# Opportunities & Challenges of Using Biomass Ash and Biochar in Concrete

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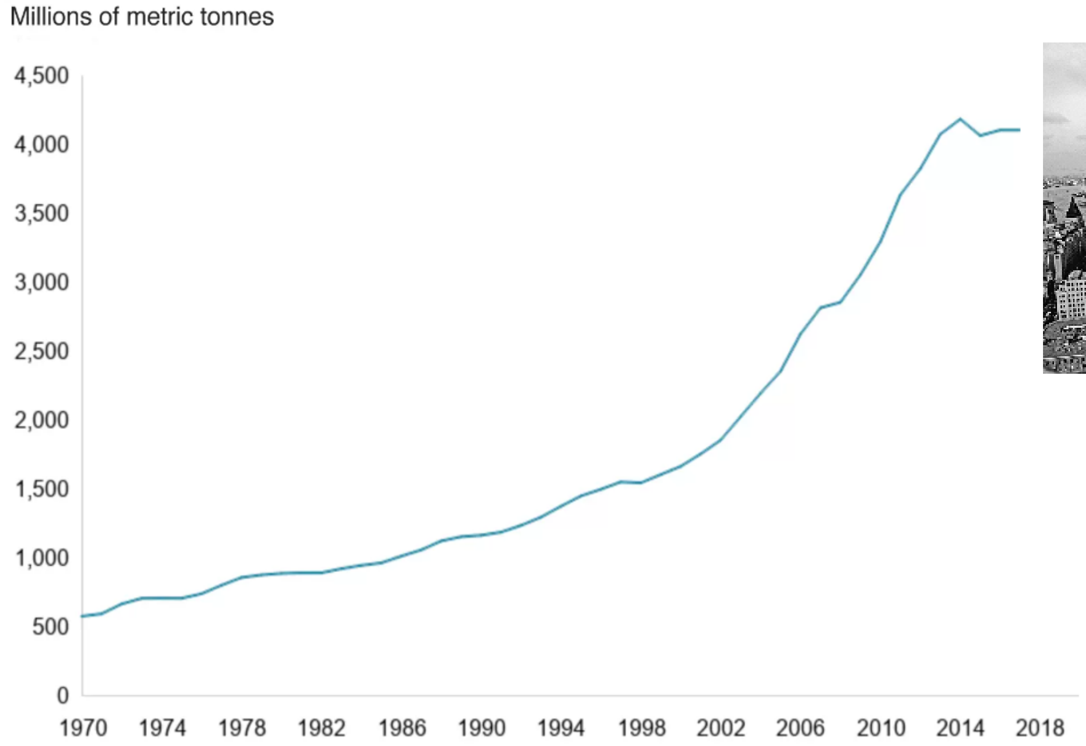
# Global Cement Demand Projection

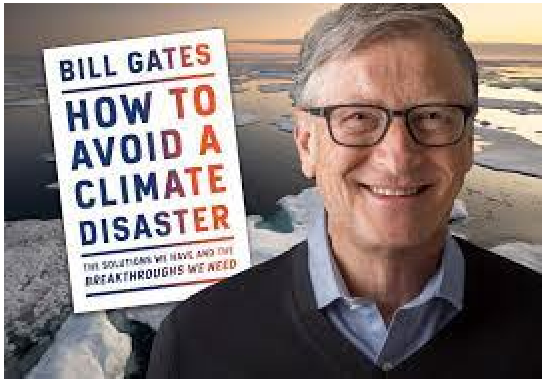
- Main challenge facing the cement industry is to reduce $CO_2$ emissions while meeting global demand



