west virginia department of environmental protection

Office of Explosives and Blasting
601 57th Street SE
Charleston, West Virginia 25304
Phone (304) 926-0464

Earl Ray Tomblin, Governor
Randy C. Huffman, Cabinet Secretary
dep.wv.gov

December 30, 2011

Mr. Aaron Allred
Joint Committee on Government Finance
Building 1, Room 132-E
Charleston, WV 25305

RE: Annual Report of Research

Dear Mr. Allred:

In compliance with West Virginia Code §22-3A-10, please accept the enclosed annual report of research conducted by the Office of Explosives and Blasting (OEB). As mandated, the research focuses on the development of scientifically based data and recommendations.

Please contact me if you, or members of the committee, have questions or need further explanation of the enclosed report.

Sincerely,

David L. Vande Linde, Chief
Office of Explosives and Blasting

# Report of Studies Being Considered and Conducted by West Virginia Department of Environmental Protection Office of Explosives and Blasting December 31, 2011

This report is being submitted by the Office of Explosives and Blasting (OEB) to the Joint Committee on Government Finance in accordance with the requirement of Chapter 22, Article 3A, Section 10(b). Below is a summary of the various research projects OEB is currently working on, or may work on in the future. Some of these studies will continue throughout 2012 and some will not conclude until 2013 or later. The studies that will be presented for peer review in 2012 will be discussed in next year's annual report. The status of the various projects is discussed below.

## Airblast Predictability

In 2009, OEB started research dealing with the predictability of airblast by acceptable methods using data related to blasts at surface coal mines in West Virginia. Air Blast, as defined under the West Virginia Surface Coal Mining and Reclamation Act Title 199-2.2, is "an air-born shock wave resulting from the detonation of explosives" and is measured by specially designed blasting seismograph microphones in pounds-per-square-inch (psi) and reported in decibels (dB). Airblast can be an adverse effect of blasting. Typically, adverse effects of blasting are associated with ground vibrations and the related damage potential. The OEB receives many complaints from citizens that their homes are being shaken by blasting. Upon investigation, it has often been determined that blasting ground vibrations should not be the cause of the complaints and that the complaints are more likely airblast related. This observation, coupled with increased incidents of airblast violations, led OEB to examine the predictability of airblast and to reconsider current seismograph monitoring requirements.

This study is evaluating the various methods of airblast prediction. The United States Bureau of Mines (USBM) developed scaled distance factors for ground vibrations; these are used to regulate blasting in West Virginia. These regulations are intended to protect low-rise residential structures from blast damage caused by ground vibration. The USBM also established a relationship for predicting airblast by modifying this scaled distance equation using the cube root function of the explosive charge rather than a square root function. This cube-root scaled-distance equation has never been written into federal or OEB blasting regulations. Predictive airblast equations are generally reliable if good blasting techniques are followed. Undetected geological conditions and atmospheric conditions can have adverse effects on the airblast propagation from well-designed shots.

Both Federal and West Virginia blasting laws require periodic monitoring to ensure blasting operations are not exceeding the maximum allowable limits on airblast. These monitoring requirements are detailed in the blast plan submitted by the permittee and approved by OEB. The frequency of the monitoring may vary from plan to plan, but must be conducted at least once per quarter.

The use of the scaled distance equation for compliance on ground vibration does not consider airblast regulations and airblast effects on citizens. When investigating blasting complaints, it is difficult to forensically determine the actual blast parameters and offsite effects in the absence of seismograph monitoring. There can be blowouts or lightly burdened shots that create high airblast that will go undocumented in the absence of seismograph monitoring.

In the process of evaluating blast performance, it is necessary to review blasting plans and practices for remediation of a high airblast event. This can be very difficult if all the parameters needed to evaluate the blasting are not adequately documented for each shot. The design, location, and performance of the shot, along with detailed local weather conditions, are needed to use the predictive airblast equations for evaluation. Preliminary review of the data collected appears to show that inclement weather alone can cause an airblast increase of 6-12 dB versus blasting on a clear weather day.

Based on preliminary review of project's data, it appears that airblast may merit more comprehensive monitoring at the onset of blasting for a new permit to effectively determine the baseline effects of airblast from the permit. The field work was concluded in 2010 and we are currently awaiting peer review of the draft report on those findings.

In 2011, airblast data was collected at various additional mines to verify the applicability of the 2009-10 preliminary findings. This 2011 data is currently being analyzed and a draft report is expected to be sent out in 2012 for peer review.

## Autonomous Crack Measurement

Although Autonomous Crack Measurement (ACM )was mentioned in the 2010 Legislative report, the project was not conducted by the primary investigator, Chuck Dowding, due to the lack of funding for his project.

## Comparisons Electronic Detonators vs. Conventional Pyrotechnic Delay Detonators

A study is being funded by OSM and conducted by Dr. Braden Lusk, a professor at the University of Kentucky. The purpose of the study is to evaluate the performance of electronic detonators as compared to conventional non-electric pyrotechnic delay detonators at a West Virginia coal mine. OEB provided three of the ten seismographs being used in the study and assisted the research team in dealing with mine personnel, as well as deployment locations and installation of seismographs.

