Subsurface Investigation and Conceptual Alternatives

Mitigation of Gypsum Mine Voids Under SR-2 in Ottawa County, Ohio

Presented By: Ohio Department of Transportation
CH2M HILL
CTL Engineering
Technos, Inc.
Workhorse Technologies
DANGER

OLD MINES - UNSTABLE GROUND
NO TRESPASSING
VIOLATORS WILL BE PROSECUTED

United State Gypsum Co.
419-734-3161
History

- Gypsum mined from 1902 to 1977
- Section under SR-2 mined 1950’s – 1960’s
- SR-2 constructed in 1965
- Mines flooded in 1979
- Active sinkholes since Dec. 2004
Difficult Mine Conditions

- Lower mine seam covers 500 acres
- Gypsum mine seam 16 feet
- Mine voids average 10 feet, but locally may be up to 15 feet in height
- Deepest section (Ahrens) 85 feet
- Room and pillar, with 15’x15’ pillars and rooms span 20 feet
- Overlain by 10-15 feet of dolomite, shale, and gypsum
Purpose & Need Goals

Minimize Community Impacts

• Airport, residential properties, large-scale camping facilities, cemeteries and municipal properties in project area
• Minimize environmental impacts
• Project be consistent with existing local plans
Purpose & Need Goals

Minimize Peak Season Traffic Disruptions

• SR-2 carries 18,000 vpd
• SR-2 is vital to tourist industry along Lake Erie
• Primary access to Marblehead peninsula and Ferry access to Middle & South Bass
• Secondary access to Cedar Point
• Minimize construction duration
Purpose & Need Goals

Retain Limited Access Functionality

• SR-2 is important east-west corridor
• Limited access facility throughout Ottawa County
• Maintain Norfolk & Southern Rail
OTT-2 Detour Route and Traffic Volumes

## Detour Cost

<table>
<thead>
<tr>
<th>Closure</th>
<th>Duration (Days)</th>
<th>Cost to SR-2 Motorists</th>
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<tbody>
<tr>
<td>A</td>
<td>30</td>
<td>$5,401,222.20</td>
</tr>
<tr>
<td>B</td>
<td>180</td>
<td>$32,407,333.20</td>
</tr>
<tr>
<td>C</td>
<td>365</td>
<td>$65,714,870.10</td>
</tr>
<tr>
<td>D</td>
<td>365</td>
<td>$65,714,870.10</td>
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Project Goals

- Understand the existing geologic conditions
- Verify and define the approximate limits of the mine
- Understand the risks involved with mitigating the existing conditions
Project Goals

• Develop and evaluate conceptual alternatives based on the Purpose & Need
  – Remediate existing mines (SR-2 maintains current alignment)
  – Land bridge (SR-2 maintains current alignment)
  – Relocate/Shift SR-2
Geotechnical Investigation

- Surface geophysical
- Confirmation borings (21 Total)
- Laboratory testing
- Sonar modeling
Surface Geophysics to Help Identify Mine Boundaries

Approach included two surface geophysical methods:

• Microgravity – primarily to map mine boundaries

• Resistivity Imaging – primarily to identify other geologic variability and to aid in interpreting the gravity data
Microgravity

Gravity measurements detect changes in the earth’s gravitational field caused by local changes in the density of the soil and rock or engineered structures.
Mapping of Top of Rock

Microgravity Data

Microgravity Model

Borings Showing Depth to Rock

Clay and Weathered Limestone

Limestone
Mapping Old Paleo-Collapse Sinkholes

Gravity Contour Map
Terrain and Fill Corrected

Buried paleo-collapse
Detection of Large Conduits

- Observed Gravity (filtered)
- Modeled Gravity

Simplified Conduit Model

- Sand
- Limestone

Depth (ft)

- Known Mapped Conduits: 30-ft diameter, 100-ft Deep
- Known Mapped Conduit: 50-ft diameter, 100-ft Deep
- Estimated Conduit: Based upon Gravity 140x70-ft, 250-ft Deep

