MUS-93-12.84: MINE GROUTING

• The Ohio Department of Transportation (ODOT) inspects nearly 12,000 structures annually.

• During the inspection of MUS-93-12.84 Bridge in 2007, a large subsidence feature was noted under the right rear abutment.

• Bridge carries traffic over Interstate Route 70 in Muskingum County.

• Determined that corrective actions were necessary to protect the structure and roadway.
MUS-93-12.84: MINE GROUTING

Project Location: Pleasant Grove, Ohio
MUS-93-12.84: MINE GROUTING

Subsidence Feature Noted During Bridge Inspection at Rear Abutment
MUS-93-12.84: MINE GROUTING

- No historical mine maps were available for the workings
- Historical archives, construction diaries, indicated that Interstate 70 was over-excavated through the mine interval, including the bridge piers, but the north and south bridge abutments and approach roadway and ramps could be underlain by mine voids
- Original construction plans indicated an abandoned mine entrance within project
- Underground utility vault, east side of rear abutment, encountered a void during installation.
MUS-93-12.84: MINE GROUTING

- Area has been noted for active subsidence:
  - 1962: two subsidence features noted on original soil profile notes;
  - 2000: large subsidence(s) investigated in northwest quadrant infield;
  - 2007: Subsidence feature under rear abutment.
MUS-93-12.84: MINE GROUTING

REGIONAL GEOLOGY & MINING

- Area located in the non-glaciated Marietta-Pittsburgh Plateau which is characterized by its moderately high to high relief

- Pennsylvanian aged bedrock rock consists of siltstone, shale, sandstone, coal, and claystone

- Locally: No. 7 coal typically mined through drift entries

- Drift entries advanced into the coal seam from the head of tributary valleys

- Shallow soil cover typically ranging form 5 to 20 feet

- No Site Specific Mine Map for the project
MUS-93-12.84: MINE GROUTING

ODNR Map BG-1
MUS-93-12.84: MINE GROUTING

REGIONAL GEOLOGY & MINING

• Typically: All of the local mines were abandoned prior to mechanization, circa 1930’s.

• Most exhibit pre-mechanization mining features, i.e.,
  – Long, Narrow Rooms & Pillars (5-6 foot widths),
  – ± 50% Extraction,
  – Rooms Driven on the Face Cleat,
  – No retreat or second mining.
MUS-93-12.84: MINE GROUTING

Known Mapped Workings

Project Location

Local AML GIS Coverage – ODNR Web Site
MUS-93-12.84: MINE GROUTING

Typical Mine Map From Area (Local 1 mi. east of project)

- Rooms driven on Face Cleat; N6°W
- Long, Narrow Pillars
- No Secondary (retreat) mining
- Coal Elev. 858.0±; 30 ft. below MUS-93 site (El. 890.0)
- Drift entry from valley outcrop
Remediation Selection

• Monitoring of the structure and roadway:
  High traffic resulted in unacceptable risk due to potential catastrophic failure

• Excavation and replacement:
  High costs and long closure time
  Impractical at the abutments

• Drill and grout options:
  Expensive and small risk for subsidence

Drill and Grout Selected due to time constraints!
**MUS-93-12.84: MINE GROUTING**

**Project Concerns**

1) Limiting Road Closure Due To Heavy Truck Volumes From Industrial Park
2) Limiting Access To Emergency Vehicles
3) Settlement of Structure During Grouting
4) Blowout of the Cut Slope Above IR 70
MUS-93-12.84: MINE GROUTING

1) Limiting Road Closure Due To Heavy Truck Volumes From Industrial Park:

- Selection Of Drill and Grout To Limit The Time Required For The Road Closure
- Do Not Implement Road Closure Until Drilling Of The Roadway Production Holes
2) Limiting Access To Emergency Vehicles:

- Only Work In One Traffic Lane At A Time, Even During Closure Period, To Allow Access To Emergency Vehicles
3) Settlement of Structure During Grouting:

- Required Structure Monitoring 24/7 For The Duration Of The Construction.
4) Blowout of the Cut Slope Above IR 70:

- Contractor Must Have Contingency For Immediate Interstate Closure If Blow Out Occurs With Cleanup Plan;

- Monitoring Of The Slope Required During Grouting Operations.
STRUCTURE MONITORING

- Leica RCRP 1200+ robotic system was manned 24 hours a day, 7 days a week during the project.
- Reflective glass targets were mounted on each concrete abutment and concrete pier.
- Vertical Surface Monitoring Points were surveyed once daily during the project.
MUS-93-12.84: MINE GROUTING

Monitoring Results of Targets
Due To Lack Of Mine Map, In-situ Underground Mapping Was Completed to Determine Working Layout and Condition

Workhorse Technologies, Pittsburgh PA, Were Retained To Perform Mapping Using Sonar “Wet Ferret” and/or LiDAR “Dry Ferret”
MUS-93-12.84: MINE GROUTING

