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## Opportunities to Demonstrate Low Carbon Concrete in Transportation Infrastructure

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## Demonstration Projects Are An Essential Step to Successful Implementation

- Assist producers of innovative materials in understanding the concrete industry
- Creates collaboration between materials suppliers, contractors, and owners
  - Risk is recognized and shared
- Technical assistance provided before, during, and after construction
  - Performance is monitored
- Broad dissemination of results to build confidence in the industry
  - Pathway to move from innovation to specification

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## Demonstrating Innovation in Transportation Infrastructure

- State highway agencies have a long history of conducting research and demonstration projects
  - AASHTO Road Test (1958-1960), Long-Term Pavement Performance Project (1987-present), MnROAD (1990-present)
- Pavements are a suitable place to demonstrate innovation
  - Greater tolerance for failure
  - Geometry is simple
  - behavior understood



# LTTPP

Long Term Pavement Performance

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## Portland-Limestone Cement as an Example?

- PLC has been used for decades in Europe
  - How did that experience translate to the US market?
- Holcim invested heavily in PLC development in the U.S. in the early-2000's
  - Considerable work at Mississippi State University/WES
- Demonstration projects conducted in Colorado and Utah in the mid- to late-2000's
- Became “practice” in this region by mid-2010's



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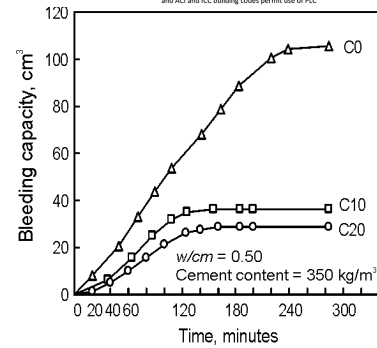
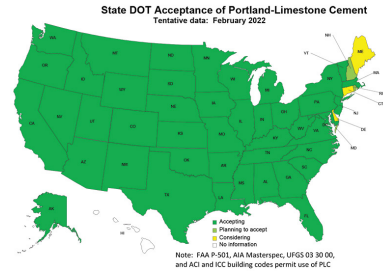


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## Portland-Limestone Cement as an Example?

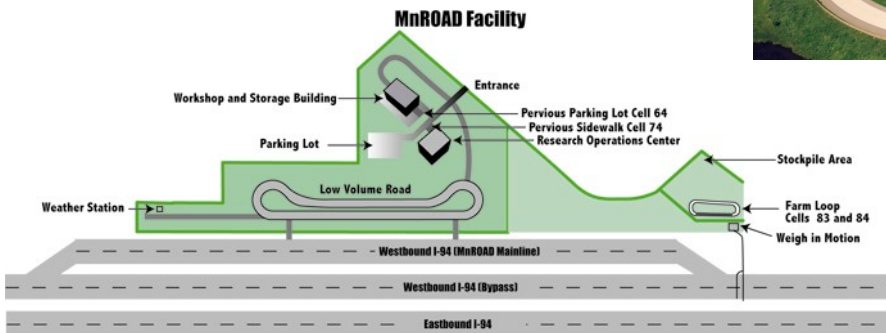
- Slow to catch-on elsewhere in the U.S.
  - Little motivation or incentive to change
- Massive roll-out of PLC began nationwide in 2021
  - Coincided with acceptance by Caltrans after intensive study
- “Problems” were encountered in some regions and by some sectors of the concrete industry
  - Some problems may be related to a rush to implement
- It takes considerable effort to overcome a bad first impression

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## This Type of Experience Brings Us to MnROAD



