CHANGE YOUR UNIVERSE

Soil-Cement for Building Foundations

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Presentation Outline

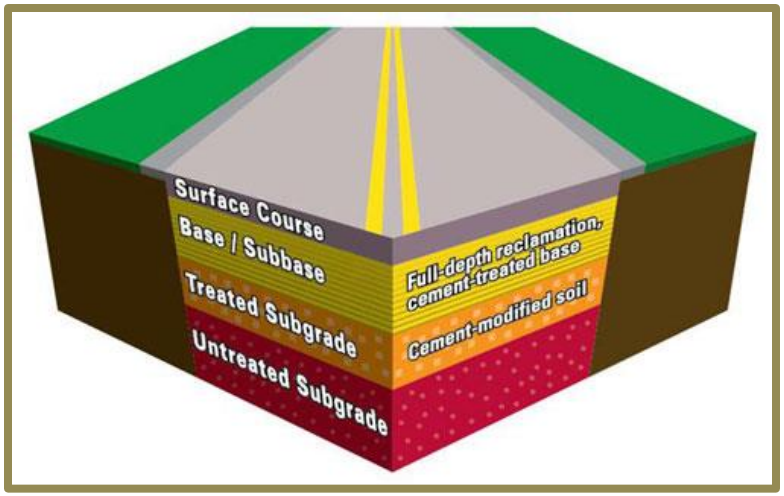
- Introduction
- Overview
- Case Study
- Inspection & Testing
- Advantages
- Applications
- Closing/Questions

What is Soil-Cement?

- Highly-compacted mixture of soil, cement and water
- Distributes load over broad areas
- Sometimes called “cement-stabilized soil”

Where is Soil-Cement Used?

- Method of subgrade improvement
- Successfully used for roadbuilding in Michigan
- Rarely (if ever) used for structure foundations in Michigan



Case Study

- **St. Marys Cement**
  - Charlevoix Upgrade Project
- **Long-term professional relationship**
  - Geotechnical engineering and materials testing since 1970's
  - Environmental services
  - Surveying


Boulder Park
Fisherman's
Island
State Park

Case Study

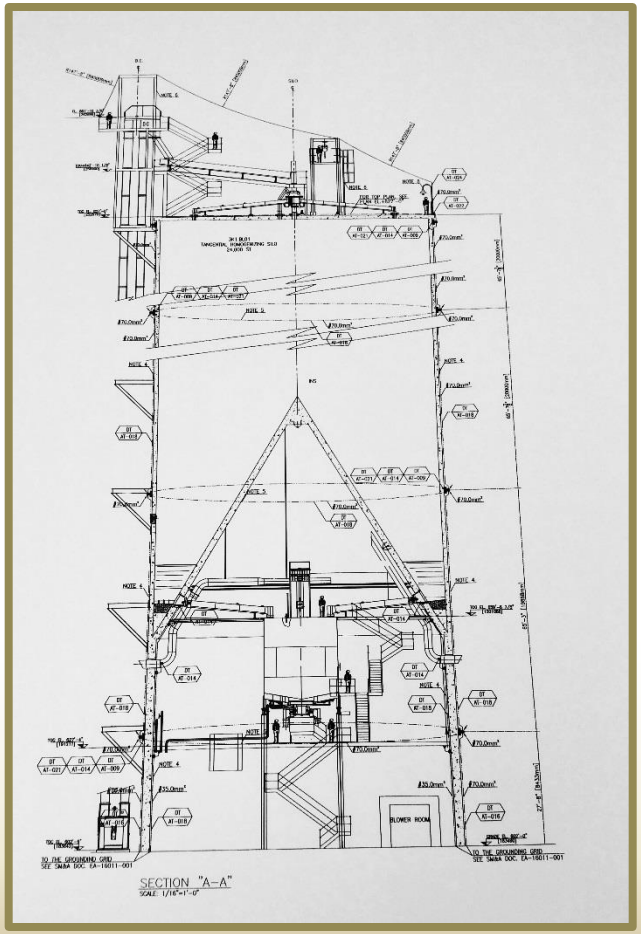
- **Industrial Plant Upgrade**
  - Required large foundation bearing capacity beneath multiple large structures
    - Blend Silo
    - Coal Mill Building
    - Raw Mill Cyclone
    - Finish Mill Building
    - A variety of other smaller structures

Case Study

- **Existing Site Conditions**
  - Extensive geotechnical exploration
  - Highly variable depth to bedrock
  - Variety of old fill – gravel, sand, silt & clay + cobbles & boulders
- **Piles considered for foundation**
  - Soil-cement as alternative
  - “Change the Universe”

Case Study

- Soil-cement allowed subgrade soil bearing pressure to be increased from 3,000 psf to 8,000 psf
- The first component to be constructed was the blend silo
  - 79 feet in diameter
  - 225 feet tall
  - February in Northern Michigan
  - What could possibly go wrong?



