



Mine Waste and Geotechnical Engineering Division

November 13, 2008

MEMORANDUM FOR IRVING McCRAE

Contracting Officer, Acquisition Management Division
MSHA - Headquarters, Arlington

THROUGH:


STANLEY J. MICHALEK

Chief, Mine Waste and Geotechnical Engineering Division


J. JARROD DURIG

Supervisory Civil Engineer, Mine Waste and Geotechnical
Engineering Division


DAI S. CHOI

FROM:

DAI S. CHOI

Civil Engineer, Mine Waste and Geotechnical Engineering
Division

SUBJECT:

Summary of Phase 2 Geophysical Void Detection
Demonstration Project - In-Seam Seismic Method; Performed by
Pennsylvania State University, MSHA Account Number
B2532532, RFP Number MSHA J53R1011

Pennsylvania State University (PSU) has fulfilled the first year of Phase 2 of their contract to demonstrate the in-seam seismic reflection method for detecting underground mine voids. Dr. Dai Choi served as Contract Officer's Technical Representative (COTR) for the project. The purpose of this memo is to provide a general summary of this multi-phase project and discuss the results obtained during this phase of the study.

PSU has submitted their final report for this project. The optional contract for additional work during the second year of Phase 2 was not exercised.

BACKGROUND

In October 2004, PSU was awarded a contract to demonstrate the use of the in-seam seismic reflection method for locating mine voids. The work was divided into two phases to be completed within 3 years. Phase 2 was further separated into 2 years, each with distinct work to be completed. The PSU team originally proposed to write a manual for the in-seam seismic technique during the second year of the Phase 2 work. Each part of the contract could be exercised based on the results of previous parts. The first year of the Phase 2 work was completed and paid in full on September 30, 2008. At that time, based on the results and completion schedule, MSHA decided not to exercise the second year of the Phase 2. The PSU team submitted a report to document and describe the work completed during Phase 2, year 1.

The project was carried out by the principal investigator, Dr. Maochen Ge, and others. The project team had three consultants to assist with site arrangement and instrument installation. They were Drs. R. V. Ramani, H. R. Hardy, Jr., and M. C. Radomsky. Dr. H. R. Hardy, Jr. passed away in January 2008 and was replaced by Dr. L. Grayson who assisted in the selection of field test sites during this phase of work.

The void detection field tests were conducted at Nolo Mine, Black King Mine, and Cumberland Mine. Nolo Mine is located near Nolo in Indiana County in central Pennsylvania. Black King Mine is near Sylvester in Boone County in central West Virginia. Cumberland Mine is near Waynesburg in Greene County in southwestern Pennsylvania. All the mines produce bituminous coal. They are located in the Lower Kittanning, Lower Cedar Grove, and Pittsburgh coal seams, respectively.

The collected field data was analyzed at PSU. Draft versions of the Phase 2 report were delivered to the Pittsburgh Safety and Health Technology Center on June 15, 2008. The draft reports were disseminated to an expert Peer Review team for feedback. The draft reports were revised on the basis of the feedback from the COTR and peer reviewers and resubmitted on September 4, 2008. The report addressed the comments from the Peer Review team and was subsequently accepted as the final Phase 2 report.

FIELD TESTS OF IN-SEAM SEISMIC REFLECTION

The PSU team conducted field tests using the same data acquisition system and sensors as those used during the Phase 1 work. This system is described in greater detail in the MSHA summary of the Phase 1 work dated January 15, 2008. The 28V DC rectifier in the data acquisition system malfunctioned and was replaced during the second field test at Nolo Mine and the field test at Black King Mine. The 1-amp output unit was sensitive to vibration which caused it to burn out. Because of its malfunction, the project team made extra field trips to collect the data.

Site No. 1 - Nolo Mine

The PSU team conducted two field tests on April 29, 2007, and June 23, 2007 at the Nolo Mine. The site for the first field test was conducted along a 120-foot-wide portion of a barrier pillar, while the second was conducted along a 180-foot-wide portion. Figure 1 shows the location of the test sites.

