Geotechnical-Geophysical Void Mapping and Foamed-Sand Backfilling of the Rapson Coal Mine, Colorado Springs, Colorado – Case Study

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Joint Conference
2nd Wyoming Reclamation and Restoration Symposium
30th Annual Meeting of the American Society of Mining and Reclamation
Focus

- Project Site Location & Subsidence/Sinkhole Problems
- Geotechnical-Geophysical Methodology
  - Subsurface data acquisition and interpretation
  - Exploratory boring
  - Laser, sonar and video void investigation
- Colorado DRMS/Hayward Baker Ground Modification Treatment
  - Low mobility grouting or compaction grouting (LMG) beneath houses
  - Foamed sand slurry backfilling of large underground opening
- ZAPATA Video Monitoring of the Foamed-Sand Backfilling of the Rapson Mine

ZAPATA Services

- A/E & Construction Management
- Munitions Response Services
- Environmental Engineering & Remediation
- Mining
- Water Resources
- Energy
Country Club Circle (CCC) Residential Neighborhood

Historic subsidence

Trough subsidence

Sinkhole mitigation
Project site conditions required:

- A combination of several geophysical methods to provide reliable information

- Geology
  - 40 to 50 ft of sand

- Cultural noise

- Site conditions & accessibility
  - Buried utilities

- Target types & depth
  - B & A seams
Three seismic techniques were used:
1. Surface seismic, &
2. Two borehole seismic.

MASW (surface) survey:
- Shallow subsurface evaluation
- Target drilling

RVSP (borehole-surface) survey:
- Mine working delineation
- Target drilling

XHT (borehole-borehole) Survey:
- Pre & post grouting evaluation

Exploratory borings:
- Ground truthing

Supplemental tools:
1. Geophysical logging
2. Void mapping tools:
   - Laser,
   - Video camera, &
   - Sonar.
Site Map and Geophysical Survey Layout

MASW Lines 1 - 8

RVSP

Mine maps do not exist

XHT, laser, video
Land streamer setup: 48 channel, 4.5 Hz geophones

iVi Envirovibe seismic source

Recording vehicle (doghouse)
MASW data plots - Lines 3 & 8
RVSP setup: 136 channels, 40 Hz geophones, 2 ft spacing
Survey lines crossing street and driveway

Survey line crossing residence yard
Recording vehicle (doghouse)

Airgun seismic source
RVSP data plot – “A” seam mine working delineation: Borehole CCC3
Drilling and sampling

- CSM 75 drill rig setup
- Drilling through ~ 40 ft sand
- Drilling through ~ 7 ft coal
- 4 inch PVC casing installation
- Casing/grout setup w/ 10% bentonite
Standard penetration tests (SPTs)
Geophysical logs – Sonic, bulk density, resistivity
Geologic cross section (A-A’)

- Void (6-7 ft)
- No cutting
- Rubble Zones
Geologic cross section (B-B’)

Geologic Profiles
Mine Workings Void Investigation – Data Acquisition

Laser, video camera, and sonar – Field setup

- Laser – Void scanning
- Video camera – Void imaging
- Sonar – Void scanning
Laser scans – Borehole CCC6

Interpreted haulageway
Size: 230 ft L, 10 ft W, 7 ft H
Volume: 511 yd³

X-cuts
Intact rib line
Mine Workings Void Investigation – Laser Results

Laser 3-D model of haulageway (main entry)
Borehole CCC6

Laser 2D interpretation plan view
Borehole CCC13
Video images interpretation – Borehole CCC6

Borehole CCC6

Wood Post
Rubble on Mine Floor

Pillar Corner
X-cut

SE View

Roof Line
Intact Pillar Corner
X-cut
Mine Floor

W View

Borehole CCC13

Immediate Roof Failure

Intact Pillar
W Rib
Wood Post
X-cut

N View

Rubble Pile on Mine Floor

Intact Pillar
E Rib
X-cut

NE View

Intact Pillar Rib
Haulageway

W-SW View
Reconciliation of interpreted geophysical results w/ historic base mine maps

Alignment of the Rapson No. 2 historic base mine map and haulageway entry

- RVSP results: The position of the mine workings in the north-northeast was shifted 25 ft north.

- Laser results: The position of the re-constructed haulageway was shifted 25 ft south and 17 ft west.
Colorado DRMS applied two ground stabilization techniques:

- Low mobility grouting (LMG) beneath houses, and
- Foamed sand slurry in entries/haulageways

Hayward Baker performing ground stabilization (LMG) beneath a house area:

- Injection at 600 psi at the bottom of the hole, and
- 200 psi near the top of the hole
- Grout amount per house averaged ~ 348 yd³ @ cost of ~ $66,600
Colorado DRMS applied two ground stabilization techniques:
- Low mobility grouting (LMG) beneath houses, and
- Foamed sand slurry of large mine opening (entries/haulageways)

Hayward Baker performed stabilization in large mine opening using Geofoam™ developed and supplied by Cellular Concrete:
- The foam is generated on site and mixed with sand in a concrete mixer truck
- The foam takes the place of water, allowing the sand to flow similar to sand-and-water slurry
- Approximately 3 yd³ of foam was mixed with 6 yd³ of damp sand for ~ 5 minutes,
- The foamed sand slurry was then gravity fed down the 4-in PVC casing
- The flow of sand was monitored by the video camera from a nearby borehole, approximately 50 ft away
- The foamed sand slurry filled the void to the approx. quantity estimated by the laser scans (511 yd³)
- The cost of the foam sand slurry is approx. half the cost per yd³ of the LMG treatment
Video images from CCC13 of foamed sand slurry backfilling in Borehole CCC6
Foamed Sand Slurry Backfilling
Country Club Circle
Colorado Springs, Colorado

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For:

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HAYWARD BAKER
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