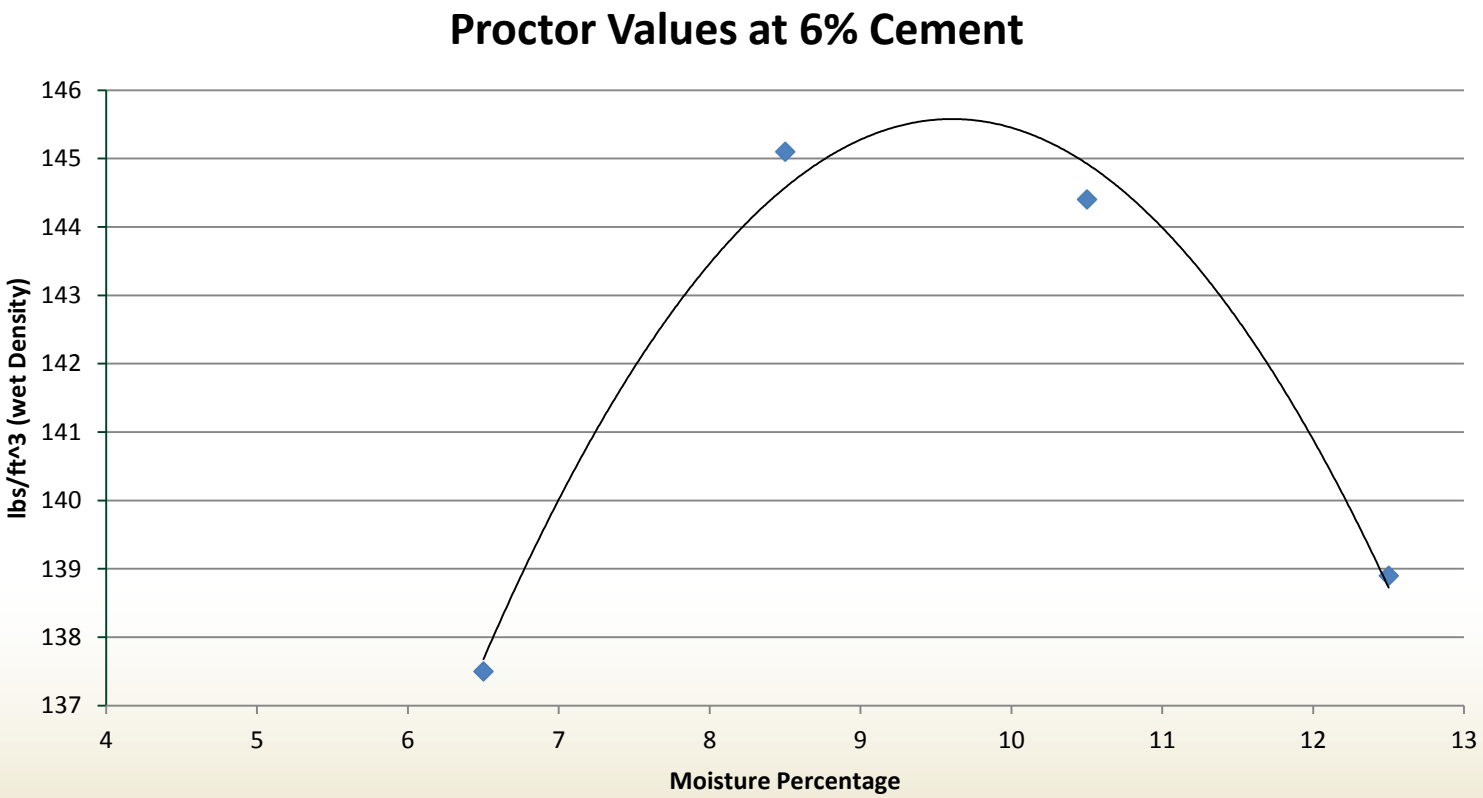
Mix Design and Trial Batching

- **Develop mix design to achieve 0.8 MPa (116 psi)**
- **Samples of material**
  - Cement
  - Soil (sand)
- **Variables**
  - Amount of cement
  - Moisture content
  - Compactive effort

