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

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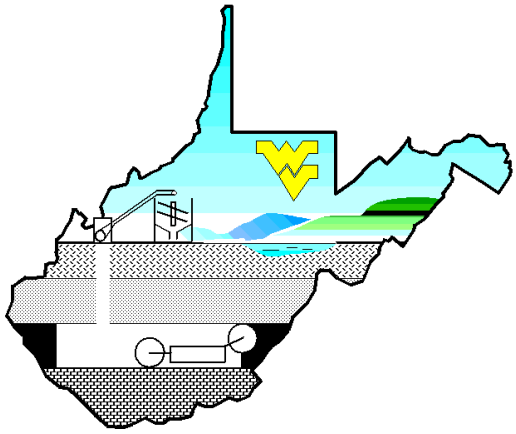

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DISCLAIMER

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) one more field test has been conducted in an underground coal mine, (2) optimization studies of the control parameters have been conducted, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (3) about 98% of the development work for the roof geology mapping program, MRGIS, has completed, (4) A real time roof geology mapping system for roof bolters in limestone mine, including a special version of the geology mapping program and hardware, has already been verified to perform very well in underground production condition.

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Executive Summary

This research is to develop a method for identifying the geological features in the mine roof strata in real time during roof bolting operation. Based on such information, better decision on roof bolting can be made to reduce the risks of roof falls.

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. One more field test has been conducted in an underground coal mine where roof strata within the drilling horizon were consist of sandstone. The purposes of this test were to verify and/or modify the interpretation methods and the new mapping software as considering the impacts of characteristics and conditions of the roof bolter itself on drilling parameters.
2. Optimization studies of the control parameters have been conducted to determine the best combination of the control parameters (i.e., penetration rate, rotational rate and thrust cap) that can produce more accurate interpretations.
3. About 98% of the development work for the roof geology mapping program, MRGIS, has completed.
4. A mine roof geology mapping system has been successfully developed. This system consists of a special version of Mine Roof Geology Information System (MRGIS) and a compact touch screen computer installed on a production roof bolter in a limestone mine. This system has already been verified to perform very well in underground production condition.
5. One technical paper has been prepared for the presentation and publication in the proceedings of 2005 SME Annual Meeting to be held on Feb. 28-Mar. 2, 2005, Salt Lake City, Utah.

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

- *Field Tests*
  - In this quarter, one more field test has been conducted in an underground coal mine in southern West Virginia where hard sandstone roof strata were presented in the roof bolting horizon. The purposes of the tests were: (1) to make it clear how much effect the characteristics and conditions of the dedicated roof bolter for this research have on the drilling parameters, (2) to confirm the repeatability, and (3) test the real-time geological mapping software developed so far. The locations of the drill holes are shown in Fig. 1.
  - Both the penetration and rotational rates were controlled at various levels during these tests. The thrust was also been capped at a number of levels.

- *Optimization of Drilling Control Parameters Studies*
  - Optimization of the drilling control parameters for the purposes of
    - Improving the drilling productivity under safe operation

- Improving the accuracy and resolution of the geology interpretation using the data.