Constructed 1990-93

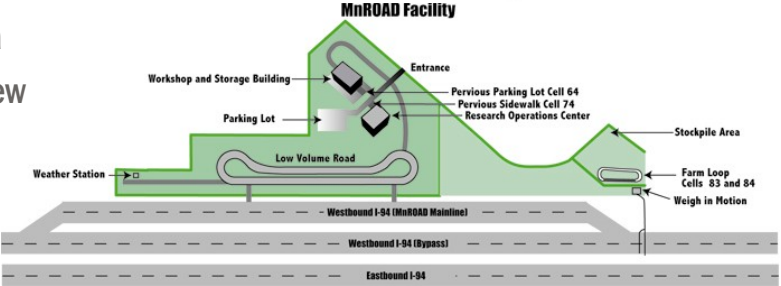
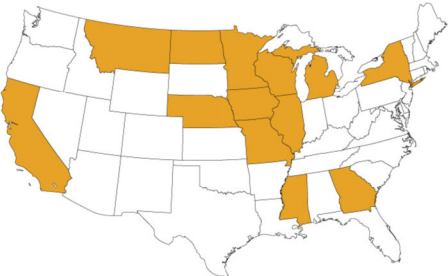
A partnership between Minnesota Department of Transportation and the Minnesota Local Road Research Board

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## MnROAD - NRRRA

- 3.5 mile of I-94 operated by MnDOT
- Partnership with the National Road Research Alliance (NRRRA)
- 11 states, 50 industries, associations, and academia
- Designed to demonstrate new technologies in a real-world environment



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## MnROAD Project General Requirements

- Portland cement mixtures will use an ASTM C595 Type IL(10) blended cement
- Mixtures tested according to AASHTO R 101 - Developing Performance Engineered Concrete Pavement Mixtures
  - Required 500 psi flex @ 28 days, 5-8% air
- Batched and mixed at a central plant and paved using conventional slipform paving equipment
  - Batch plant had two cementitious materials silos

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## Final Test Site Construction

- Test site constructed at MnROAD mainline to evaluate strategies to reduce GHG emission in concrete paving
- Test site consists of 16 test cells
  - 2 control cells
  - 1 optimized mixture (based on control)
  - 3 CarbonCure™ cells
  - 8 alternative SCM cells (nominally)
  - 2 alternative cements (nominal)
- Construction completed August 2022



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## Project Specific Mixtures

- Control Mixtures – Standard MnDOT paving mixture
  - 570 pcy total cementitious with 30% Class F fly ash (Coal Creek)
- Optimized Mixture – designed with conventional materials with reduced cementitious materials content
  - 501 pcy total cementitious; 30% Class F fly ash (Coal Creek)
- CarbonCure™
  - CarbonCure™ with CO<sub>2</sub> injection – 558 pcy total cementitious; 30% Class F fly ash (Coal Creek)

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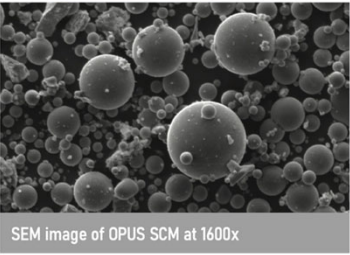



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## Project Specific Mixtures - ASCMs

- **Carbon Upcycling**
  - Fly ash processed by grinding in a pressurized carbon-rich environment
  - 500 pcy total cementitious; 30% treated ash
- **Urban Mining**
  - Ground-glass pozzolan meeting ASTM C1866
  - 570 pcy total cementitious; 30% GGP
- **TerraCO2**
  - Manufactured SCM resembling fly ash
  - 570 pcy total cementitious; 35% manufactured ASCM

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SEM image of OPUS SCM at 1600x



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## Project Specific Mixtures - ASCMs

- **Carbon Limit**
  - Proprietary material, ground limestone, natural pozzolan
  - 570 pcy total cementitious; 30% ASCM
- **Hess Pumice**
  - 570 pcy total cementitious; 30% pumice natural pozzolan
- **3M**
  - 570 pcy total cementitious; 15% 3M natural pozzolan, 15% Class F fly ash (Portage Station)
- **Burgess Pigments**
  - 570 pcy total cementitious; 12% metakaolin, 18% Class F fly ash (Coal Creek)

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## Project Specific Mixtures - ACMs

