

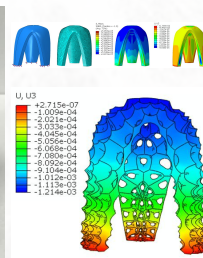
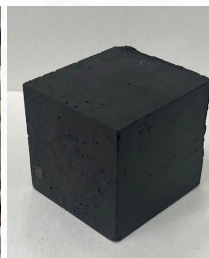
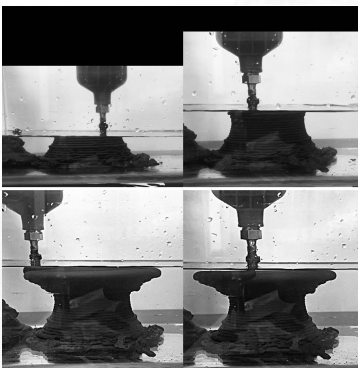
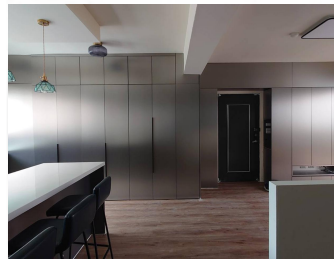
Utilizing Manufacturing Paper Sludge as **Fly Ash** with Engineered Biochar for Geopolymer Binder Systems

Research:

- CCS Building Materials
- Form-Finding Structures
- Biodegradable Materials
- Performance Based Design

Innovation:

- The world first 3D printed concrete formwork under water.
- Carbon Storage via Architectural Design.



GP Research Goals

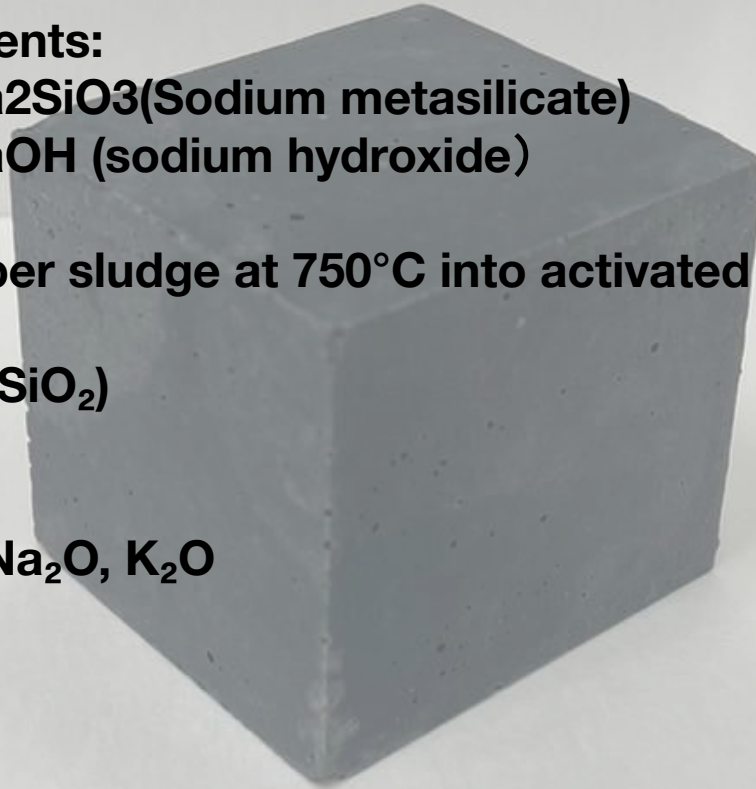
1. Processing industrial wasted rice husk biochar as filler for GP.

a. It contents:

- | | |
|--|-----------|
| i. Na_2SiO_3 (Sodium metasilicate) | 5-15% |
| ii. NaOH (sodium hydroxide) | <1% total |

2. Processing paper sludge at 750°C into activated material for GP.

- | | |
|--|-----------|
| a. CaO | 50-80% |
| b. Silica (SiO_2) | 5-15% |
| c. Al_2O_3 | 2-10% |
| d. Fe_2O_3 | 0.5-2% |
| e. MgO , Na_2O , K_2O | <5% total |