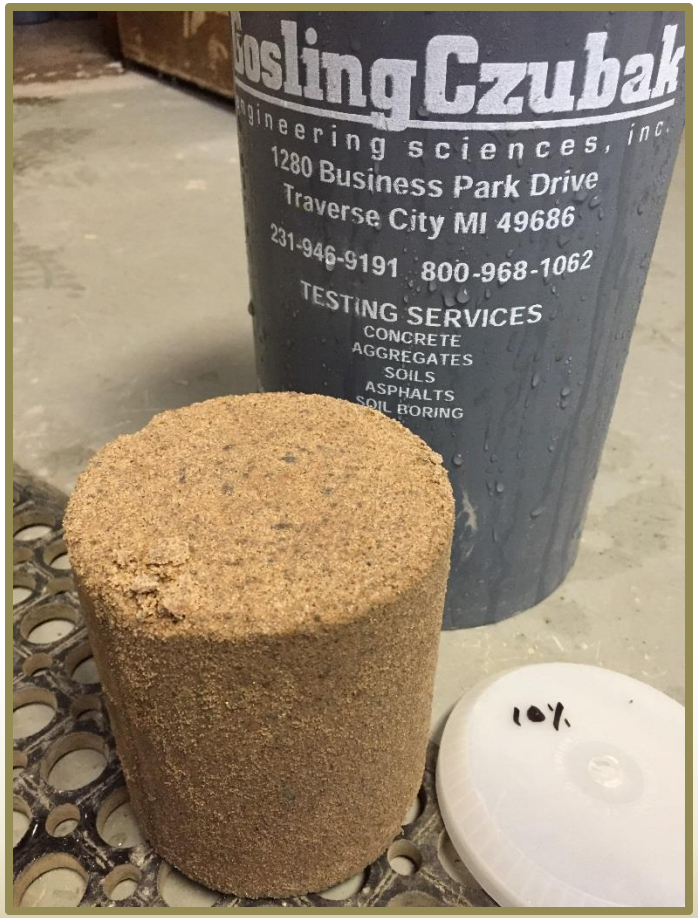
Trial Batching

Mix ID	Specimen	% Moisture	% Cement	Diameter (in)	Height (in)	wt (gm)
1	A	8.5	6	4.000	4.625	2123.0
	B	8.5	6	4.000	4.625	2112.6
2	A	8.5	8	4.000	4.625	2062.0
	B	8.5	8	4.000	4.625	2091.0
3	A	8.5	10	4.000	4.625	2101.0
	B	8.5	10	4.000	4.625	2081.5
4	A	10	8	4.000	4.625	2159.7
5	A	10	10	4.000	4.625	2165.5