- **Ash Grove – IP(30)**
  - Desire was to test an LC3 using 50% clinker, 30% calcined clay, 15% limestone
  - Instead, 570 pcy ASTM C595 IP(30) using calcined clay natural pozzolan
- **Continental Cement – High Limestone ASTM C1157 Type IL(20)**
  - Blended cement with 20% limestone
  - 570 pcy total cementitious with 30% Coal Creek Class F fly ash
- **UltraHigh Materials**
  - 0% portland cement clinker-based hydraulic cement (meets ASTM C1157)
  - Mixture Design – 650 pcy total cementitious

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## Lessons Learned #1 – Shipping Matters



Super sacks of cementitious materials not easy to unload – especially those filled with ground glass pozzolan

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## Lessons Learned: #2 – Blending Matters



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Two materials were delivered without being blended – resulted in difficulties during placement and impacted test results



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## Lesson #3 – Cement Matters

- CarbonCure<sup>TM</sup> was not optimized for a portland limestone cement system
  - Later found out a higher dosage was needed for calcium carbonate mineralization to become effective
- UltraHigh Materials alkali-activated cement is really sensitive to portland limestone cement contamination
  - Residual Type IL in silo impacted early-age setting behavior
  - Who knew?

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## Lesson #4 – Admixtures Matter

Ground glass pozzolans needed a HRWRA even though the individual batching the concrete thought otherwise



