The Ohio Department of Transportation
Office of Research & Development
Executive Summary Report

Sonar Imaging of Flooded Subsurface Voids
Phase I: Proof of Concept

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Principal Investigator:
Patrick J. Fox

ODOT Contacts:

Technical:
Kirk Beach
Gene Geiger

Administrative:
Andrew Williams, P.E.
Administrator, R&D
614-728-6048

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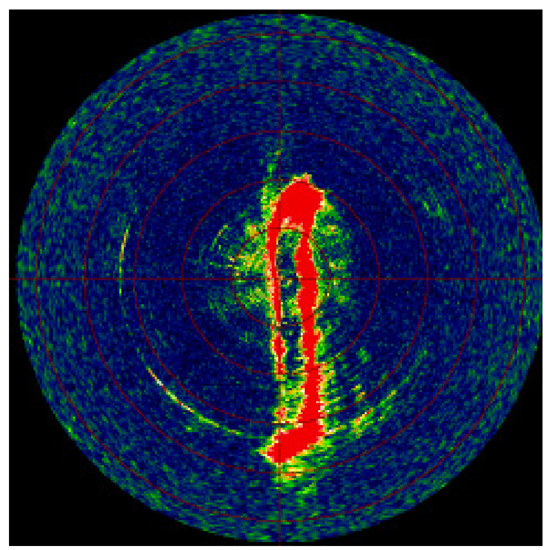
or call 614-644-8173.

Ohio Department of Transportation
Office of Research & Development
1980 West Broad Street
Columbus, OH 43223



Problem

Damage to Ohio highways due to subsidence or collapse of subsurface voids is a serious problem for the Ohio Department of Transportation (ODOT). These voids have often resulted from past underground mining activities for coal, clay, limestone and gypsum but may also result from dissolution of bedrock as with karst formations. Subsurface voids are flooded if they lie below the local drainage and may be partially flooded or open if they lie above the local drainage.

Several methods can be used to remediate a problem area with underground voids. If the voids are shallow, they can be excavated and filled. Dewatering may also be needed for filling of shallow voids. Otherwise, the voids are drilled and grouted. Occasionally, for high-risk highways subjected to differential settlement, a land bridge may be constructed over an area with subsurface voids. Over 1700 underground mine void sites are known to exist in Ohio. The age of the majority of abandoned underground mines ranges from 50 to 150 years. In some cases (about one-third), accurate maps of void location and geometry do not exist.

Since past records are often missing or of limited accuracy to establish the location of underground voids, subsurface investigation and grouting methods essentially consist of a random or grid-based drilling pattern. This is expensive because many unusable holes are drilled into existing pillars, walls or unmined areas. More information on void geometry would save considerable time and drilling costs. Such information can be obtained using downhole investigation equipment, such as cameras, laser scanning and sonar. These methods can delineate the geometry of an underground void or void network to guide further drilling and remediation operations. Even for mapped mines, there is still a need to verify the location of the map relative to existing surface features and design layouts.

Objectives

The objective of this project was to conduct a feasibility study for the development of new technologies or the acquisition of existing equipment for downhole investigation of subsurface voids. Specifically, ODOT is interested in accurate mapping of these underground features.

Description

Investigation indicated that the resulting system should provide high-resolution video and laser scanning for open voids and sonar imaging for flooded voids. The system should be capable of reaching depths of 300 feet with full inundation and provide real-time monitoring capabilities. The resolution of the system should be sufficient to identify timbers, pillars, roof falls, and other pertinent features of underground voids. Ideally, the system should be a one-piece unit suitable for deployment down a 4-inch, or preferred 3-inch, diameter borehole. Output of the system should consist of video imagery of the void along with a 3D cloud of coordinate points demarking the floor, walls and roof of the void, all referenced to surface coordinates and features.

Site visits were conducted to see existing equipment at the Robotics Institute of Carnegie Mellon University (CMU) and the Office of Surface Mines (OSM), both in

Pittsburgh. A field demonstration test was conducted using the CMU equipment in Zanesville, Ohio, for a void at a depth of approximately 30 ft. immediately adjacent to SR93 + I-70. In addition, an internet search was conducted, equipment quotes were obtained from various suppliers, and capabilities and limitations of equipment options were established.

Conclusions & Recommendations

This investigation produced the following conclusions and recommendations:

- In situ mapping can provide significant additional information to aid a mine grouting project.
- A vertical downhole camera is required for initial investigation of a borehole such that subsequently deployed equipment (e.g., sonar) will not become lodged.
- A high resolution camera is needed for investigation of open voids.
- Laser scanning can provide detailed geometry data for open voids.
- Sonar scanning can provide detailed geometry data for flooded voids but maybe limited by turbid mine waters.
- Equipment should have zoom/pan/tilt capabilities in order to obtain full 3D void geometry information with azimuth orientation relative to surface coordinates. Pseudo 3D imaging techniques are also acceptable.
- Software with the capability to calculate void volume is needed for laser scanning and sonar applications.
- Separate equipment is now available for video, laser and sonar scanning of underground voids through commercial vendors.
- Good estimates of mine void volume were obtained using sonar mapping in the field demonstration project.
- It is recommended that ODOT purchase a downhole sonar probe due to the high percentage of flooded voids in Ohio. A laser scanning probe should also be considered.
- The development of a single modular probe with video/laser/sonar or laser/sonar capabilities and that can fit down a narrow borehole is not cost-effective at the current time.
- Due to cost considerations, ODOT should not engage in the development of new equipment or technologies. Instead, ODOT should make use of off-the-shelf equipment to the greatest possible extent. Thus, Phase II development of a custom modular video/laser/sonar probe is not recommended at the current time.

Implementation Potential

The findings of this project represent a first step toward the routine use of multiple downhole technologies by ODOT to investigate subsurface voids. Based on the results of this study, it is recommended that ODOT delay the development of a complete modular void investigation system and instead make use of existing equipment, either through purchase or contract services. As a result of this project, a downhole video camera has been purchased.