Note: Figures for 2016 and 2017 are estimates

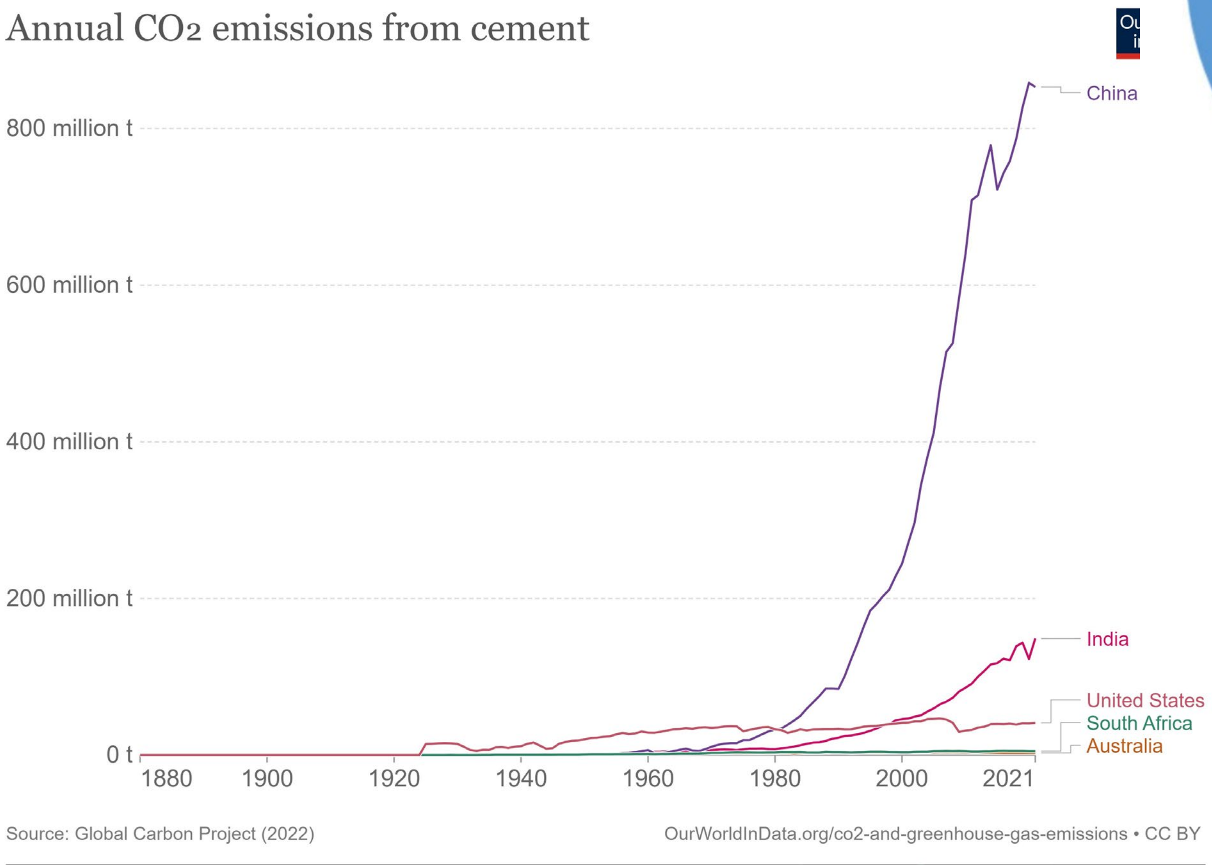
Source: USGS

1987 (left) and 2013 (right).



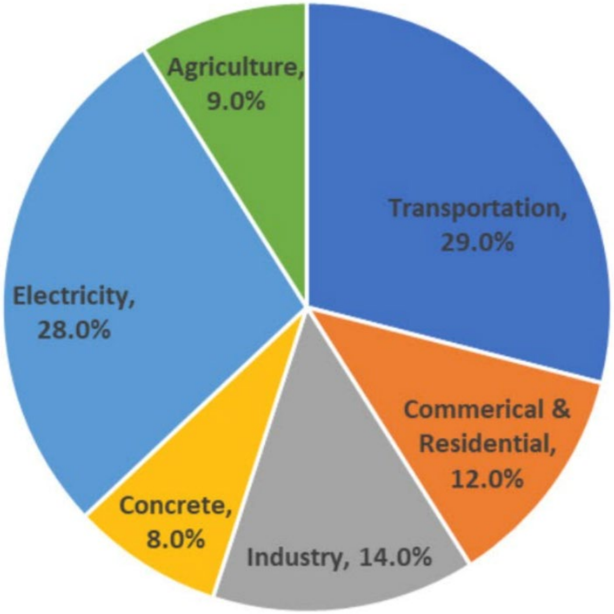
# $CO_2$ Emissions from Cement Production-Global

- Concrete responsible for 8% of global anthropogenic $CO_2$ emissions



Source: Global Carbon Project (2022)