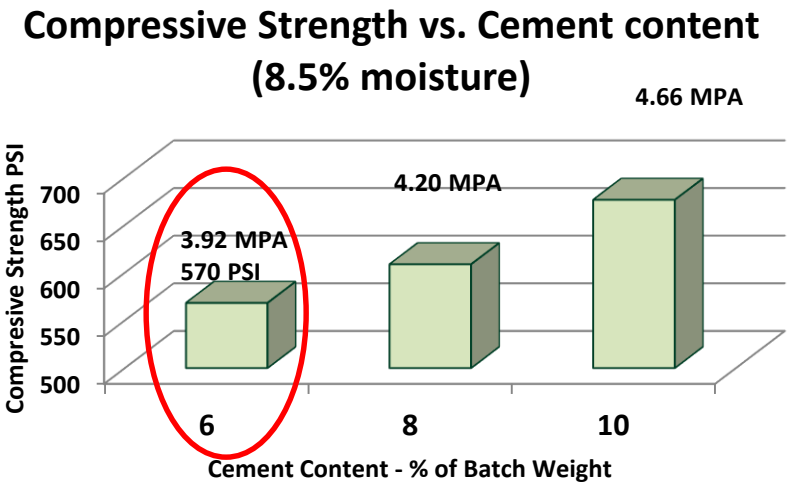
Trial Batching

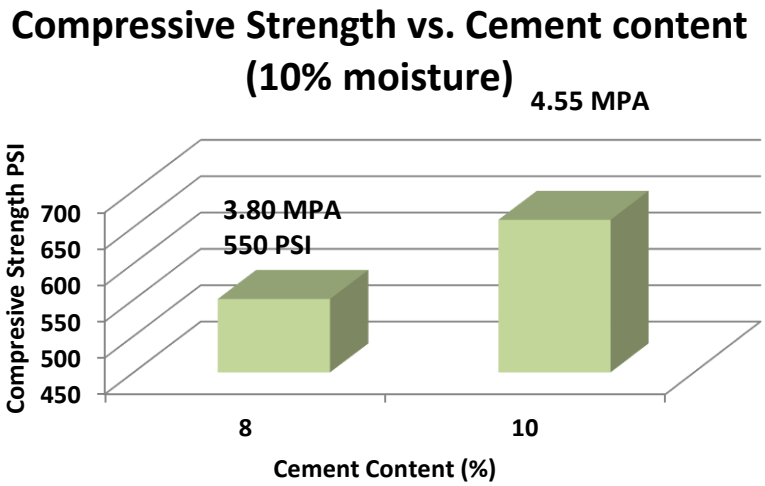


Trial Batching



Trial Batching





Trial Batching

- **Conclusions**
  - Every combination of variables in the lab produced results that met and exceeded the minimum required design strength
  - **6%** cement content at **8.5%** moisture was recommended
    - Most economical mix
    - Adequate strength to ensure successful construction

Pre-Construction

- **Methods Considered**
  - Batch and mix in excavation
  - Use of a pug mill
  - **Batch and mix materials nearby, then place and compact in the excavation**
    - **Better control**
    - **Consistent layers**
    - **Cost-conscious vs. pug mill**

Mixing

Excavator Bucket Method

- Slow process; not enough mixing happening

Mixing

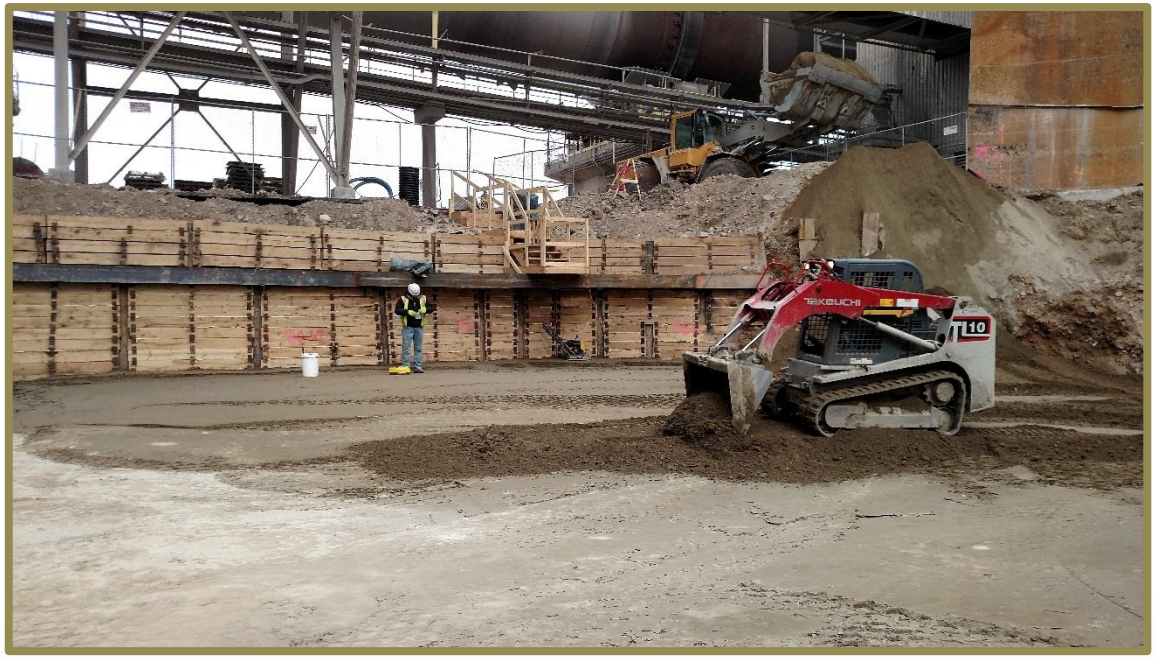
Front End Loader Method

- Now we're making progress!