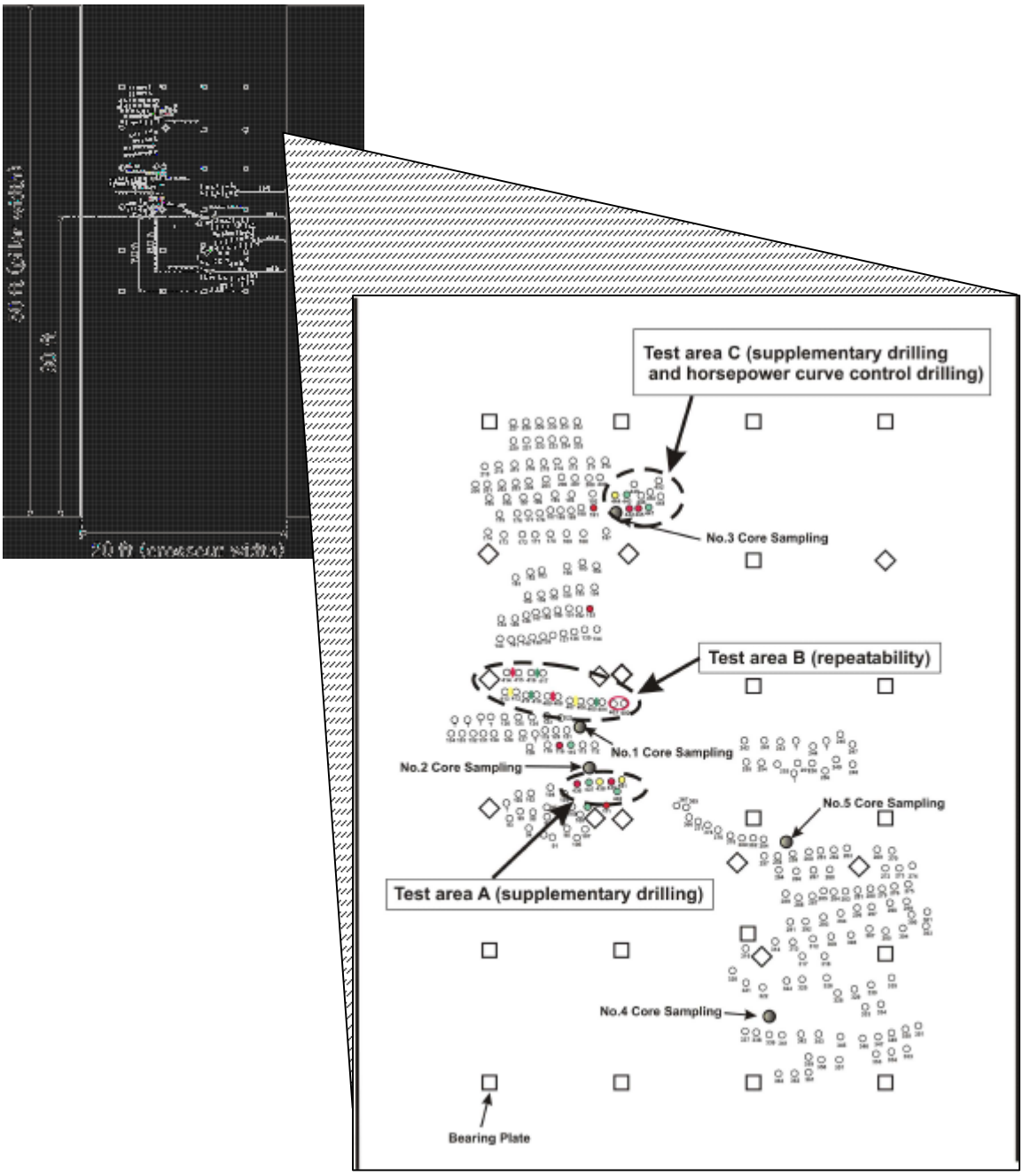

Fig. 1 Location of Drill Holes at Test Site
(An underground coal mine, WV, December 6, 2004)

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 method to use torque to thrust ratio as an indicator of relative rock hardness has also been developed and tested. It seems that torque/thrust ratio is a good indicator for relative rock hardness especially when feed pressure is kept constant.

As to improve the accuracy of the geology interpretation, it was made clear in detail how much impact the dedicated roof bolter itself has on drilling parameters under different conditions and settings. Repeatability was also verified.

2. Exploring the Roof Bolting Mechanisms

Finite element method has been used to explore the mechanisms of tensioned and resin roof bolts in enhancing the roof strata. Most of the work in this stage has been completed. One technical paper on the roof bolting mechanisms will be presented at and included in the proceedings of 2005 SME Annual Meeting to be held on Feb. 28-Mar. 2, 2005, Salt Lake City, Utah.

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.

A real time roof geology mapping system for roof bolters in limestone mine, including a special version of the geology mapping program and hardware, has already been verified to perform very well in underground production condition.

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) one more field test has been conducted in an underground coal mine, (2) optimization studies of the control parameters have been conducted, (3) method to use torque to thrust ratio as indicator of rock relative hardness has also been explored, and (4) about 98% of the development work for the roof geology mapping program, MRGIS, has completed, (5) a real time roof geology mapping system for roof bolters in limestone mine, including a special version of the geology mapping program and hardware, has already been verified to perform very well in underground production condition.

Fig. 2 Special Version of MRGIS Program
in an Underground Limestone Mine

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	98% completed
Drilling parameter data analysis and correlation	10/01/03	96% completed
Software development for mapping of roof conditions.	10/01/03	98% Completed
Computer modeling to investigate the mechanisms	10/01/03	100% completed
Development of computerized bolting design system	10/01/03	95% completed

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