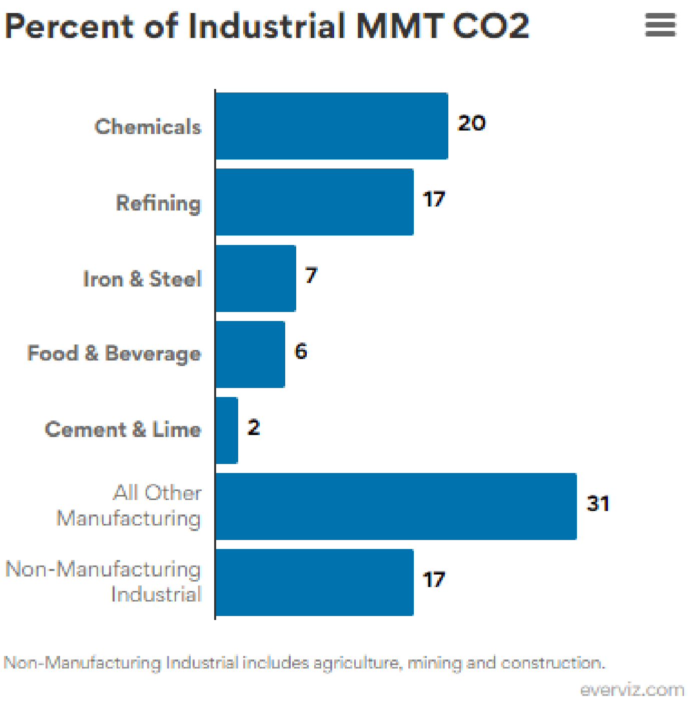
OurWorldInData.org/co2-and-greenhouse-gas-emissions • CC BY



Princeton Student Climate Initiative

# CO2 Emissions from Cement Production- US

- $CO_2$ emissions from calcination of limestone ~58% of total $CO_2$ emissions and energy-related $CO_2$ emissions ~42% of total emissions
- Making cement requires high levels of heat, with heat from coal and petroleum coke combustion ~88% of total energy consumption.
- Several strategies to reduce emissions
  - Increase use of… supplementary cementitious materials in concrete



Non-Manufacturing Industrial includes agriculture, mining and construction.

**Source: DOE Industrial Decarbonization Roadmap**

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# Replace Some of Cement with Other Materials

- Calcareous or siliceous-aluminous materials in fine particles chemically react with CH (water requried) …to form compounds with cementitious properties (ASTM C125)

- SCMs from industrial sector:
  - Coal Fly ash (most common)
    1. Domestic supplies of fly ash diminishing
    2. Sources of fly ash in UT, AZ, CO, NM and foreign countries
  - Steel slag (GGBFS)
    1. Little steel making in the US, GGBFS mainly imported
  - Natural materials: diatomaceous earths,…, tuffs and volcanic ashes or pumicites,…, and some clays and shales (AASHTO M295)
  - Biomass ashes????
  - Biochars?

CLIMATE CHANGE, COAL

# Can Coal Fly Ash Waste Be Put To Good Use?

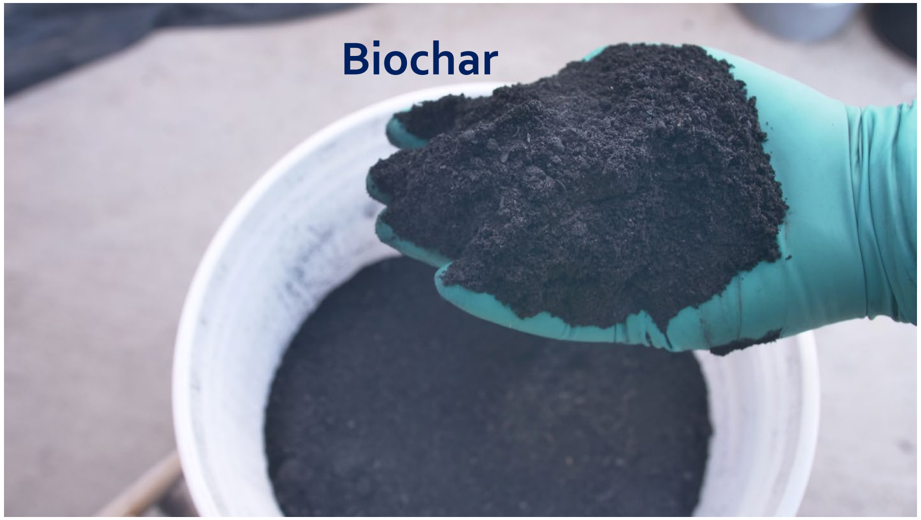
By ED DODGE

on February 18, 2014 at 12:00 PM

# Industry Participation

- Wood and rice hull fly ash and bottom ash samples have been collected from 8 energy producers: a total of 18 plants
- 14 biochar samples from forestry and ag-based biomass feedstock (wood, walnut shells, rice hulls)
  - Pyrolysis or Gasification (Temp. 500-800 °C or 930-1470 °F)
  - Torrefaction (Temp. 200-300 °C or 390-570 °F)


Biomass ash


Biochar

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# Sample Preparation & Characterization

- Step 1: Grinding or ball milling
- Step 2: Fineness check by wet sieve #325 must retain < 34%
- Step 3: Chemical composition, moisture content, loss on ignition, density
- For biochar: zeta potential, proximity test, surface groups