DEERE
CAT
966K

Placement

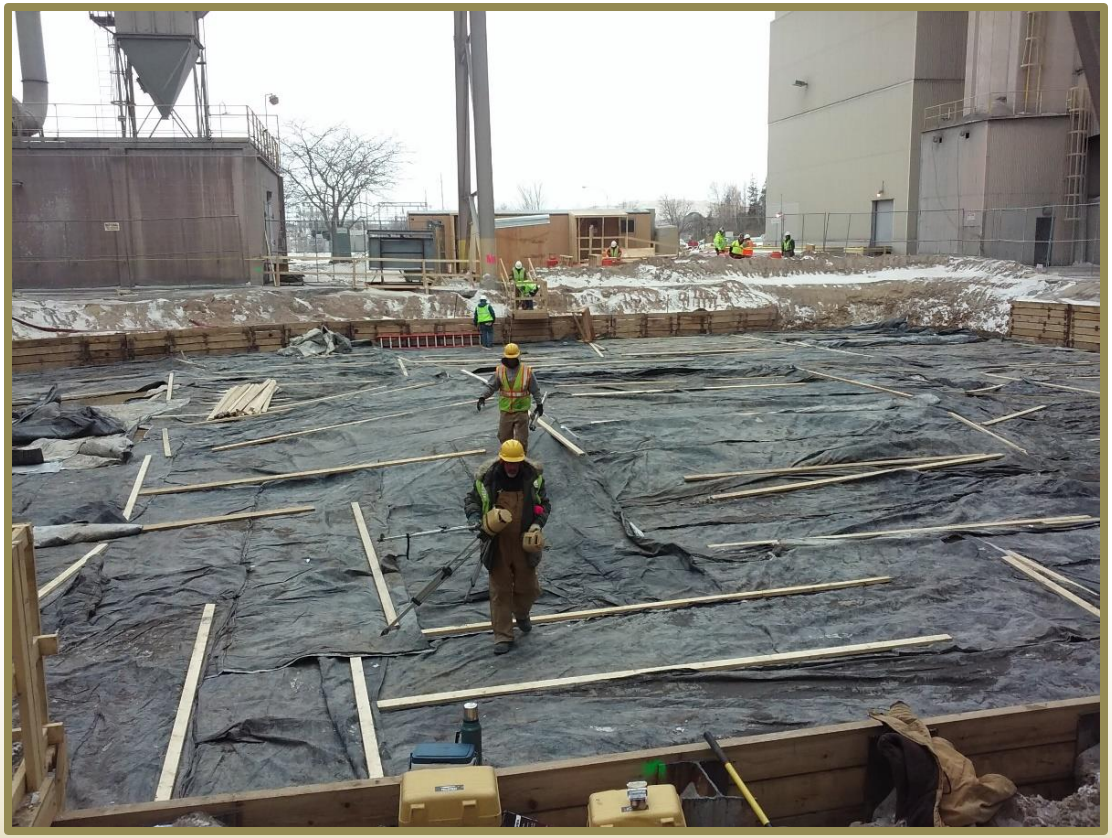
- **Soil-cement was placed in 12” layers & compacted**
  - Density testing and sample collection for compressive strength




HITACHI
DANGER
TAKEUCHI
TL10

Placement

- **Insulated blankets protected material from freezing**
  - Average overnight temperature of 19° F



Placement

The next day, it was as hard as concrete (almost!)

1 MPa = 145 psi

145 psi ≠ 3000 psi

Results

- **Average actual strength at 7 days was 930 psi**
  - Well above minimum strength
  - Low 240 psi (200% of design), High 1425 psi

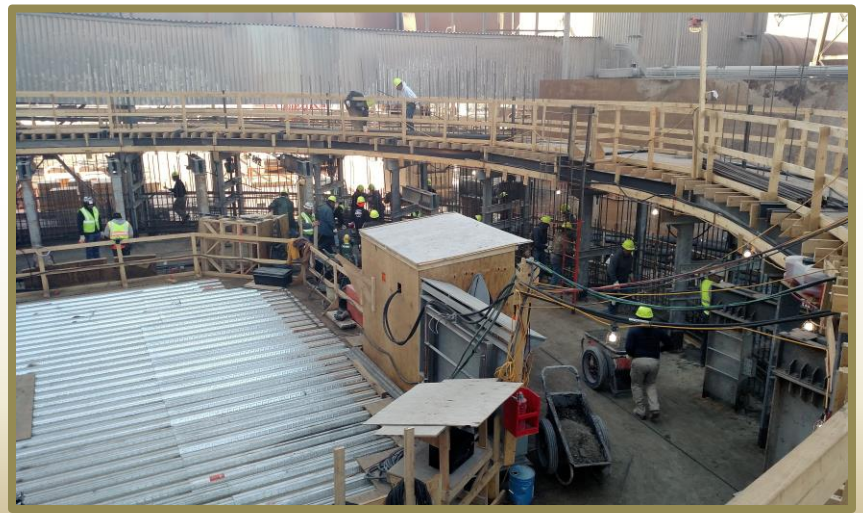
[We were never really worried]

