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

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Quarterly Technical Progress Report

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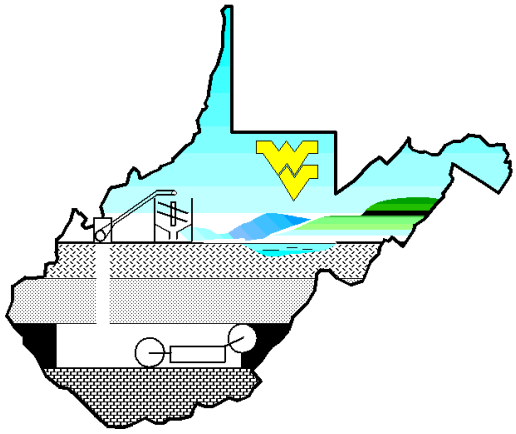

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DISCLAIMER

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 and the interfaces and voids can be more reliably detected, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (3) about 80% 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, a number of 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 test the new approaches in data interpretations
- To examine the range of the variations of the roof bolter due to the changes made in its hardware and software.

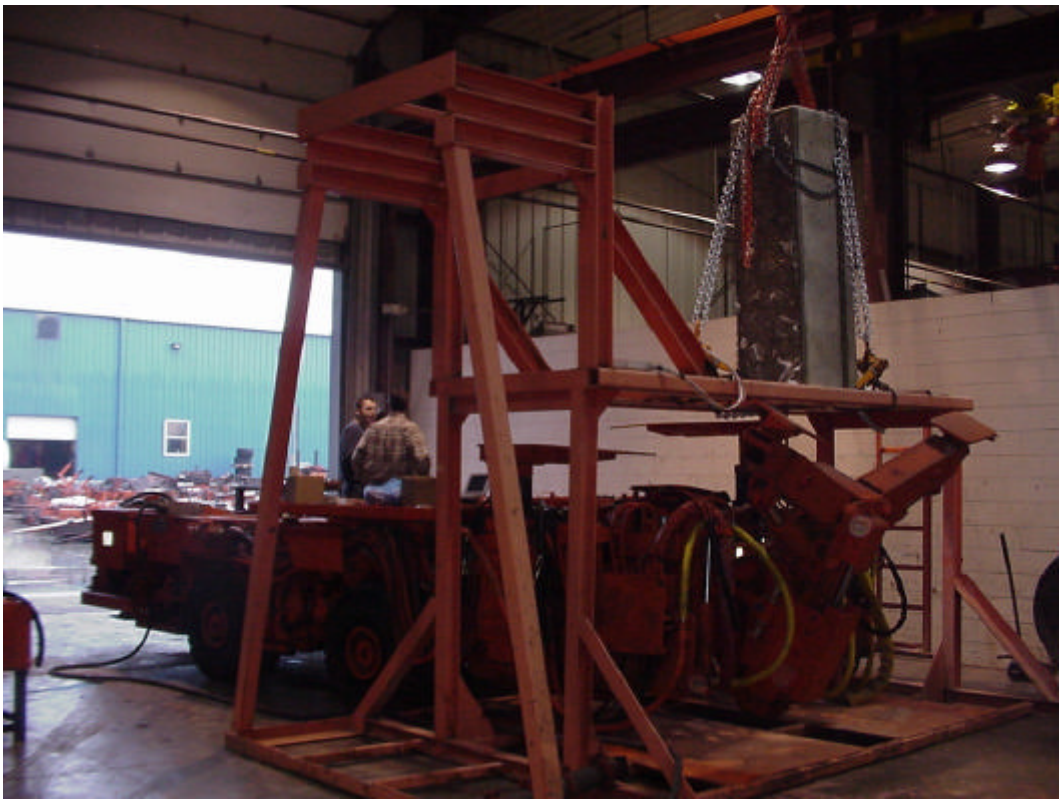

Fig. 1 Laboratory Test Setup

Results and Discussion

1. Development of Data Interpretation Methodologies

The development of data interpretation methodology is still continuing in this quarter. Development of the systematic and mechanics-based approach for interpreting the drilling parameters is continuing. A new trendline analysis method to filter out the extreme points that are results of data noises and errors has been developed. The derived trendlines for thrust, torques, penetration and rotational rates are used in the determination process for rock strengths to improve the accuracy. It shows that incorporating this trendline method with the original mechanical approach to make the data interpretation

more reliable. Another benefit of using the trendline method is that it is capable of more positively identify the fractures/voids in the strata.

A method to use torque to thrust ratio as indicator of relative rock hardness and to identify the fractures and voids has also been developed and tested. It seems that torque/thrust ratio is a good indicator for relative rock hardness based on the testing results.

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 and to display the interpretation results for easy comprehension. 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. Using the roof geology information, the suitability of the current roof bolting design will be assessed.

The commercialization of the research results is also under way. A special version of the geology mapping program for roof bolters in limestone mine is in development per the request from the J.H. Fletcher & Co.

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 and the interfaces and voids can be more reliably detected, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (3) about 80% 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**	**95% completed**
Drilling parameter data analysis and correlation	**10/01/03**	**85% completed**
Software development for mapping of roof conditions.	**10/01/03**	**80% Completed**
Computer modeling to investigate the mechanisms	**10/01/03**	**90% completed**
Development of computerized bolting design system	**10/01/03**	**70% completed**