# ASTM C618 Compliance for Coal Fly Ash and Natural Pozzolans

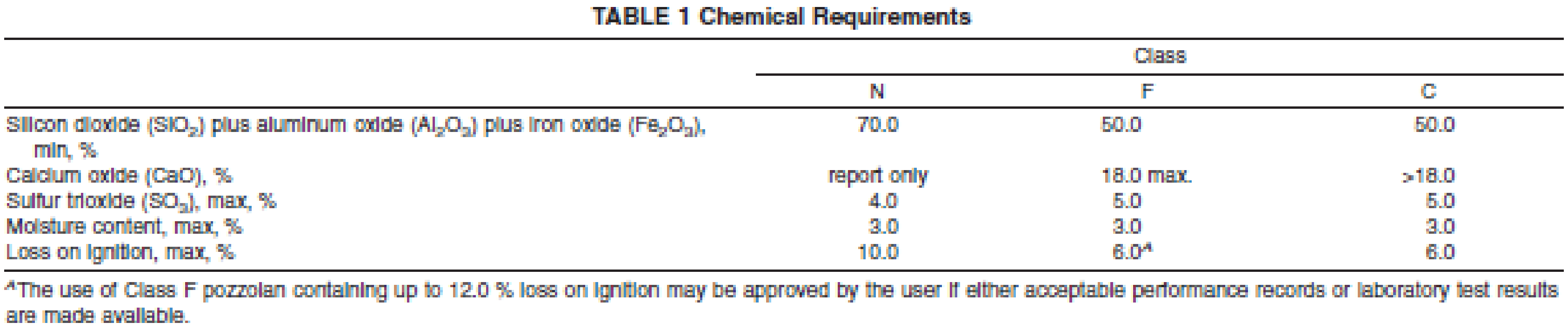


**TABLE 1 Chemical Requirements**

| | Class | | |
|---|---|---|---|
| | N | F | C |
| Silicon dioxide ($SiO_2$) plus aluminum oxide ($Al_2O_3$) plus iron oxide ($Fe_2O_3$), min, % | 70.0 | 50.0 | 50.0 |
| Calcium oxide (CaO), % | report only | 18.0 max. | >18.0 |
| Sulfur trioxide ($SO_3$), max, % | 4.0 | 5.0 | 5.0 |
| Moisture content, max, % | 3.0 | 3.0 | 3.0 |
| Loss on ignition, max, % | 10.0 | 6.0[A] | 6.0 |

[A] The use of Class F pozzolan containing up to 12.0 % loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

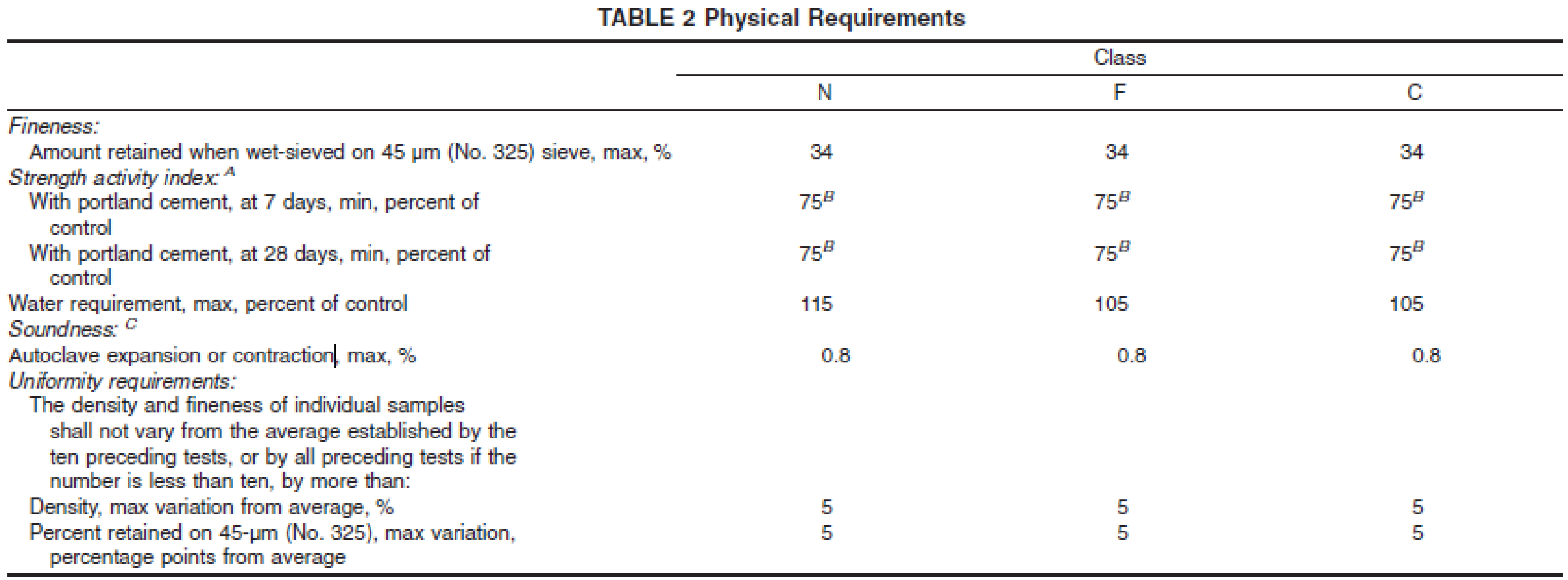
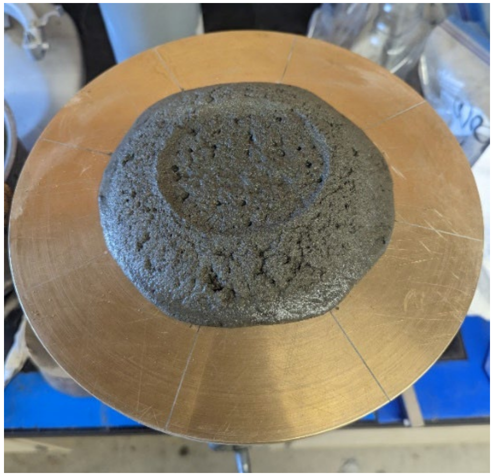