Discussion of Results

The PSU team was able to locate voids in the highly fractured Lower Kittanning coal seam. The coal pillar was spalled and coal fragments were piled along the pillar rib line. The void in the coal seam was located by plotting multiple of ellipses without applying the migration correction. The recorded frequencies for Love waves were 200 to 300 Hz for the seam condition. The velocity of Love waves, 1692 feet/second (ft/s) for the first field test and 1642 ft/s for the second field test, was used to calculate the void location. These values were determined from the average wave velocity calculated from wave transmission tests and direct arrival data collected during the reflection tests.

Site No. 2 - Black King Mine

The field test at Black King Mine was conducted on May 10, 2008. The coal seam at the test site was only 36 inches high. The roof and floor of the seam were competent sandstone and the coal had high strength with no pillar spalling. The barrier pillar was 100 feet wide. Only the entry where the test was conducted was in a fresh air environment; thus, due to safety concerns, no seismic source for transmission tests could be located in the entry across the barrier pillar. Figure 2 shows an overview of the test setup.

Discussion of Results

Transmission tests were used to measure the propagation velocity and dominant frequency of the Love wave through the Cedar Grove Coal seam which were 2,705 ft/s and 550 Hz, respectively. The void in the seam was located using travel velocity of 2,639 ft/s, the average of the travel velocity of transmission tests and calculated velocity of the direct arrivals from the reflection tests. The maximum location error was determined to be ± 30 feet for the detection distance of 100 feet. It is noticed that the rib of the coal pillar was not straight, due to oblique cuts of a continuous miner, and the sensors were located on a curved portion of the entries which resulted in the higher measurement error.

Site 3 - Cumberland Mine

On May 12, 2008, the project team conducted field tests at the Cumberland Mine. The test site, shown in figure 3, is a barrier left at the end of Longwall Panel 54. The barrier pillar was approximately 200 feet wide. The coal seam at the test site is 7 feet thick with shale in the roof and floor.

Discussion of Results

The Love wave in the Pittsburgh coal seam had a propagation velocity of 2,429 ft/s with a dominant frequency of 250 Hz. However, the propagation velocity of 2,099 ft/s was used in the void location plots. This is due to the average value calculated from the transmission tests and direct arrivals of the reflection tests. The mapping error of the void location was ± 15 feet for the field tests. The recorded waveforms present well defined Love waves.

CONCLUSIONS

The work in Phase 2 has been successful in detecting mine voids when a void is parallel to the sensor array. Reflected waves from mine voids were detected at three different, bituminous coal mines in very different geologic settings. However, the elliptical mapping technique used by the team needs further refinement if it is to be used to predict the location of voids more precisely. Although the project team claims an accuracy of ± 20 feet for void detection, MSHA could not fully confirm this precision based solely on the test data. Additional developments in the area of data analyses and modeling should be completed to make the technique more useful and applicable in void detection in advance of mining. In addition, it would be beneficial to determine the maximum range over which the technique would be useful, since the short distances tested may have limited applicability to actual mining situations.

The optional second year contract of Phase 2 was not exercised and the project has been completed as of September 30, 2008. All the expenses for the first year of Phase 2 have been paid. Further developmental works, which may lead to practical application of this technique, are beyond the scope of this project.