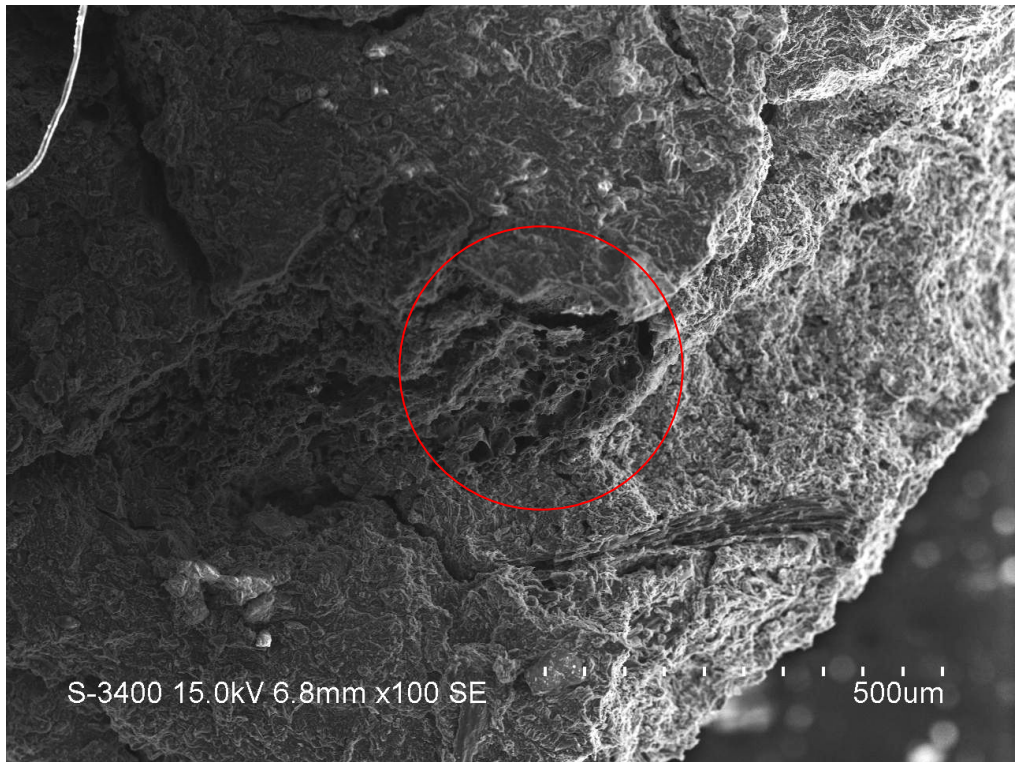


1. Why biochar?

- **1g biochar = 2.65 CO₂e, a natural CCS material**
- **Micro climate control material**
- **It can trap VOCs**
- **Low thermal conductivity**