**TABLE 2 Physical Requirements**

| | Class | | |
|---|---|---|---|
| | N | F | C |
| *Fineness:* | | | |
| Amount retained when wet-sieved on 45 µm (No. 325) sieve, max, % | 34 | 34 | 34 |
| *Strength activity index:*[A] | | | |
| With portland cement, at 7 days, min, percent of control | 75[B] | 75[B] | 75[B] |
| With portland cement, at 28 days, min, percent of control | 75[B] | 75[B] | 75[B] |
| Water requirement, max, percent of control | 115 | 105 | 105 |
| *Soundness:*[C] | | | |
| Autoclave expansion or contraction, max, % | 0.8 | 0.8 | 0.8 |
| *Uniformity requirements:* | | | |
| The density and fineness of individual samples shall not vary from the average established by the ten preceding tests, or by all preceding tests if the number is less than ten, by more than: | | | |
| Density, max variation from average, % | 5 | 5 | 5 |
| Percent retained on 45-µm (No. 325), max variation, percentage points from average | 5 | 5 | 5 |

# Water Demand and Strength Activity Index

- Step 4- Batch mortar, measure water demand
  - 400 g of portland cement
  - 100 g of SCM (20% replacement of cement)
  - 1375 g of graded standard sand
  - mL of water required for flow ± 5 of control mixture
  - Water requirement, max, percent of control: Class N : 115, Class F: 105, Class C: 105
- Step 5- Measure 7- & 28-day compressive strength of three cubes
  - Strength needs to be 75% or greater than the control mixture



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# Chemical and Physical Properties