Results

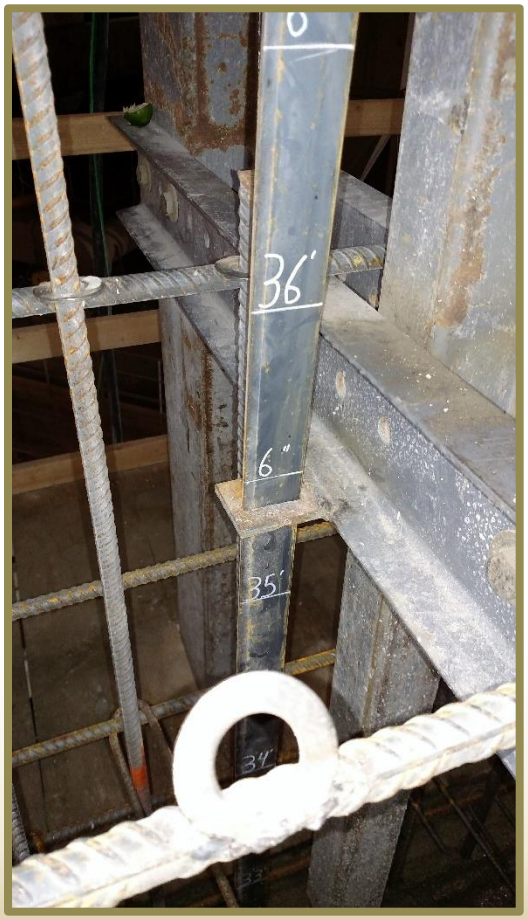
- **The entire soil-cement foundation was placed in 12 days**
  - Excellent working surface for placing forms and reinforcing steel

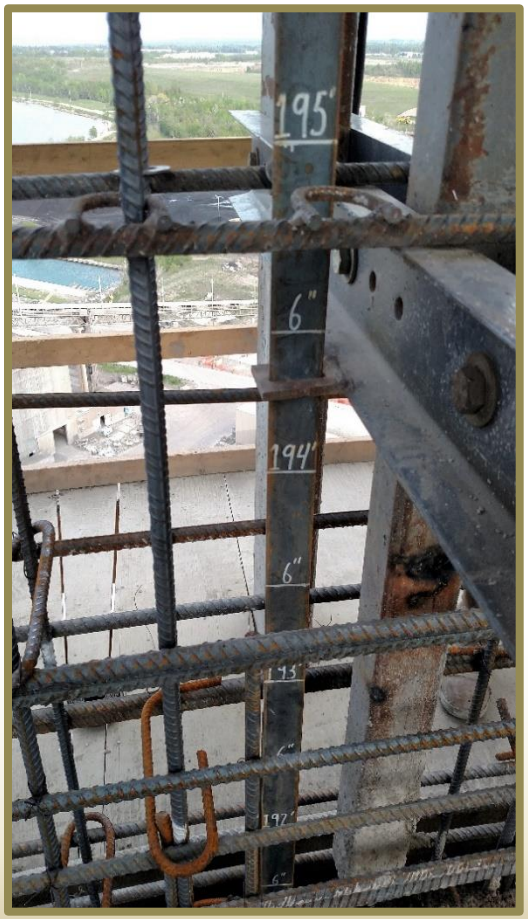
Blend Silo

- **Concrete foundation complete, starting walls**
  - 78’ 8-7/8” diameter, 224’ 0-7/8” high walls
  - Placed using continuous slipform method



