA10
matched CP+BI+NSI in compressive
strength thanks to pozzolanic reaction
of FA after crystallization of CH

Can we use more SCM
w/ Biochar to save cement?

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