| ID | $Al_2O_3 + SiO_2 + Fe_2O_3$ | CaO | Class N/C/F | $SO_3 < 4\%$ | Moisture content (%) < 3% | LOI @750℃ < 10% | Finessness (% passing #325) | Total alkalis: $Na_2O_{eq} < 5\%$ | Available alkalis: $Na_2O_{eq} < 1.5\%$ |
|---|---|---|---|---|---|---|---|---|---|
| W-FA-M1-P1(09-22) | 53.3 | 22.3 | Class C | 2.7 | 32.0 | 56.3% | 97.4 | 9.2 | 2.42 |
| W-FA-M1-P2(09-22) | 25.90 | 35.60 | None | 4.66 | 8.00 | 61.8% | 98.8 | 17.14 | |
| W-FA-M1-P3(09-22) | 59.95 | 17.34 | Class F | 2.64 | 37.70 | 57.2% | 71.2 | 7.40 | 2.24 |
| W-FA-M1-P4(01-23) | 36.94 | 19.08 | None | 7.15 | 63.38 | 62.7% | 82.4 | 21.44 | 2.30 |
| W-FA-M1-P5(01-23) | 33.26 | 24.08 | None | 10.17 | 56.91 | 62.0% | 76.0 | 15.65 | |
| W-FA-M1-P6(01-23) | 29.10 | 33.82 | None | 5.90 | 62.17 | 63.2% | 82.4 | 15.30 | 2.01 |
| W-FA-M1-P7(01-23) | 75.83 | 9.34 | Class N | 2.77 | 28.23 | 14.3% | 54.9 | 5.63 | 1.14 |
| W-FA-M1-P8(01-23) | 2.28 | 12.30 | None | 1.12 | 5.32 | 98.1% | 77.3 | 76.00 | |
| W-FA-M1-P9(01-23) | 16.07 | 24.57 | None | 23.78 | 6.64 | 36.2% | 83.4 | 14.95 | 6.84 |
| | | | | | | | | | |
| | | | | | | | | | |
| W-FA-M2-P1(09-22) | 53.05 | 26.27 | Class C | 4.48 | 2.00 | 4.9% | 61.3 | 7.36 | 2.26 |
| W-FA-M2-P2(09-22) | 40.47 | 23.23 | None | 15.86 | 0.45 | 6.0% | 34.2 | 11.31 | 3.79 |
| W-FA-M2-P3(09-22) | 56.91 | 23.87 | Class C | 5.00 | 0.04 | 5.2% | 63.8 | 6.36 | |
| W-BA-M2-P1(09-22) | 86.90 | 3.67 | Class N | 0.19 | 2.00 | 0.8% | 90.5 | 4.22 | 0.84 |
| W-BA-M2-P2(09-22) | 81.76 | 8.30 | Class N | 0.45 | 20.00 | 4.4% | 96.8 | 4.60 | |
| | | | | | | | | | |
| | | | | | | | | | |
| W-BA-M3-P1(05-23) | 82.59 | 8.35 | Class N | 1.45 | 25.23 | 12.4% | 99.3 | 2.61 | 1.18 |
| W-FA-M4-P1(09-22) | 50.96 | 22.54 | Class C | 3.33 | 40.00 | 21.2% | 67.6 | 13.79 | 3.56 |
| | | | | | | | | | |
| | | | | | | | | | |
| W-FA-M5-P1(09-22) | 38.15 | 24.74 | None | 11.09 | 2.00 | 31.0% | 93.3 | 12.85 | 5.69 |
| W-BA-BRT-M5-P1(05-23) | 88.90 | 3.73 | Class N | 2.45 | 6.72 | 1.3% | 87.8 | 2.41 | 0.98 |
| W-BA-Drk-M5-P1(05-23) | 88.10 | 3.18 | Class N | 3.45 | 8.75 | 2.4% | 95.0 | 4.00 | 0.75 |
| | | | | | | | | | |
| | | | | | | | | | |
| W-FA-M6-P1(05-23) | 25.06 | 22.62 | None | 2.51 | 40.64 | 31.6% | 72.9 | 43.44 | 1.75 |
| | | | | | | | | | |
| | | | | | | | | | |
| RH-FA-M7-P1(06-23) | 91.62 | 0.47 | Class N | 5.45 | 0.00 | 6.2% | 73.3 | 5.51 | 0.79 |
| RH-FA-M8-P1(09-22) | 89.50 | 0.54 | Class N | 4.45 | 67.51 | 4.3% | 90.6 | 6.69 | 1.27 |