• South and North Side “Dry” at Completion of Production Hole Drilling – To Be Mapped Using “Dry Ferret” – LiDAR Scanning

• At Time of Mapping:
  ➢ South Side had “Squeezed” Closed with only a 6-inch opening below roof rock
  ➢ North Side “flooded”

• South Side Not Mapped
• North Side Mapped Using “Wet Ferret” - Sonar
WET FERRET

- Used in Flooded Conditions
- Requires Minimum 3-foot “Clear” (low Turbidity) Water
- Single Planar Scan Six-inch Thick on a 360° Horizontal Profile
- Resolution: 0.4-inches from 6 inch to 300 feet; up to a depth of 3280 feet

(Photo Courtesy Workhorse Technologies, LLC.)
MUS-93-12.84: MINE GROUTING
MUS-93-12.84: MINE GROUTING

Raw Data Point Collection by “Wet Ferret”

(Courtesy Workhorse Technologies, LLC.)
Post Processed Data Point Collection by “Wet Ferret” (at a single scan point)

(Courtesy Workhorse Technologies, LLC.)
MUS-93-12.84: MINE GROUTING

• Scan in P6 revealed a void:
  – 2.5 ft. high.
  – 15 ft. wide.
  – 70 ft. long.
  – Est. volume 97 cy.

• Excellent correlation with borehole camera.

• P6 took 90 cy grout!
DRY FERRET

- Used in Dry Air Filled Void Conditions;
- LiDAR scanning sequence collecting thousands of measurements;
- Scanning sequence is processed into a 3-D model of the void;
- Accuracy: 1-inch up to 160 feet from scanner; up to a depth of 2500 feet.

(Courtesy of Workhorse Technologies, LLC. Web Site: http://www.workhorsetech.com/etomite0613/)
Example 3-D Model Created From “Dry Ferret”

Note the Cribbing Outline

(Courtesy of Workhorse Technologies, LLC. Web Site: http://www.workhorsetech.com/etomite0613/)
Project Stats:

- Drilled 2,000 liner feet of injection holes.
- Placed about 2,000CY of Barrier Grout.
- Placed about 250 CY of Production grout (virtually all on the north side).
- Began project Feb 14th, completed Mar 4th.
MUS-93-12.84: MINE GROUTING

Interesting Facts & Pondering Points

• North side IR70 lots of open voids, South side mostly coal.

• Proximity to crop line and shallow cover contribute to poor roof stability.

• Proximity to entrance, more coal left insitu.
MUS-93-12.84: MINE GROUTING

Interesting Facts & Pondering Points

• Mine workings on the north side were “flooded”, south side workings were “dry”.
• Originally presumed a regional NW-SE geologic dip; drilling revealed a N-S dip.
• Construction fill on IR70 Cut slopes acted to dam water on North side.
• Greater aerial extent of mine workings to north
• South side drained to local drainages along US40.
Interesting Facts & Pondering Points

- A3 & A4 both encountered voids at 898.0 and 900.7, respectively. A3 was open 5 feet and full of water; A4 was open 5 feet and dry;
- Put light source in A3 could not see from A4;
- Borehole camera could see towards A3;
- A3 took 18 CY grout; A4 took 58 CY grout;
- Possible collapse, but drilled like insitu material;

- Miners could have used soil or “mine gob” to block rooms for ventilation control since this section of the mine was near the crop line.
MUS-93-12.84: MINE GROUTING

- Pump Test in I1A, monitored in I3. 4-inch Godwin, CD100M operating at 1900 rpm (710 gpm);
- Pumped for 88 minutes. Obtained a drawdown of 0.3 ft (30 min/0.1 ft);
- Wanted to drawdown pool ±2 ft. (10 hrs.) so grout injection wouldn’t overpressure the mine pool;
- 12 hours later the pump was sucking air.
MUS-93-12.84: MINE GROUTING

Interesting Facts & Pondering Points

• A1 hit a coal pillar. A1A encountered a void. As soon as drill tools removed hole, hole would squeeze in with a highly plastic soil material. A1A was drilled out 3 times, same result;

• 9 feet of rock was drilled before encountering the void;

• Backfilled soil/gob has become saturated enough to be at/near the liquid limit so as to act as a pseudo-liquid; 

• Grout could not displace the “mud”, virtually no take.
MUS-93-12.84: MINE GROUTING

CONCLUSIONS

- In-situ mapping can aid in mine grouting project;
- Sonar has limited applications due to poor performance in muddy water;
- LiDAR good in dry situations;
- Should be used prior to drilling of production holes to move hole locations to avoid pillars;
- Help refine the production volumes to reduce waste;
- Structure monitoring may be expensive, but worth piece of mine for “critical structures”;
- Structure monitoring should be automated to reduce labor costs associated with 24/7 monitoring.
MUS-93-12.84: MINE GROUTING

THANK YOU!

QUESTIONS??