Widely Spaced Shear Walls for Slope Stabilization
Crookston, MN

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Presentation Outline

• Project Background
• Geology/Subsurface Conditions
• Contracting Approach and Requirements
• Stabilizing Methods Considered
• Shear Wall Design
• Shear Wall Construction
• Performance to Date
• Summary and Conclusions
Site Location and Geologic Setting

Background
Project Site
The 1934 DARKOW Landslide in Crookston, Minnesota — The Green Gables tourist center was established here by Paul and Dwight Darkow, later proprietors of the Country Club Motel, located in the same area. As picture indicates some of the Green Gables “took a drop.”
Cross Section “A”

Formation | SPT N | $c_u$ (psf) | $c'$(psf) | $\phi'$
--- | --- | --- | --- | ---
Huot Clay | 0 - 6 | 500 – 1,250 | 200 | 21
Red Lake Falls Till | > 50 | N/A | | 36
Artesian Conditions Relative to River

- A Surface Elev. 881'
- A Surface Elev. 856'
- B Surface Elev. 867'
- B Surface Elev. 853'
- Hydrostatic Head

![Graph showing water pressure and elevation relationship](image)
MnDOT Design Build Contracting Approach

- Prequalification Stage – five contractors selected.
- Technical and Cost proposal submitted by four contractors.
- Technical Proposals are rated out of 100%
- Cost proposal opened and price divided by rating to get score.
  - eg. Rating = 75%; Price = $7.5M; => Score = $7.5M/0.75 = $10M
  - Rating = 90%; Price = $8.5M; => Score = $8.5M/0.90 = $9.4M
- Deformation/Velocity Criteria Warranted for three years
- Stipend of $40K for those meeting minimum requirements.
- All design and proposal information available to public.
Contract Shape Accel Array Installation
Shape Accel Array Locations

75 ft deep
Stabilizing Methods Considered

- Anchored Blocks
Stabilizing Methods Considered

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- Large Diameter Piles (likely with anchors)
Stabilizing Methods Considered

- Anchored Blocks
- Large Diameter Piles (likely with anchors)
- **Shear Walls**: Soil mixing, concrete replacement, cement-bentonite replacement
Final Approach: Shear Walls Through Clay into Glacial Till

- 75 ft deep
- 100 ft
- 90 to 100 ft

Legend:
- RED LAKE RIVER
- CONSTRUCTION LIMITS
- ENVIRONMENTALLY SENSITIVE AREA
- PROPOSED SHEAR WALL LOCATION
- MONITORING HOLE LOCATION
- PROPOSED WPD IN TILL
Stability Analyses – Limit Equilibrium

- Good geotech data with slip surface "well" defined.
- Pore water pressures "well" defined.
- Back-analysis used to assess residual strength (compare empirically).
- Determine optimum combination of wall length, spacing and strength.
- Confirm that failing between walls does not control.
FLAC3D – Modeling of Shear Walls

- Assess residual strength based on strength reduction (~16 deg).
- Evaluate stability improvements with shear walls.
- Confirm failure between walls does not control.
Strength Reduction Results

- Shear Surface I, UCS = 2.0 MPa (300 psi)
- Shear Surface II, UCS = 2.0 MPa (300 psi)
- Shear Surface II, UCS = 1.5 MPa (225 psi)
- Huot Clay, UCS = 1.5 MPa (225 psi)
- All Materials, UCS = 1.5 MPa (225 psi)

Target Safety Factor = 1.5
Cement - Bentonite Lab Tests

Compressive Strength (MPa) vs. Time (days)

- 35/5
- 35/7
- 40/6
- 40/8
- 45/7
- 45/9

300psi
Construction Activities

Initial Site Conditions
Site Grading Prior to Construction

Shape Accel Arrays
Case 210 Excavator  - Little Dog
"Big Dog" Excavator – 100 ft Reach
Trench Excavation
Trench Excavation
Clay Spoil
Quality Control Strength Testing

Trench Grab Samples
- Grab samples daily from three depths

Cured in Place Samples
- Double wall pipe installed in C-B
- Steel outer casing
- PVC Inner casing.
- Water filled annulus.
- Casing extracted after 32 days.
- Bottom 40 ft lost – broke off.
Grab Samples

Unconfined Compressive Strength (MPa) vs. Time (days)

- Average Lab Data

- No influence with sample depth

- Target 300 psi
Grab Samples with Pipe Samples

The graph illustrates the unconfined compressive strength (in MPa) over time (in days) for different sample types:

- **Average** (yellow line)
- **Max** (gray line)
- **Min** (blue line)
- **Average Pipe Samples** (red line)

The target strength is 300 psi, indicated by the dashed horizontal line.

Time (days) ranges from 0 to 100 days.
Deformation Measurements

- Deformations ~ 4 to 7 inches/ year before construction.
- Six new Shape Accel Arrays installed by Sol Data.
- Baseline data gathered for about 5 weeks.
- Deformations slowed after grading for equipment access.
- Deformation during construction – 1 to 2 inches.
- About 1 inch of deformation anticipated between walls after installation to mobilize loads.
Current SAA Deformation Data

- GEOSCOPE
Sol Data Instrumentation Boxes
Deformation Profile and Chronology

SAA 3

Elevation (feet)

Deformation (inches)

SAA 4

Elevation (feet)

Deformation (inches)
Deformation Versus Time

Baseline Velocity

SAA 4
Summary and Conclusions

- Unique solution to an interesting problem.
- Shear walls spaced much wider than conventionally considered.
- Deep failure surface provided opportunity for wide wall spacing.
- Gentle natural slope allowed access for large equipment.
- Monitoring to date is in line with expectations – warranty requires less than one inch in the third year.
- Technically and commercially a rewarding project.
Questions?