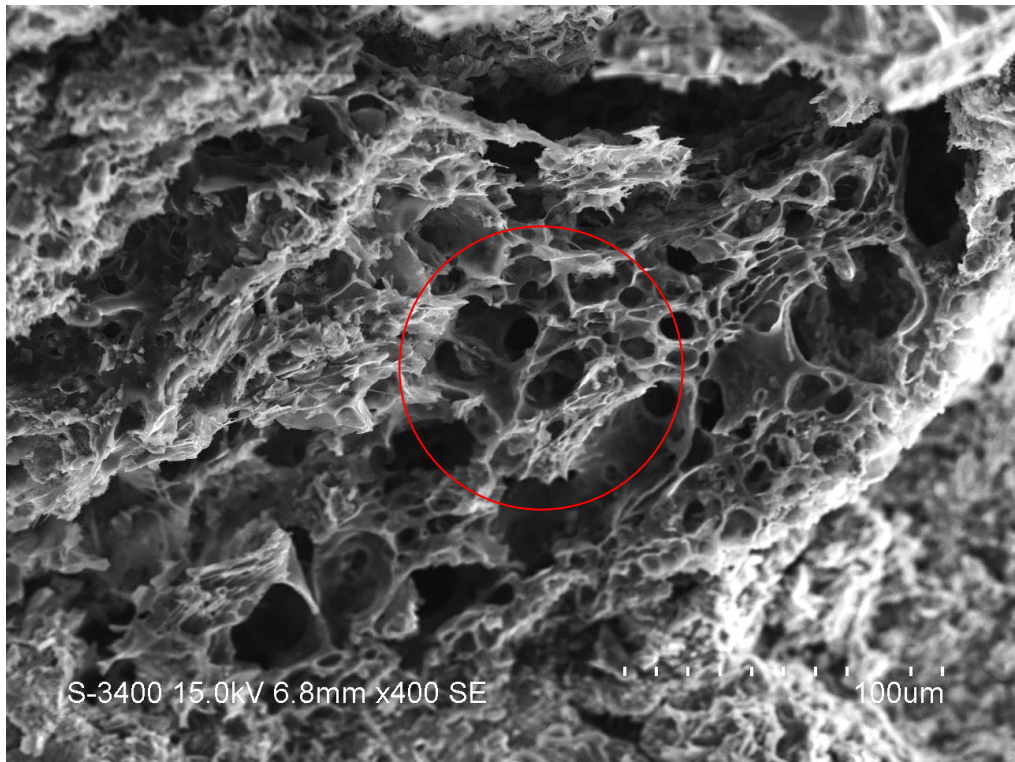
Processed Biochar Scanning Electron Microscope (SEM)



Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)
C	6	4157	34.53	41.48	54.80	1.85
O	8	3433	21.40	25.71	25.50	1.11
Na	11	5618	11.61	13.95	9.63	1.12
Mg	12	300	0.58	0.70	0.46	0.08
Si	14	11234	12.44	14.94	8.44	0.81
K	19	341	0.33	0.40	0.16	0.04
Ca	20	1465	1.53	1.84	0.73	0.09
Mn	25	221	0.37	0.45	0.13	0.05
Fe	26	226	0.45	0.54	0.15	0.06
		Sum	83.26	100.00	100.00	

生物炭 (biochar)、矽酸鈉 Na_2SiO_3 (Sodium metasilicate)、氫氧化鈉 NaOH (sodium hydroxide)

Processed Biochar Scanning Electron Microscope (SEM)



Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)
C	6	4157	34.53	41.48	54.80	1.85
O	8	3433	21.40	25.71	25.50	1.11
Na	11	5618	11.61	13.95	9.63	1.12
Mg	12	300	0.58	0.70	0.46	0.08
Si	14	11234	12.44	14.94	8.44	0.81
K	19	341	0.33	0.40	0.16	0.04
Ca	20	1465	1.53	1.84	0.73	0.09
Mn	25	221	0.37	0.45	0.13	0.05
Fe	26	226	0.45	0.54	0.15	0.06
		Sum	83.26	100.00	100.00	

生物炭 (biochar)、矽酸鈉 Na_2SiO_3 (Sodium metasilicate)、氫氧化鈉 NaOH (sodium hydroxide)

