Underground Mine Exploration and Void Mapping along Interstate 70 (MUS-70-15.31) and State Route 93 (MUS-SR 93-12.80) Muskingum County, Ohio

By:

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- Project Information and Investigation Methodology
  - Ohio DOT proactive approach
- Abandoned Mine Subsidence Challenge
  - The problems
- Geotechnical Underground Mine Exploration Investigations
  - Exploratory borings
  - Void imaging and mapping
- Void Volume Determination
- High Risk Areas Identification
- Conclusions and Recommendations
Ohio DOT Proactive Approach

Development of a comprehensive abandoned mine subsidence risk assessment and mitigation program for...

- Minimizing subsidence risk through cooperative team effort involving ODOT, Terracon, and ZAPATA
- Mapping known and unknown mines that exist beneath roadways
- Focusing exploratory borings and void mapping where mitigation efforts should be directed
- Determining void volume
- Identifying high risk areas which require mitigation
Abandoned Mine Subsidence Challenge

Why abandoned mine subsidence is so complex to solve?

The Problem
Many unknown conditions…!

Subsurface
- Strata
- Geologic setting
- Mining depth

Mine workings
- Dry and/or flooded
- Stable
- Collapse / rubble / gob

Voids / openings
- Location & orientation
- Size
- Lateral extent

Mine records / maps
- Incomplete
- Incorrectly geo-referenced
- Nonexistent

Extraction rate
- 40% to 70%, or
- 80% to 100%

Time-dependent
- Integrity of coal
- Integrity of roof structure

The Solution
- Accurate risk assessment
- Cost-effective mitigation techniques
Geotechnical Underground Mine Exploration Investigations

Proactive Approach

ODOT Two Projects
- MUS-70-15.31 (I-70)
- MUS-SR93-12.80 (SR-93)

Void Imaging
- Video camera
- Sonar & laser imaging

Focused Exploratory Borings Program
- Total 70 Borings
  - Drill cutting logging

Geotechnical Engineering Solution
- Developed 2D and 3D images of the voids
- Determined current mine conditions
- Determined volumes of mapped voids
- Identified high risk areas that require mitigation

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Along I-70 East of Zanesville, Ohio

I-70 between ~ MM 157 & 159

Exit 157 – I-70 & State Route 93
Site Location

Along I-70 East of Zanesville, Ohio
Abandoned Underground Mines - Washington Twp., Muskingum Co. Ohio

MM -202
- Forest Hill Mine
- Abandoned 1932
- Upper Freeport No. 7 coal

MM -128
- Greiner Mine
- Abandoned 1959
- Upper Freeport No. 7 coal; Mine EL. ~ 887 ft

MM –OGS-051
- Handchy Mine
- Date ~1917 – Mined for local use
- Upper Freeport No. 7 coal; Mine EL. ~900 ft
Projects Location Plans

I-70 Project Site
- Mining method: Room-and-pillar extraction
- Coal seam thickness: ~ 5 ft
- Overburden thickness: 15 to 60 ft
- Lithology: Consisting of clay, sandstone, and shale

SR-93 Project Site
- Mining method: Room-and-pillar extraction
- Coal seam thickness: ~ 4.5 ft
- Overburden thickness: 15 to 37 ft
- Lithology: Consisting of clay, sandy silt, sandstone, and shale
I-70 Project Objectives

- MUS-70-15.31 Project: ~ 3,800 feet long through area of historic underground and surface coal mining
  - Ohio DOT first observed ground subsidence at the R/W fence left of Sta. 122+00 in 2006
  - Ohio DOT conducted literature search and performed multiple prior phases of drilling and geophysical surveys

- Objectives of Exploration: Use Down-the-Borehole Laser and Sonar Void Imaging and Mapping to:
  - Confirm the accuracy of Mine Map MM-128
  - Map the mine workings around prior borings B-027-11 and B-004-06
  - Confirm the location of the mine entry of Mine Map MM-202
  - Map Mine workings in the vicinity of original subsidence and prior boring B-001-06
I-70 Project Objectives

Original Mine Subsidence

Map mine workings in vicinity of 2006 mine subsidence and boring B-001-06

Confirm accuracy of Mine Map MM-128

Map mine workings around prior boring B-004-06

Confirm location of mine entry of Mine Map MM-202

Map mine workings around prior boring B-027-11
I-70 Project Objectives – Sta. 116+00 to 130+50

- Confirm location of mine entry of Mine Map MM-202
- Map mine workings in vicinity of 2006 mine subsidence and boring B-001-06
- Map mine workings around prior boring B-004-06
Prior Borings – Sta. 116+00 to 130+50

Void (typ.)

