The Issue: OPC and CO\textsubscript{2} emissions

- Production of Ordinary Portland cement (OPC):
  \[
  \text{Limestone + Shale + Energy} \rightarrow \text{Cement + CO}_2
  \]
  For 1 ton of cement produced $\rightarrow \approx 1$ ton of CO\textsubscript{2} is emitted
  $\approx 50\%$ from the calcination of limestone
  $\approx 40\%$ from the fossil fuels to heat kiln

- Why do we keep producing OPC?
  - Commonly Available Materials
  - Easy to Produce
  - Great Performance
  - But Large Carbon Emission: responsible for 8\% of the global CO\textsubscript{2}-emissions

- The issue:
  - Replacing and displacing Portland cement is one of the greatest materials engineering challenges of our time

- What Can We Do About It?
  - Alternate Cements: “Lower Energy Lower CO\textsubscript{2}”
  - Increased Use of Supplementary Cementitious Material
  - Use Lean Material Strategies
What does this group do?

- The Cement Group develops construction materials and novel cements from coal combustion by-products (CCBs) and industrial waste streams.

What is cement?
Binder that hardens and adheres to sand (mortar) and/or sand and aggregates (concrete).

What are CCBs and industrial waste streams?

- Fly ash
- Bottom ash
- FGD products
- Post-consumer glass...
- Ponded ash
- Red mud
- Slag
What does this group do?

- **Low Energy, Low CO₂ Cement**
  - Calcium Sulfoaluminates (CSA)
  - Clinkerless Cement (FBC)
  - Supplementary Cementitious Materials
    - Fly Ash, Gypsum
    - GGBFS (Ecocem)
  - Dry Scrubber Materials (EPRI, Longking)

- **Coal Ash Beneficiation**
  - Use of ponded ash (EPRI)
  - Ash Guidelines (EPRI)

- **Piezoelectric Properties** (NSF)

- **Polyurethane Foams**

- **Cementitious Coatings** (Masco Coatings Group – “BEHR Brands”)
What does this group do?

• **Project: Tekcrete Fast**

After Four Years and $2 MM, the DHS/NIHS Program Resulted in “Breakthrough Technology”

Unique technology that allows a fiber-reinforced, high-strength, ultra-rapid setting concrete to be applied for **almost immediate stabilization** of unstable geological strat for mining purposes, and **damaged infrastructures**.

→ Technology that is simple, robust and deliverable with portable equipment
→ Works with wide variety of water to cement ratios
→ Does not require surface preparation, bonds to portland concrete, wood, steel, aluminum etc.
→ Can be tailored to other applications
→ Laid the groundwork for a new generation of materials


**Military Applications**

Rapid Placement of Instant Hardening of Force Protection “Instant Armor”

Instant Runways

Instant Hardening of Potential Targets
Ongoing Projects: Spray Drier Absorber Materials

Replacement for OPC:
Determine their potential use as replacement for Portland cement in concrete

Use as a raw material for the production of CSA cements

X-ray diffractograms of hybrid clinkers
Use of ponded ash:
Coal combustion by-products (CCBs) are disposed of in ponds (wet storage) or in landfills (dry storage).

In 2012 → 470 coal-fired electric utilities generated 110 millions tons of CCBs → 40% were beneficially used

→ Ponds are being closed
→ Our group is looking to reuse this ponded ash in cement and concrete and create guidelines

Production of mortar in a Hobart mixer
Carbonation testing

Concrete cylinder tested for compressive strength
Freezing and thawing testing

https://www.epa.gov/coalash/frequent-questions-about-coal-ash-disposal-rule

What skills and expertise can you acquire?

- **Chemical Engineering**
  - Processing and analysis of raw materials
  - Chemical testing of cement
  - Design and safety of cement production

- **Materials Engineering**
  - Material characterization (XRF, LOI, XRD, SEM, PSD, Microscope,...)
  - Synthesis and optimization of clinker / cement / concrete
  - Mechanical testing
  - Hydration process

- **Mechanical Engineering**
  - Mechanical testing
  - Equipment design
  - Optimization of process / testing / methods

- **Civil Engineering**
  - Material characterization (XRF, LOI, XRD, SEM, PSD, Microscope,...)
  - Synthesis and optimization of clinker / cement / concrete
  - Mechanical testing
The Cement group has collaborations all over the world:
- Australia, China, France, Scotland, Turkey,...

Where does the Cement group get funding from?
- National Institute for Hometown Security (Department of Homeland Security)
- Electric Power Research Institute (EPRI)
- Companies (Minova, Ecocem)
- Utilities (WE Energies, Duke, AEP)
- National Science Foundation (NSF)
- Longjin (China)

Where does the Cement group publish?
- Cement and Concrete Research
- American Concrete Institute (ACI)
- Shotcrete Magazine
- Journal of Sustainable Cement-Based Materials
- Coal Combustion and Gasification Products

Where does the Cement group present its results?
- World of Coal Ash (WOCA)
- American Concrete Institute
- International Concrete Conferences in Dundee
- Asian Coal Ash Association (ACAA) in China

Where do students that work in the Cement group go afterwards?
- Academia (ESIREM, Middle East Technical University, Nanjing Tech University)
- Industries / Utilities (Palmer Engineering, Vantage Engineering, Boral, C&I Engineering)