cc: M. Hoch - Chief, PSHTC
G. Gardner - TS

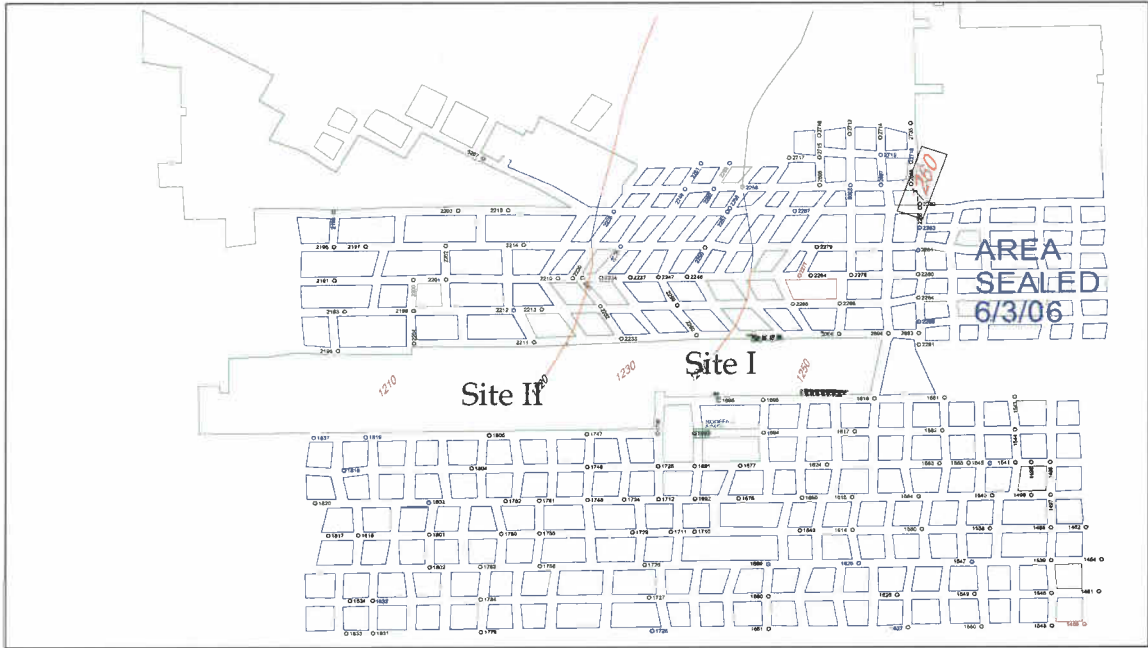


Figure 1: Nolo Mine Test Sites

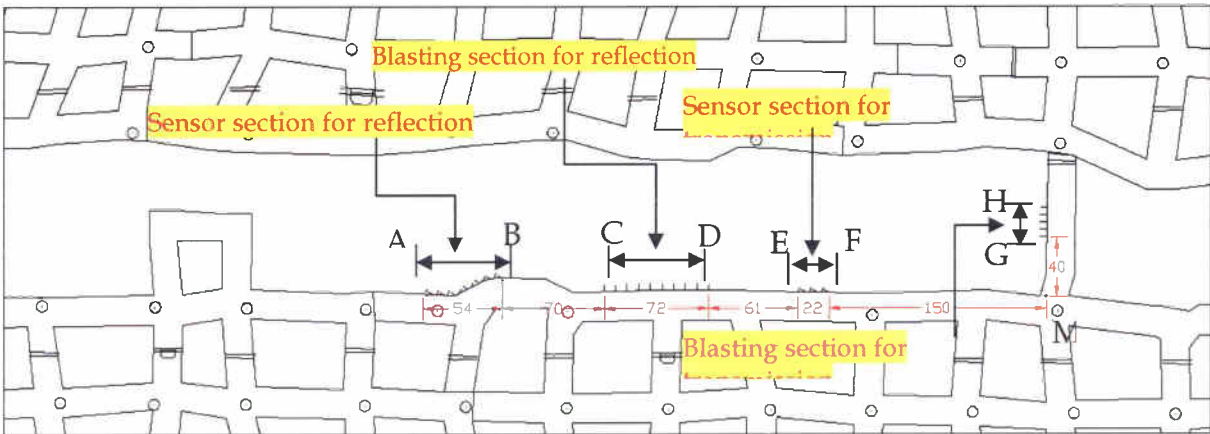


Figure 2: Black King Mine Test Site