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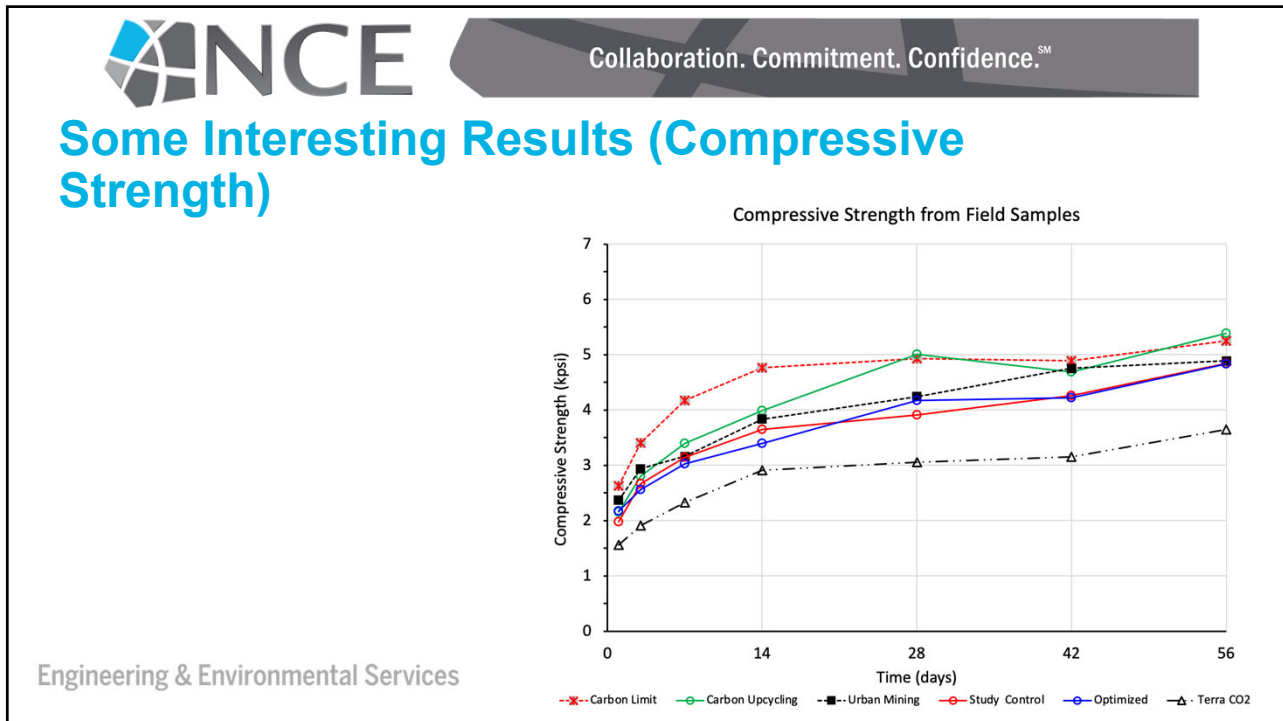
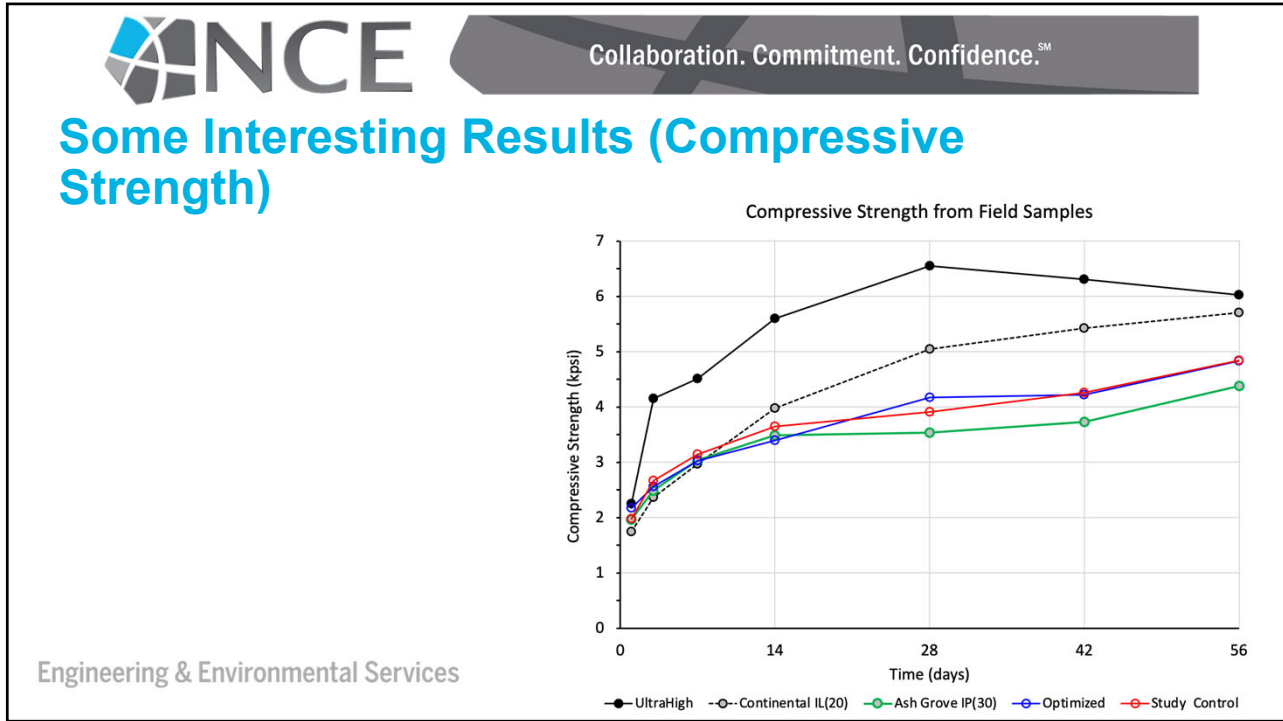