Continuous Slip Form





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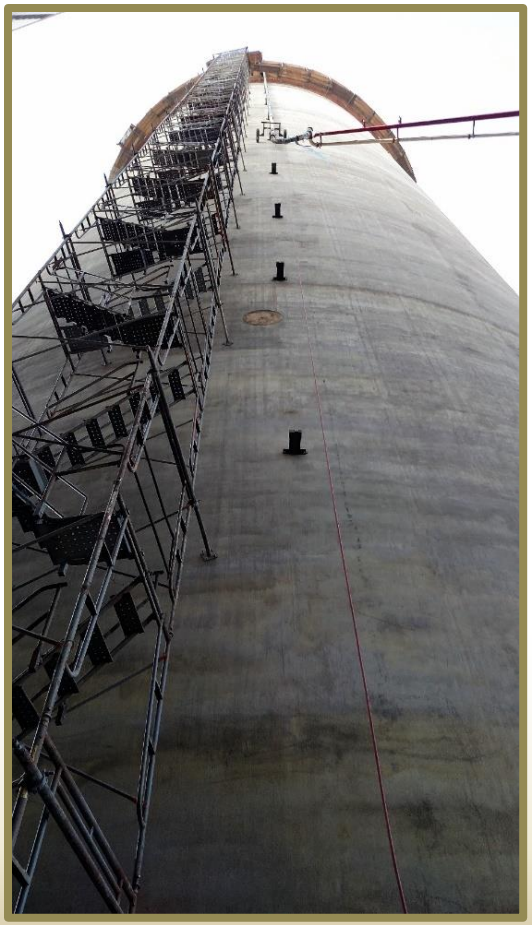
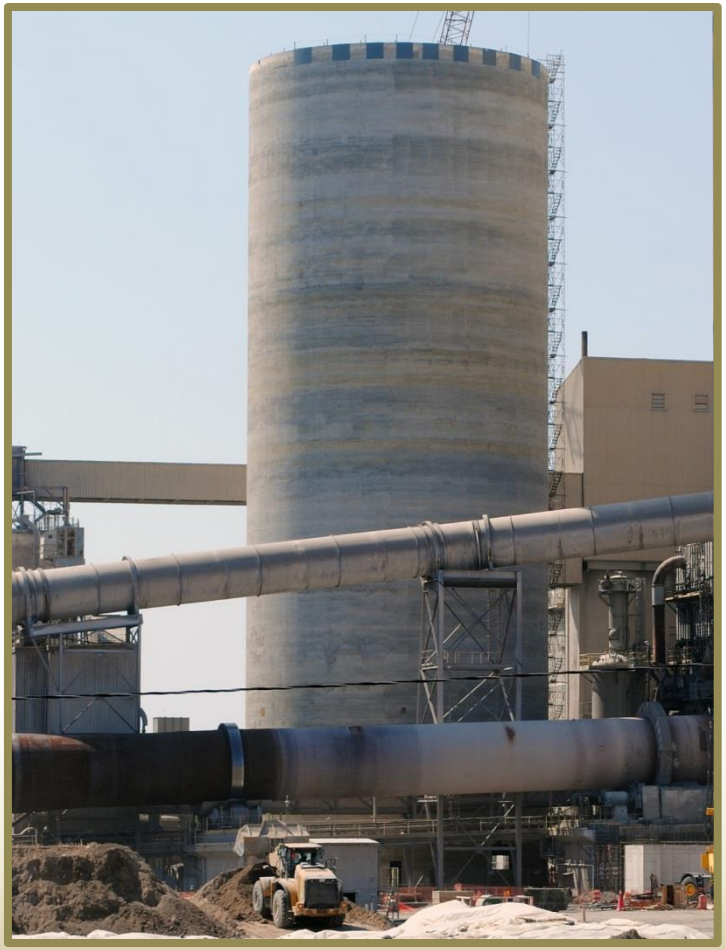


Blend Silo

- Soil-cement foundation did not move under the weight of the silo
- Settlement monitoring will continue as the silo is loaded with material



Other Structures

- **Raw Mill Cyclone Building– 3,900 sf**
- **Coal Mill Building – 8,700 sf**
- **Finish Mill Building – 16,900 sf**
- **Clinker Cooler (Partial) – 2,500 sf**
  - All have heavy equipment and dynamic loads

Raw Mill Cyclone Building

Raw Mill Cyclone Building

Raw Mill Cyclone Building

Coal Mill Building

Coal Mill Building

Finish Mill Building

Finish Mill Building

Inspection & Testing

- Monitoring to ensure proper proportions and moisture content
- Adequate mixing
- Layer thickness and compaction
- Compressive strength
- Protection of placed and cured material