Conventional Concrete Mixture with Biochar



Slag



Fly Ash



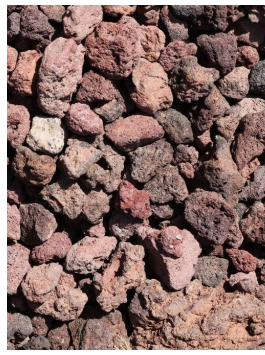
Cement



Additives



Sand



Aggregates



Cement-Based Samples with 30% Biochar



5 samples
Avg. 0.34 MPa

Biochar+Calcium hydroxide:20%
Dredged Material:30%
Clay:20%
Sand:0%
Cement:7%



5 samples
Avg. 0.74 MPa

Biochar+Calcium hydroxide:10%
Dredged Material:40%
Clay:20%
Sand:0%
Cement:7%



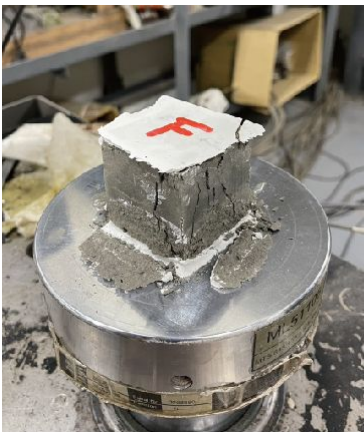
7 samples
Avg. 1.4 MPa

Biochar+Sodium Silicate:10%
Dredged Material:40%
Clay:20%
Sand:0%
Cement:7%



4 samples
Avg. 2.4 MPa

Biochar+Sodium Silicate:7%
Dredged Material:50%
Clay:20%
Sand:0%
Cement:7%



6 samples
Avg. 5.1 MPa

Biochar+Sodium Silicate:7%
Dredged Material:50%
Clay:0%
Sand:20%
Cement:7%

10% Biochar + Geopolymer



Rice Husk

Neutral / Inactive Material



Slag



MK

Sodium Silicate

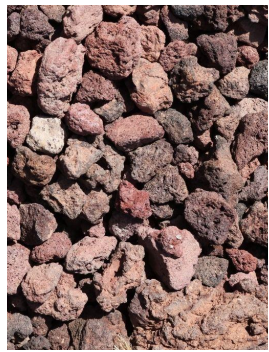
Na+



Additives



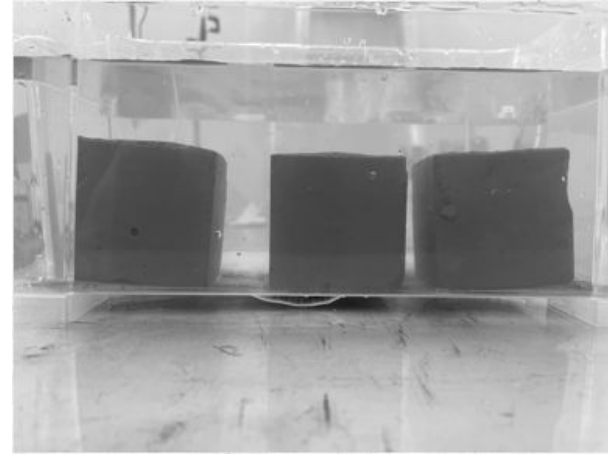
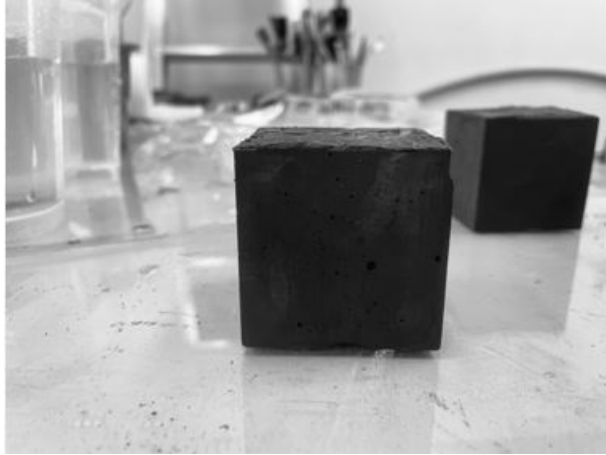
Quartz



Aggregates



10% Biochar + Geopolymer



10% Biochar + Geopolymer



**3 samples
Avg. 10.34 MPa**



**3 samples
Avg. 12.3 MPa**



**3 samples
Avg. 13.74 MPa**

Research:

- Learning from the GP camp tutorial:
 - ◆ Testing the binder ingredients.
 - ◆ Re-order the mixture sequence from less reactive to the most reactive.
 - ◆ Mixing time adjustment.
 - ◆ Calculate binder $\text{Na}^+/\text{Al} = 1$
- $\text{SI}/\text{Al} \leq 2$
- Surface modification biochar is possible to enhance final product's mechanical properties. But it will serve as the filler not the binder in GP.
- Paper sludge processed fly ash needs to be tested and determined the mineralogy.
- If dredged material can be calcined (microwave), its compositions and mineralogy need to be determined.

Thank you