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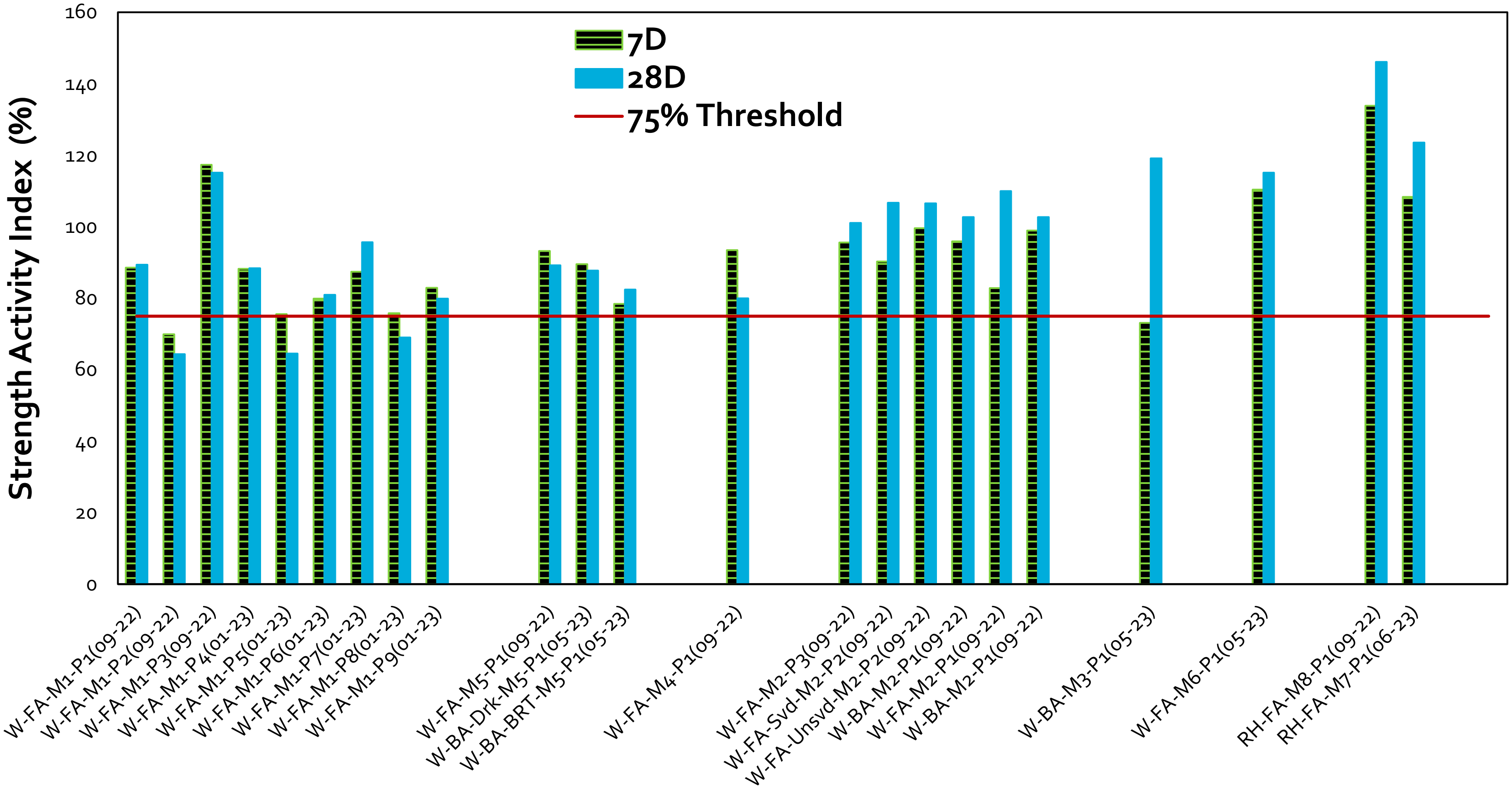
# Strength Results: Biomass Ashes



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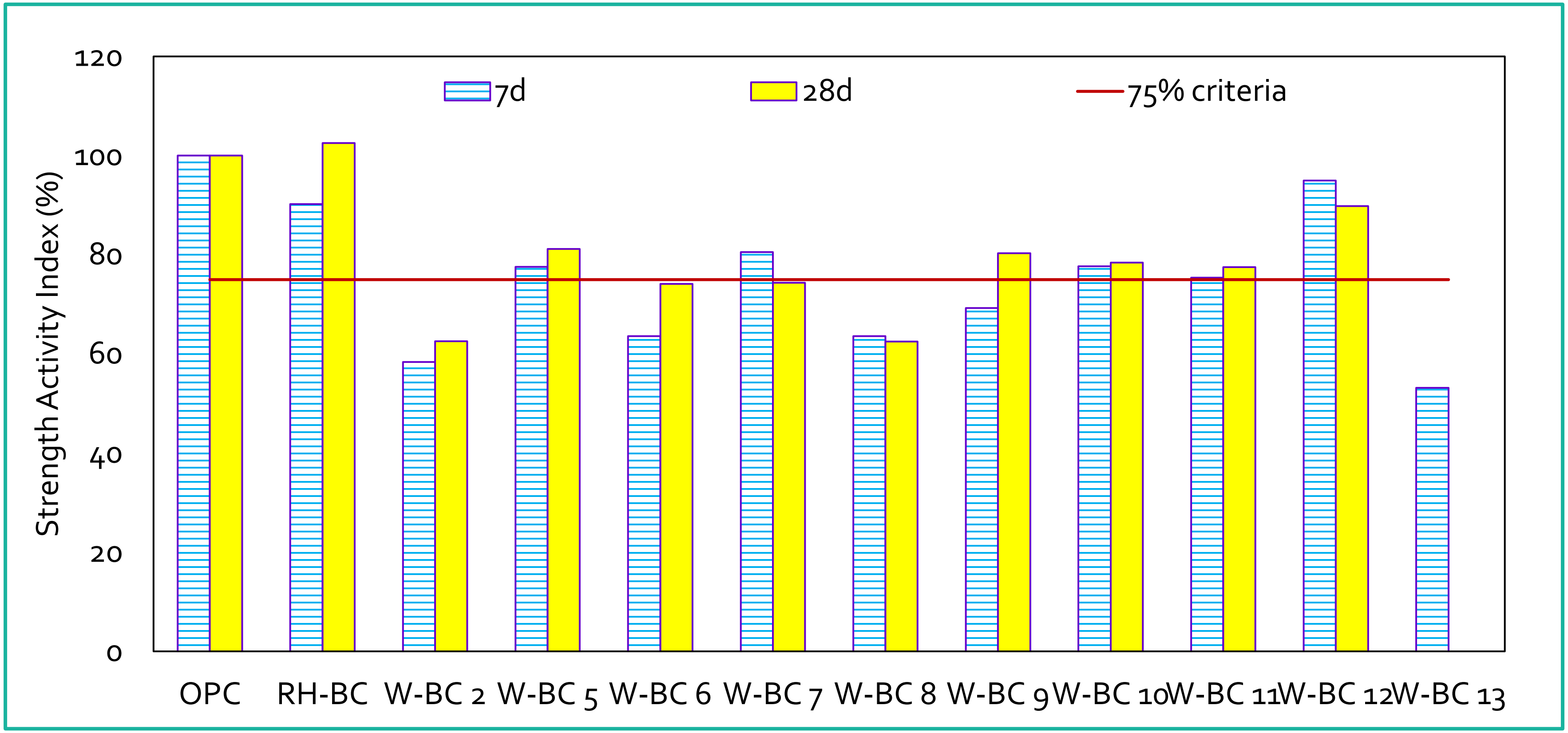
# Strength Results: Biochars