Void

Void
I-70 Project Objectives – Sta.130+50 to 144+50

Confirm accuracy of Mine Map MM-128
Prior Borings – Sta. 130+50 to 144+50

No Voids
Map mine workings around prior boring B-027-11
Prior Borings – Sta. 144+50 to 158+50

Surface Mine Spoils

Void
SR-93 Project Objectives

- MUS-SR 93-12.80 Project: Interchange of SR-93 and I-70 area of historic underground and surface coal mining
  - Ohio DOT conducted a literature review of original construction plans, results of drilling and prior grouting of SR 93 bridge, and their exploratory borings
  - Construction diaries indicated that some mine remediation work was performed during original construction; however records were vague relative to where on the ramps remediation can be considered complete and where further exploration was needed

- Objectives of Exploration:
  - Use Down-the-Borehole Laser and Sonar systems to map the mine workings north and south of the prior bridge grouting project; and mine workings encountered in boring B-005-11
  - Perform geotechnical test borings along the ramps and SR 93 to:
    - check for the presence of mine workings; and
    - perform laser and sonar void mapping, if mine workings encountered
SR 93 Project Objectives – South of Bridge

Map mine workings south of prior bridge grouting project

Bridge abutment previously grouted by Ohio DOT
SR 93 Project Objectives – North of Bridge

Map mine workings around prior boring B-005-11

Bridge abutment previously grouted by Ohio DOT

Map mine workings north of prior bridge grouting project
Prior SR 93 Boring – B-005-11

Boring B-005-11 location

Void
Project Team

- **Client:** ODOT District 5 – Nikunj Kadakia, P.E. – Transportation Engineer
  Brian Logston, P.E. – Geotechnical Engineer
- **Terracon Consultants, Inc.** – Kevin Ernst, P.E. – Project Manager
  Jennifer Sorg, P.E. – Project Engineer
  - Project Management and Planning
  - Field Coordination and Borehole Logging
  - Drilling Services – Geotechnical Test Borings
  - Report Preparation
- **ZAPATA Incorporated** – Kanaan Hanna – Mining Engineer
  Jim Pfeiffer - Geophysicist
  - Down-the-Borehole Laser and Sonar and Scanning
  - Data Reduction and Analysis, Void Mapping, Volume Calculations, Report
- **Woolpert Consultants, Inc.** – Steve Newell, P.S. – Project Surveyor
- **Beckley Drilling and Blasting, Inc.** – Drilling Services
  - Drilling 6-inch diameter boreholes for Down-the-Borehole Scanning
- **Area Wide Protection** – Traffic Control
Exploration Plan

- Boring Locations
- Drilling and Sampling Methods
- Casing Installation
- Down-the-borehole scanning
- Boring sealing
- Traffic Controls
- Field Coordination and Communications
- Schedule
- Safety
Drilling – Boreholes for Down-the-Hole Scanning

- **Boreholes**
  - Beckley provided Atlas Copco L6 Drilling Rig
  - 6-inch diameter borehole
  - Down-the-Hole Percussion Hammer
  - Rapid Advancement of Borehole
  - Air drilling

- **Casing**
  - 4-in diameter casing
  - Casing grouted
  - Flush mounted protective cover
  - Allows for future grouting /observation
Void Imaging and Mapping Systems

Laser, Sonar, and Video Camera Tools

Tethered Robotic Downhole Systems
Void Mapping & Imaging
“Real Time Visualization”

Downhole Sonar Void Scanning / Mapping
(Water-filled void)
- Imagenex Digital Multi-frequency Profiling
- One-axis scanning: horizontal plane (360-degree scan)
- Scans: multiple 2-D plans create 3-D model
- Distance measurements: 300 ft
- Accuracy: ± 1 degree