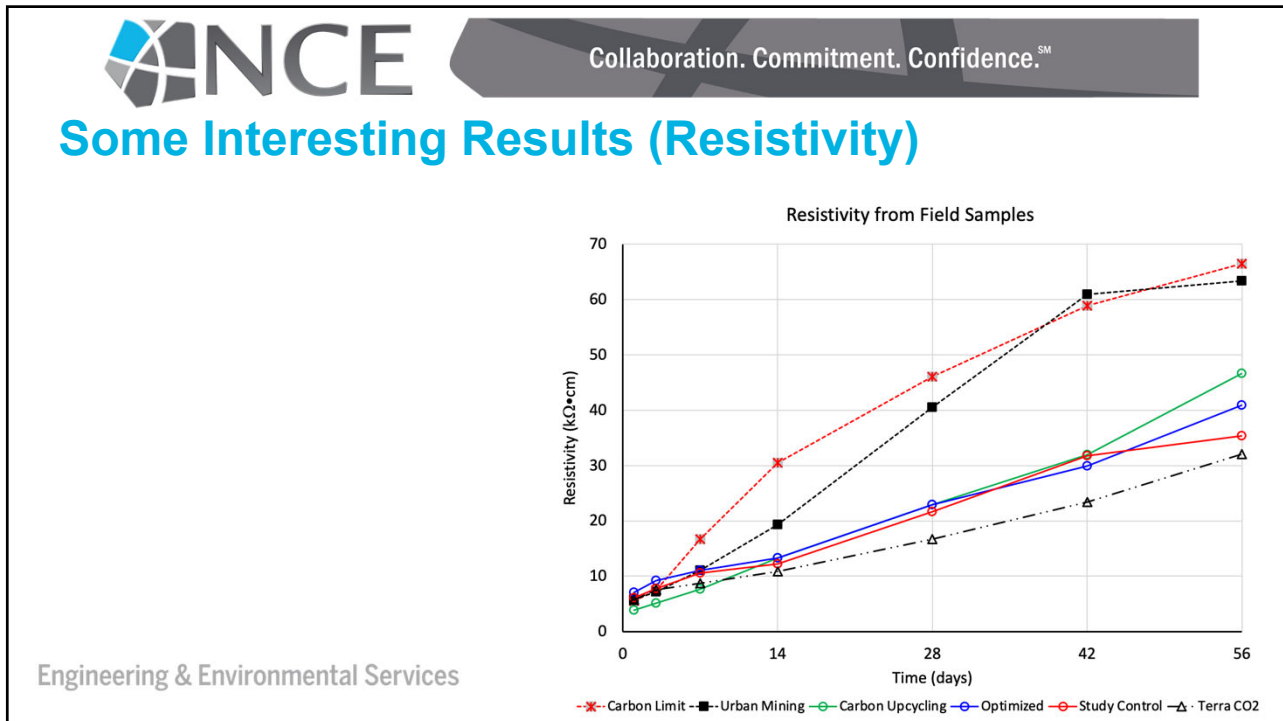
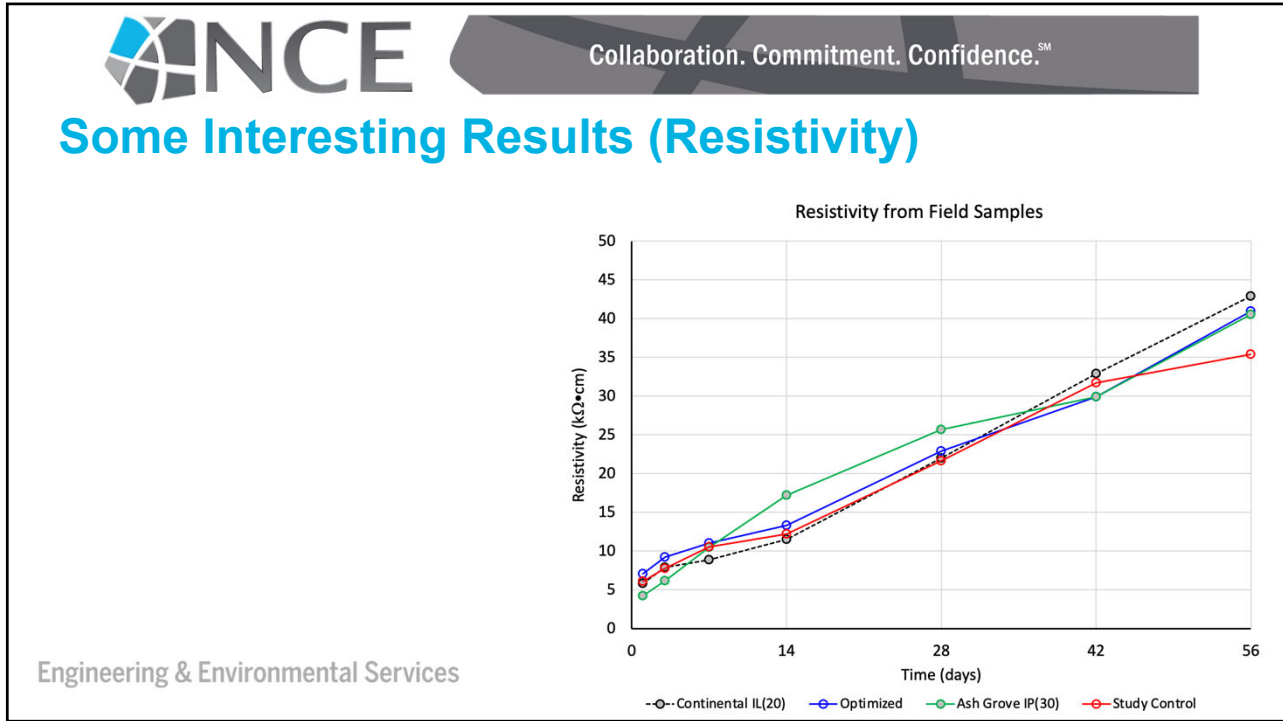
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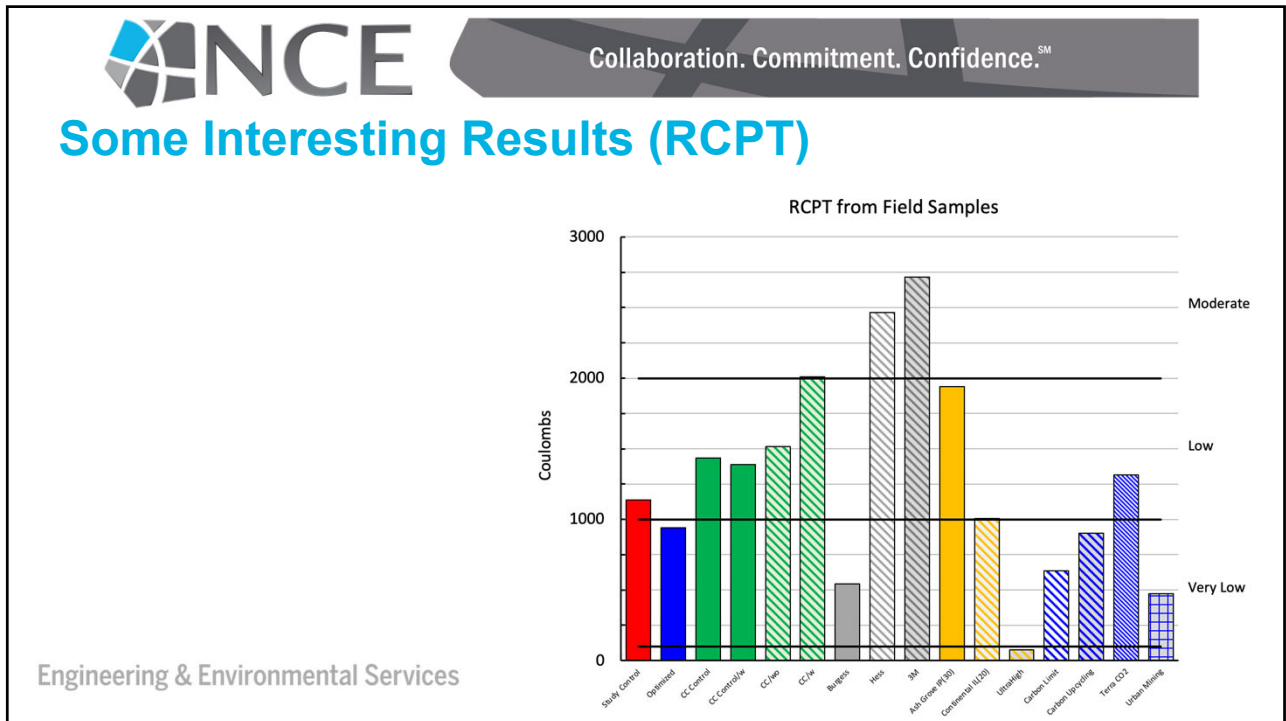
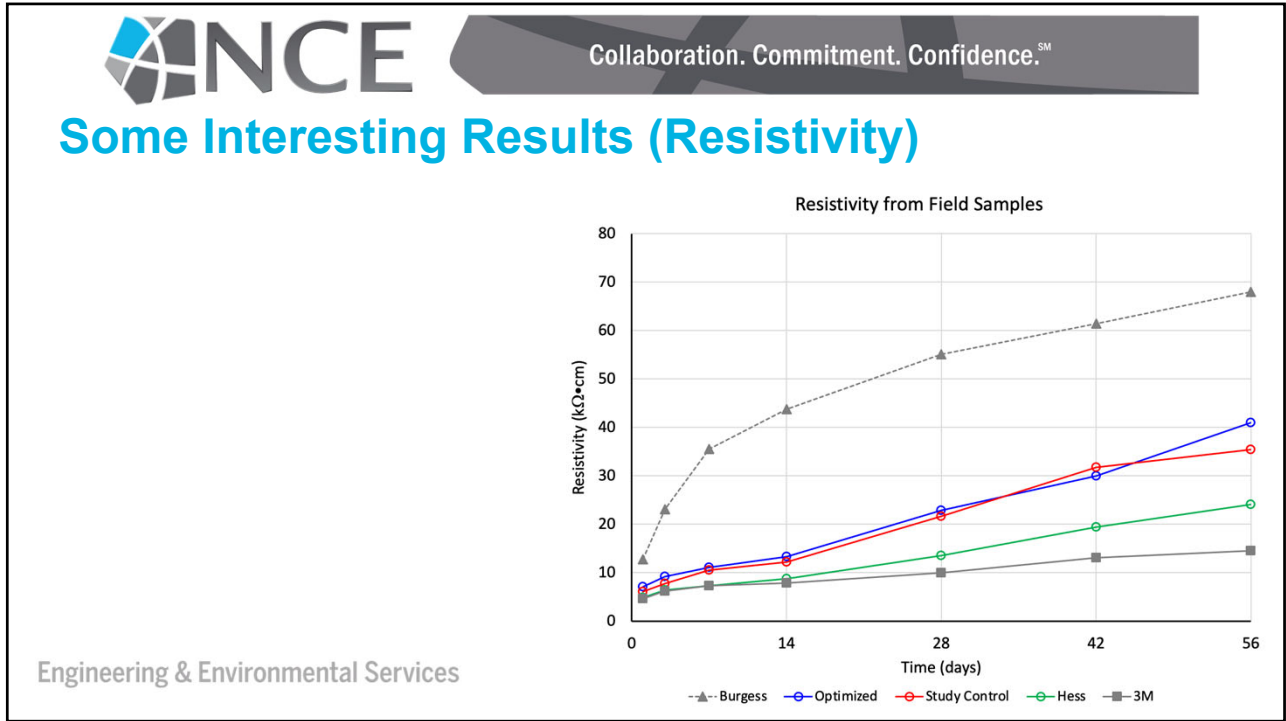
## This Is Why We Do Demonstration Projects

- Many alternative systems batched and placed well
- The kinks got worked out of those that did not have initial success
- Suppliers of cementitious materials that are not currently in the industry learned a few things about concrete production and placement
- Demonstration projects allow us to take risks and learn

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## We Are Looking For Willing Participants!

- Our team (NCE, Larry Sutter, Doug Hooton, and Al Innis) is funded by ClimateWorks Foundation and Breakthrough Energy Foundation to support SHAs, local agencies, and owners in conducting demonstration projects
  - Agency projects should be eligible for IRA funding
  - Pre-construction, construction, and post-construction assistance available
- In process of setting up a Low Carbon Concrete Consortium for agencies and industry partners
  - Looking for participants

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## Questions?

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