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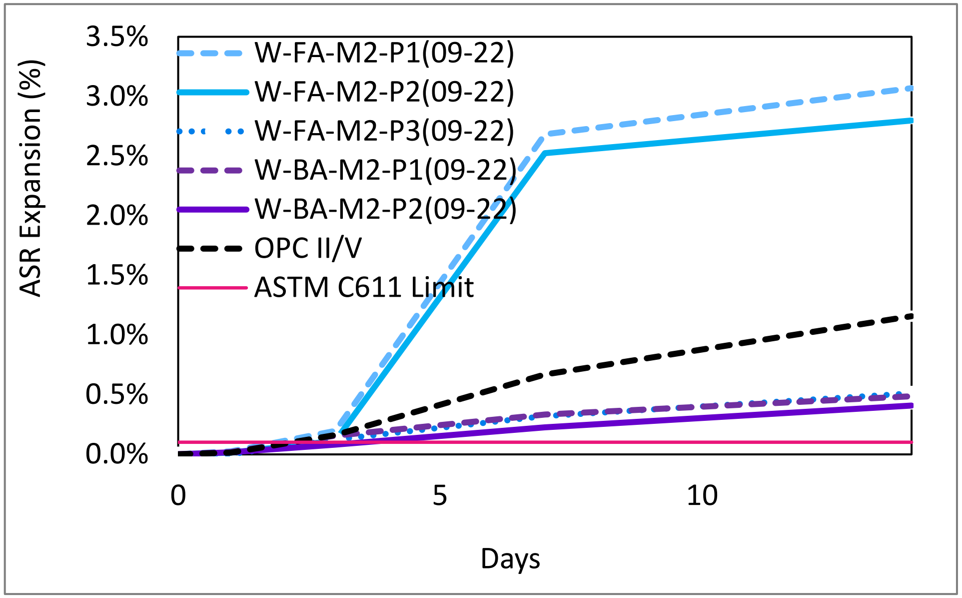
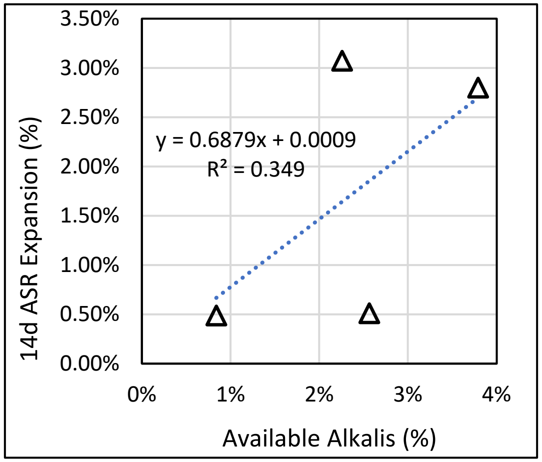
# Work Continues

- Challenges: for alkali-silica reaction





- Challenges: Sulfate attack resistance
- Challenges: Expansion from excess lime
- Biochars Challenges: hydrophobicity, water adsorption
- Project goal is to build a test section with biochar pavers

# Thank you!

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