Typically, conventional detonators have inherent errors commonly referred to as "cap scatter." This cap scatter error can be as high as +/- 10% of the designed millisecond (ms) delay interval of the detonator (blasting cap). Electronic detonators use relatively new technology and manufacturers claim low cap scatter (less than 1 percent of their millisecond delay). Apparently, no independent studies have been conducted to substantiate this claim.

The first phase of this project involved controlled measurement of pyrotechnic and electronic cap scatter while concurrently developing a baseline of data by monitoring of non-electric blasts to get vibration parameters for the blast area at a WV coal mine.

The second phase of the project involved planning various shots using different timing configurations with electronic detonators, and compiling ground vibrations and fragmentation data and comparing the electronic blasts to the blast data collected using non-electric pyrotechnic detonators.

The third phase of the project plans to design blasts with delay intervals of less than 8 milliseconds. Blasting regulations and the industry have long held the standard of timing blasts and evaluating blast vibrations based on 8 millisecond delay intervals for pyrotechnic detonators. The critical component of comparing these detonators will be to maintain consistency of blast parameters, i.e. burden, spacing, product usage, and other blast conditions.

OEB is not responsible for gathering or analyzing the data collected, however, OEB will receive the data collected along with the final research report. When Dr. Lusk or OSM publish the report for this research it will be made available.

## Residential Structure Response to Excessive Ground Vibration and Airblast

In September 2010, a rare opportunity to monitor blasting effects on a low-rise residential structure where vibration levels would exceed regulatory limits was made available to OEB. The unoccupied residential structure was located on a surface coal mine near Morgantown, WV. The permittee purchased the residence as mining approached it. The structure was to be dismantled and removed as the mining advanced through the area.

Blasting vibrations are measured by specially designed seismograph geophones that measure vibration in three mutually perpendicular directions and report the results as a particle velocity wave-form. Federal and WV laws regulate the maximum allowable level of vibration to prevent damage to structures. In this study, OEB hoped to document the house response to excessive vibration, calculate the strain induced to the walls of the house, and document blast damage and tie the damage to specific levels of blast vibration.

The house was a sound, one-story residential structure approximately 60 years old and similar to many dwellings near WV surface mines. OEB reviewed the pre-blast survey conducted by the permittee and conducted a follow up pre-blast survey inside and outside the house to document existing imperfections, i.e. cracks, hanging wallpaper, etc. OEB began monitoring the house response by placing seismographs inside and outside the house to record blasting vibrations and to document the effects. Seismograph geophones were mounted on interior walls to measure corner and mid-wall structural responses relative to the outside blast vibration. OEB conducted periodic inspections of the house to document changes in the structure due to the blasting and to collect data from the monitoring equipment.

A report of the study's findings will be drafted in early 2012 and sent out for peer review.

OEB is hoping to find a surface coal mine where the permittee owns an occupied dwelling or an unoccupied structure near its planned blasting operations that could provide an opportunity for more extensive research of structure response to blasting. Academia from several universities have shown interest in a possible multiyear joint project involving structural response research. Discussions with mining companies and various universities, as well as the search for a suitable site are ongoing.

## Future Project

## Influences of Geophone Coupling on Seismograph Monitoring

Blasting vibrations are measured by specially designed seismograph geophones that measure vibration in three mutually perpendicular directions and report the results as a particle velocity wave-form in inches-per-second. Federal and WV laws regulate the maximum level of vibration to prevent damage to structures.

In 2008, OEB assisted Dr. Cathy Aimone-Martin in an OSM sponsored study monitoring surface mine blasts at multiple mine sites in West Virginia. The purpose of this study was to investigate the influence of geophone placement and orientation on seismograph recordings. OEB assisted by providing field support but did not control the accumulation of the data. No final report has ever been published on this project.

Therefore, OEB will be conducting a project that will revisit the different geophone mounting methods, and the variance of vibration recordings resulting from those methods. The goal will be to conduct this type of field research and produce a report. In order to ensure consistent recording between different seismographs, the *ISEE Field Practice Guidelines for Blasting Seism*ographs – 2009 Edition has been adopted by most users as the main guide for seismograph deployment.

The Aimone-Martin study used four seismographs located side-by-side with various geophone coupling methods and these seismographs were located only a few feet apart to monitor blasts. The four methods of monitoring were: placement of the geophone on the surface without spikes; surface mounting with spikes; surface mounting with spikes and a sandbag; and burying the geophone with spikes. This monitoring was conducted for several blasts at several different mines to document the effect of geophone coupling on ground vibration readings. The intent was to strategically place the monitoring units so as to record readings in a vibration range of 0.2 to 0.8 inches per second. This should be the range of blast vibrations for most coal mine blasting operations.

OEB has completed the preliminary stage of the study that was deemed necessary before beginning the field measurements of the different geophone mounting methods. This preliminary stage of the study gathered baseline data on 5-6 geophones mounted identically side-by-side in the preferred manner, which is both buried and spiked. Research procedures are being formulated to mount six geophones next to each other; four to be mounted as in the Aimone-Martin study, with the addition of one mounted on the surface sandbagged without spikes, and one with the geophone buried without spikes. This project is scheduled for data acquisition in 2012 and final report in 2013.