Source: Technos, Inc., 2006
Map the Presence of Mines
Limitations

- Only detects features with a density contrast
- Supporting data must be used to constrain gravity models (non-unique modeling)
- Vibrations can produce noise in data (e.g. distant earthquakes, wind, waves, vehicles, construction, etc.)
- Nearby topography can introduce noise if not accounted for in the data processing
Forward Model of Gravity Response Over Expected Mine Conditions

15-foot thick semi-infinite slab, -1.4 g/cc density contrast (water-filled rock) at 85 ft depth

Mine Void Edge Detection

Soil
Bedrock

Mine

85 ft deep, 15 ft high
Planned Geophysical Lines

Test Phase Data
Microgravity Test Data

- Fairly insensitive to depth due to large planar target
- Very sensitive to thickness – 11 ft assumes water-filled, could be up to 15 ft or as little as 7 ft, if air-filled
Microgravity Data – Line 1

Possibly parallel to mine edge and not directly over the mine.
Microgravity Results
Results from Microgravity Alone

- Response from mine, even at deepest provided a good target for microgravity
- Top of rock is deeper to east
- Mine is deeper to east
- Thickness of mine varies – 2 to 12 ft, getting thinner to northwest
Sonar Deployment

- Sonar deployed by hoist from tripod
- Sonar linked mechanically to the surface providing a physical orientation
- Horizontal sonar scans are collected at 1 ft or less incremental elevations
- Computer controls and logs data from sonar unit
Statistics

- 200,000 cu ft of void modeled
- 1800 linear ft of mine corridor modeled
- Mine conditions revealed in models

<table>
<thead>
<tr>
<th>Hole</th>
<th>Date of Sonar</th>
<th>North</th>
<th>East</th>
<th>Surface Elev</th>
<th>Water Elev</th>
<th>Top of Void</th>
<th>Bottom of Void</th>
<th>Volume</th>
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<tr>
<td>P-6</td>
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<td>11/19/2010</td>
<td>11/17/2010</td>
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<td>80648 cu ft</td>
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Sonar Modeling Process

• Collect horizontal sonar scans in small vertical increments in the field
• Combine scans to create a 3 dimensional model of the flooded void
• Translate and orient the model into site coordinates
• Produce plots, models, and analyze the model for volume
• View 2-D and 3-D data to access the remaining mine structures
• Align the features in the model with the mine map features
Sonar plot from field P-18

Sonar plot for 1 elevation as viewed in the field

Red circles represent 36 ft per division in this scan

Red cross hairs show the borehole location center of the scan

Center to edge is approximately 200 ft

Dark areas are reflections from surfaces in the mine.

Crisp black lines are from vertical surfaces and fuzzy lines like shown to the left show slope of roof.
Composite plot of sonar scans P-17
P-17 sonar aligned on mine map
Sonar Results

- Confirmation and orientation of old mine maps through feature matching with sonar models
- Revealed areas of collapse and areas where pillars are still intact
- Larger models verified dip of the seam where both roof and floor were visible

Sonar data was gathered 200 ft from some of the boreholes.

The water was filled with suspended particles and visibility was minimal. The camera was only useful to verify the water level and to confirm blockage or bottom.
Alternative Development

• Minie Stabilization (SR-2 maintains current alignment)

• Land bridge (SR-2 maintains current alignment)

• Relocate/Shift SR-2
SR 2 – GENERAL SUBSURFACE PROFILE
BORING INJECTION PLAN
MINE STABILIZATION PLAN

SITE "A"
- Grouted coverage area 87,146 ft²
- x Mine Depth 11 ft / 27 ftyd
- 40% Void volume = 14,200 yd³

SITE "B"
- Grouted coverage area 61,775 ft²
- x Mine Depth 11 ft / 27 ftyd
- 40% Void volume = 10,100 yd³

SITE "C"
- Grouted coverage area 318,072 ft²
- x Mine Depth 11 ft / 27 ftyd
- 40% Void volume = 51,834 yd³

SITE "D"
- Grouted coverage area 273,217 ft²
- x Mine Depth 13 ft / 27 ftyd
- 40% Void volume = 52,620 yd³

