Evaluation of Roof Bolting Requirements Based on In-Mine Roof Bolter Drilling

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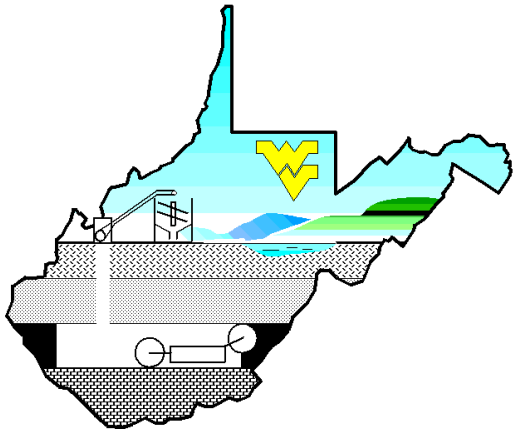

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DISCLAIMER

ABSTRACT

In this quarter, the field, theoretical and programming works have been performed toward achieving the research goals set in the proposal. The main accomplishments in this quarter included: (1) laboratory tests have been conducted, (2) with the added trend-line analysis method, the accuracy of the data interpretation methodology will be improved, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (3) about one half of the development work for the roof geology mapping program, MRGIS, has completed.

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Research Objectives

Roof bolting is the most popular method for underground openings in the mining industry, especially in the bedded deposits such as coal, potash, salt etc. In fact, all U.S. underground coal mine entries are roof-bolted as required by law.

However, roof falls still occur frequently in the roof bolted entries. The two possible reasons are: the lack of knowledge of and technology to detect the roof geological conditions in advance of mining, and lack of roof bolting design criteria for modern roof bolting systems.

This research is to develop a method for predicting the roof geology and stability condition in real time during roof bolting operation. Based on such information, roof bolting design criteria for modern roof bolting systems will be developed for implementation in real time.

For the prediction of roof geology and stability condition in real time, a microprocessor will be used and a program (ROOFSTAB) developed to monitor the drilling parameters. These parameters include thrust, penetration rate, rotation torque, rotation rate, drill position, and vacuum condition. At the same time, rock cores will be obtained a borehole drilled immediate next to bolt hole for the determination of the mechanical properties and structure of the rock strata within the bolting horizon. A relationship or relationships will be established between these drilling parameters and the mechanical and structural data of the roof strata. A roof bolter control system will be developed to monitor these drill parameters. For the development of ROOFSTAB drilling parameters will be obtained from four different coal seams in four mine sites. With this information, a computer program will be developed for use in conjunction with the roof bolter for real-time prediction of strata mechanical properties and structures in roof strata within the bolting horizon.

For the development of roof bolting design criteria, numerical simulations will be performed to investigate the mechanisms of modern roof bolting systems including both the tension and non-tensioned (or fully grouted) bolts. Parameters to be studied are: bolt size/strength, bolt length, bolt spacing, grout annulus and length, and roof geology (massive strata, fractured, and laminated or thinly-bedded). The results of these experiments will be analyzed to develop a roof bolting criterion or criteria program (ROOFBOLT) that will be combined with the ROOFSTAB for use in conjunction with roof bolt installation.

The following main tasks are to be performed for achieving the proposed research objectives:

A. Development of Operator Control Technology for Monitoring Roof Bolter Drill Operations Parameters.
B. Laboratory and Underground Testing.
C. Drill Parameters Data Analysis and Correlation with Roof Stability Conditions Software Development for Mapping of Roof Geological Conditions
D. Laboratory Tests to Investigate the Mechanisms of Roof Bolting Using Simulated Materials
E. Development of Roof Bolting Design Criteria for Implementation in Primary Roof Bolting Cycle

Experimental

In this quarter, laboratory tests have been conducted on the simulated rock layer and fracture blocks at the facility of the Fletcher Company, Huntington WV. The purposes of these laboratory tests included:

- To verify findings from field experiments. To account for the changes that have been made to the hardware and software of the roof bolter in the last one and half years. Since the last laboratory tests in 2002, the hardware and software of the roof bolter dedicated to the research have gone through a number of modifications. Some of the modifications have affected the drilling parameters. The effects of such modifications on the data processing and interpretation should be characterized through laboratory tests.
- To optimize the drilling operating parameters that can yield better data interpretation. The field and laboratory tests have shown the distributions of the resulting drilling parameters are more clearly discernable, thus better for data interpretation, if only the penetration rate is controlled and set to be high. These laboratory tests are also served to determine the optimum drilling operating parameters that would produce better data for more accurate interpretation of geological features.

Fig. 1 Laboratory Test Setup

Results and Discussion

1. Development of Data Interpretation Methodologies

The development of data interpretation methodology is still continuing in this quarter. Among the works performed, a new trendline analysis method has been developed and will be incorporated with the original approach to make the data interpretation more reliable.

The derived thrust and torques trendlines are to be used in the determination process for rock strengths to reduce the errors introduced by the noises in the original data to improve the accuracy.

It seems that the torque to thrust ratio can be used as an indicator for the rock relative hardness and for identifying locations of fractures and voids.

2. Exploring the Roof Bolting Mechanisms

In studying the mechanisms involved in roof bolting, three-dimensional finite element models for simulating the tensioned bolt have been developed and refined. Two-dimensional finite element models for simulating the fully grouted resin bolts have also been developed and refined. The effects of sliding and separation of bedding planes have been considered in these models. Based on the numerical modeling results, the design criteria for tensioned and fully grouted resin bolts are being developed. The yielding zone developed over the entry can be used to determine the bolt length, the magnitude of plastic strain can be used to judge the roof local stability, and the stress distribution around the entry and bolt load are also used to check roof stability.

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3. Development of On-Board Data Visualization and Database Program

The development of a computer program, Mine Roof Geological Information System (MRGIS), to display the original and derived drilling parameters, the estimated rock strengths and geological structures in the bolting horizon in 2-D and 3-D is continuing in this quarter. The program is a Windows-based stand-along database PC program. It provides an engineer-friendly working environment for importing AutoCAD mine map into

this program. It also provides a platform for incorporating the developed data interpretation methods for nearly real-time geological visualization of the strata drilled during the roof bolting operation. A technical paper detailing MRGIS "Mine Roof Geological Information System (MRGIS)" has been prepared for publication and presentation at the 22nd International Conference on Ground Control in Mining to be held August 5-7, 2003.

CONCLUSIONS

The project proceeds well as proposed. The status of various tasks is listed in Table 1. The main accomplishments in this quarter included: (1) laboratory tests have been conducted, (2) with the added trendline analysis method, the accuracy of the data interpretation methodology will be improved, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (3) about one half of the development work for the roof geology mapping program, MRGIS, has completed.

Table 1. Progress on Planned Tasks

Planned Milestone	*Scheduled*	*Completed*
Development of operator control technology	**09/01/01**	**completed**
Laboratory and underground testing	**12/31/01**	**90% completed**
Drilling parameter data analysis and correlation	**10/01/03**	**80% completed**
Software development for mapping of roof conditions.	**10/01/03**	**70% Completed**
Computer modeling to investigate the mechanisms	**10/01/03**	**80% completed**
Development of computerized bolting design system	**10/01/03**	**50% completed**

Reference

Peng, S.S., D. Tang, B. Mirabile, Y. Luo and G. Wilson, "Mine Roof Geological Information System (MRGIS)," Proc. 22nd International Conference on Ground Control in Mining, Morgantown, pp. 129 – 135.