Downhole Laser Void Scanning / Imaging
(Air-filled void)
- MDL: C-ALS
- Scans: 3-D or 2-D horizontal and vertical slices
- Equipped with video camera (~20 ft)
- Distance measurements: 500 ft
- Accuracy ± 0.5 degree

Downhole Video Camera Void Imaging
(Air-filled or water-filled void)
- Images: Vertical and horizontal control
- Video recording capabilities
- Distance measurements ~ 25 ft
Field Activities

Focused Underground Exploratory Borings

I-70

SR-93
Example: I-70 Boring Location Plan
Exploratory Borings

Example: SR-93 Boring Location Plan
Field Activities

Void Mapping: Sonar and Laser Systems

I-70

SR-93

www.zapeng.com
Video Snapshot Images

I-70

SR-93
Examples: I-70 Laser Void Mapping Results

2D Laser scans in various boreholes
B-014-0 plan, B-015-2 perspective, and B-013-0 plan views

3D Laser scans in borehole B-014-1
Plan, perspective, and side views
Examples: I-70 Sonar Void Mapping Results

- Composite scans B-010-1 & B-014-1
- Real time scans Various boreholes
- Composite scans B-020-4
Examples: I-70 Sonar Void Mapping Results

Borehole B-004-1: Real time and composite scans at depths from 14.5 to 16.5 ft bgs
Void Imaging and Mapping

Examples: SR-93 Sonar Void Mapping Results

Borehole B-020-2: Real time and composite scans at depths from 33.5 to 35.5 ft bgs
Examples: SR-93 Sonar Void Mapping Results

Composite scans in various boreholes showing the maximum extents of voids outlined in **blue**, and pillars outlined in **black** (Grid squares are 25 ft).
Void Volume Determination Considering Two Scenarios:

- Void volumes based on the laser and sonar void mapping, and
- Void volumes based on the current mine conditions (post-mining):
  - Average *mined* coal seam thickness/void height ~ 4.5 ft
  - Average *current* void heights ~ 2.5 to 3.5 ft
  - Percentage of the coal extracted ~ 65 – 75%

- Criteria used to determine the width of the “Danger Zone” of the area to be mitigated depends on:
  - Subsidence angle of draw “D” = 30 degree
  - Overburden depth = 15 – 60 ft
  - Width of extraction/mined-out area, and
  - Void height and void ground conditions
Void Volumes Determination for I-70 and SR-93
(Mapped void volume from the laser and sonar, and current void volume)

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<thead>
<tr>
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<th>I-70 STA. 120 to 155</th>
<th>SR-93</th>
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<tbody>
<tr>
<td>Laser and Sonar Mapped Void Volume (Yd³)</td>
<td>778</td>
<td>744</td>
</tr>
<tr>
<td>Current Void Volume (Post-Mining) Total void volume of Areas 1-11 to be mitigated (Yd³)</td>
<td>2,461</td>
<td>2,733</td>
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Boundary Limits of the Areas to be Mitigated

Examples: I-70 Areas 1 to 6 to be Mitigated
Boundary Limits of the Areas to be Mitigated

Examples: I-70 Areas 9 and 11 to be Mitigated
Boundary Limits of the Areas to be Mitigated

Examples: SR-93 Areas 1, 2, and 3 to be Mitigated
Conclusions and Recommendations

Conclusions

- Underground exploration and void mapping confirmed the presence of:
  - Mine workings of the *known* historical mine maps
  - Mine workings where historical mine mapping *is not* available

- Subsurface void mapping further delineated the geometry of entries and production sections

- The total void volume presented is for the mitigation areas identified by this study

- The proactive approach employed by ODOT is in contrast to traditional drilling techniques typically employed for subsidence risk assessment and reclamation

- The focused exploratory boring and mine void mapping demonstrated the:
  - Capability ---Viability---and Economic Feasibility of this proactive approach
Recommendations

- Additional subsurface exploration and void mapping to provide for further delineation of unmapped mine workings in both areas, and could be taken as:
  - A pre-design activity, or
  - Incorporated into the stabilization program

- Any additional exploratory drilling program could be implemented as part of the construction phase as an expedient and cost-effective measure to:
  - Simultaneously identify and remediate abandoned mine workings, resulting in...
  - A focused effort on remediation rather than ongoing studies
Thanks