UNMAPPED AREAS OF GYPSUM
EXPLORATORY BORINGS
- 70 Exploratory Holes x 70 ft Average
- Depth = 4900 ft
- 10,000 yd³ Grout

LEGEND
- MAPPED GYPSUM MINE
  GROUT INJECTION AREA
- UNMAPPED GYPSUM MINE
  EXPLORATORY BORING AREA

SCALE 1" = 400'
Area A – $3,654,330.00
107 vertical holes, 20 angled holes, 7100 yds³ Barrier Concrete Grout,
14,500 yds³ Production grout, Mob/Demob + Misc.
Area B - $3,204,626.00
78 vertical holes, 19 angled holes, 14,074 yds³ Barrier Concrete Grout,
10,100 yds³ Production grout, Mob/Demob + Misc.
Area C - $9,791,225
399 vertical holes, 109 angled holes, 23,889 yds³ Barrier Concrete Grout,
51,834 yds³ Production grout, Mob/Demob + Misc.
Area D - $9,513,363.00
348 vertical holes, 82 angled holes, 18,333 yds³ Barrier Concrete Grout,
52,620 yds³ Production grout, Mob/Demob + Misc.
Grouting Costs

– Area A – $ 3,654,330.00
  • 107 vertical holes, 20 angled holes, 7100 yds³ Barrier Concrete Grout,
  • 14,500 yds³ Production grout, Mob/Demob + Misc.

– Area B - $ 3,204,626.00
  • 78 vertical holes, 19 angled holes, 14,074 yds³ Barrier Concrete Grout,
  • 10,100 yds³ Production grout, Mob/Demob + Misc.

– Area C - $ 9,791,22500
  • 399 vertical holes, 109 angled holes, 23,889 yds³ Barrier Concrete Grout,
  • 51,834 yds³ Production grout, Mob/Demob + Misc.

– Area D - $ 9,513,363.00
  • 348 vertical holes, 82 angled holes, 18,333 yds³ Barrier Concrete Grout,
  • 52,620 yds³ Production grout, Mob/Demob + Misc.

TOTAL MINE REMEDIATION
$ 26,163,544
Land Bridge Alternative

- Segmental Concrete Box Girder
Land Bridge Alternative

- Steel Plate Girder
Shift SR-2: Alternative 3A

- Overpass reconstructed
- Avoid Mines
- Modify existing roadway
Shift SR-2: Alternative 3B

- Overpass reconstructed
- Avoid Mines
- Modify existing roadway
- Modify existing roadway
Shift SR-2: Alternative 3C

- Overpass reconstructed
- Avoid Mines
- Maintain existing connectivity
- Constructed on existing mines
Shift SR-2: Alternative 3D

- Overpass maintained
- Maintain existing connectivity
- Constructed on existing mines
Conclusions and Recommendations

• Land Bridge – Eliminated from further consideration
  – High construction cost
  – Long construction schedule
  – High impact to existing traffic

• Mine Stabilization – Continued for further consideration
  – Minimally satisfy all key elements of the Purpose & Need
Conclusions and Recommendations

• Shift SR-2: Alt. 3A and 3B – Eliminated from further consideration
  – High right-of-way needs
  – Long construction schedule
  – Alter existing roadway network

• Shift SR-2: Alt. 3A and 3B – Continued for further consideration
  – Minimally satisfy all key elements of the Purpose & Need
Next Steps

- PREPARE A DESIGN FOR A SMALL PILOT PROJECT, THERE IS A CONCERN REGARDING THE GROUTING AND BARRIERS FOR VOIDS POSSIBLY EXCEEDING 13 FEET IN HEIGHT

- EVALUATE THE RESULTS OF THE PILOT PROJECT TO DETERMINE THE MOST FEASIBLE APPROACH TO STABILIZING THESE MASSIVE VOIDS

- DEVELOP DESIGN DOCUMENTS IN ACCORDANCE WITH THE BEST ALTERNATIVE
QUESTIONS?