Advantages

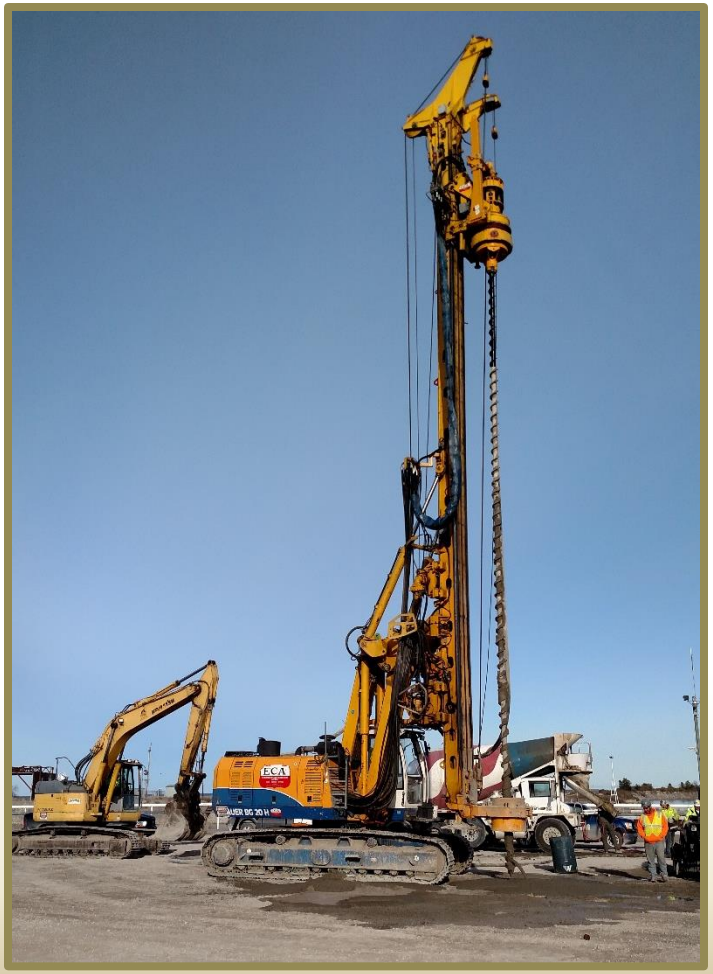
- **Speed of design and construction**
- **Frost-proof material –** eliminates minimum footing depth for frost heave
- **Cost savings compared to deep foundation options**
  - Piles, caissons, etc.
  - Soil-cement costs range from $42 to $110 per cubic yard, depending on volume produced per day

Deep Foundations

Advantages

Cost savings vs. deep foundation options

- Mobilization $25,000
- Cost per foot of piles $26/foot
- Pile load testing $15,000
- Pile caps and grade beams

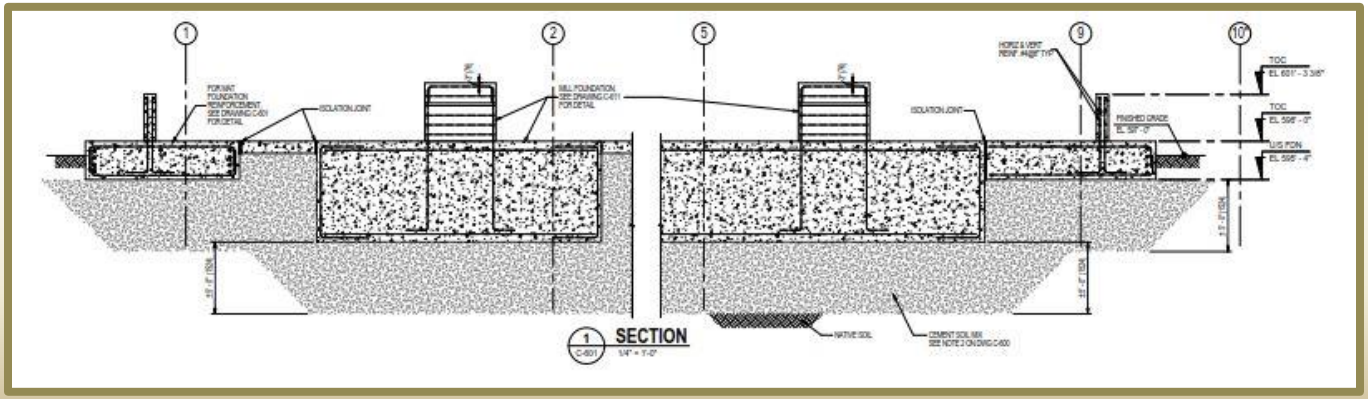


Advantages

- **Ease of construction at varying bearing levels**
- **Reliability**
  - In-place strength tests each layer vs. pile load tests on selected test piles

Applications

- Industrial projects
- Commercial projects
- Education and Healthcare projects
- Residential projects



Applications

- **Transportation projects**
- **Existing cement plant projects**
  - Cement component already on site
- **Almost any project with inadequate soil properties to support foundation loads**

Special Thanks

- Fabio Cittadin, Votorantim Cimentos North America (VCNA)
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- Rieth-Riley – Charlevoix, Michigan

Questions

For More Information

- **Geotechnical**
  - Soil & Foundation Engineering, Retaining Walls, Slopes
- **Construction Observation & Inspection**
- **Materials Testing**
- **Laboratory Testing**
- **Environmental, Surveying and other services**

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