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A Method to Characterize Risk Associated With Mine Roof Conditions

Objective

To characterize the roof fall risk associated with underground limestone mining.

Background

During the first 5 years of this decade, more than one-fourth of the underground mining fatalities occurred as the result of fall of ground. The large openings in underground stone mines present limitations in observing ground conditions because of floor-to-roof heights ranging from 20 to 60 ft or more. Generally, the status of ground conditions in underground stone mines is based on observation and experience obtained during mining development. Some mines use monitoring instruments to gain information on roof conditions, but this practice is typically focused and localized to address issues in a particular area or section of the mine.

The Roof Fall Risk Index (RFRI) described here provides a method of systematically characterizing the risk of roof falls to enhance the safety of mine workers.

Approach

As in many industries, a defective product signals the potential for failure. Similarly, defective rock or strata in an underground stone mine presents a potential risk. Assessing ground conditions relative to the concentration of defects observed provides a way to index or rate these conditions and the subsequent risk. Through observations at approximately 50 underground limestone mines in the United States, strata defects were categorized to develop a quantitative method for determining the RFRI. This method is specifically geared to underground limestone mines because strata defects are difficult to see and limited by the experience and knowledge of the observer. Overall, 10 defect categories were determined: 3 that relate to geology, 4 that result from mine development, 2 that are indicative of the roof profile, and 1 that addresses moisture or water flow (see RFRI Chart 1). The defect categories are also weighted to reflect the conditions indicative of roof or strata movement or separation (categories 4 through 8). These weights are multiplied by the assessment value to determine the total category value. The benefit of using monitoring techniques to gain information on roof conditions is also factored into the RFRI for overall assessment of an area in the mine. Each defect category is assessed with a value of 1 to 5 based on parameters as defined in each defect category, with 5 indicating the highest degree or level of defect. The assessment value of 3 is also used when information on a parameter is unknown. The parameters for the defect categories are illustrated in RFRI Chart 2 for use in determining the assessed value.

How It Works

The RFRI provides a means to categorize the risk for roof falls in underground stone mines. The concept of this calculation is aimed at providing an indication of the level or degree of defect relative to the area of the mine examined. The RFRI for the calculation produces a distribution where RFRI values approaching 0 represent a stable condition and those approaching 100 represent an unstable condition.

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To calculate the RFRI in your mine, simply assess the defect categories by parameter, multiply by the weight, add the category values (as shown at the bottom of RFRI Chart 1), and multiply by 1.11. Two factors make it necessary to develop ways to adjust RFRI values: (1) all underground mines have conditions that are unique, and (2) additional information about local strata conditions is sometimes available. As additional experience is gained, it may be necessary to amend the list of defect categories, adjust category weights, or change category assessment values. For example, if microseismic or roof deformation monitoring data are available, these data can be used to adjust the RFRI, as shown at the bottom of RFRI Chart 1. Other factors such as roof support would also impact the RFRI.

Summary

NIOSH research in underground stone mines has provided the framework for developing an RFRI. This method is centered on examining the defects contained in the roof caused by a wide range of local geologic, mining, and stress factors. The RFRI is based on observations and should be considered part of an overall strategy deployed by mining operations to assess the risk of roof falls. Clearly more information leads to less uncertainty and potentially reduces the risk associated with ever-changing mining conditions. NIOSH's aim is to develop a method to help mine safety personnel identify and track changing roof conditions.

The RFRI is an assessment technique that can be used to rate roof fall risk in important parts of a mine or potentially the entire mine property. It should also be viewed as a powerful communication tool that helps to track changes in roof conditions. In addition, it can be used as a training method to help less experienced miners identify defective rock conditions. Lastly, decision-makers can use the RFRI to examine changes in mining conditions and to help develop plans for proactive actions during the course of mine development.

To increase the use of the RFRI, NIOSH will provide a full-sized laminated card containing RFRI Charts 1 and 2 so it can readily be used in an underground mine. See "For More Information" below on how to obtain an RFRI card for your mine.

Accomplishments

The RFRI was introduced at the annual meeting of the Society for Mining, Metallurgy, and Exploration in St. Louis, MO, on March 26–29, 2006. An update on the RFRI was presented at the 25th International Conference on Ground Control in Mining in Morgantown, WV, on August 1–3, 2006. The published papers for these presentations are listed below and are available upon request:

Iannacchione AT, Prosser LJ Jr., Esterhuizen GS, Bajpayee TS [2006]. Assessing roof fall hazards for underground stone mines: a proposed methodology. SME preprint 06–059. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Iannacchione AT, Esterhuizen GS, Schilling S, Goodwin T [2006]. Field verification of the roof fall risk index: a method to assess strata conditions. In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Khair AW, Heasley KA, Luo Y, eds. Proceedings of the 25th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 128–137.

For More Information

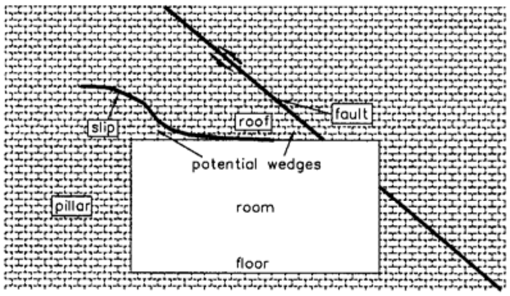
For more information on the Roof Fall Risk Index (RFRI) or to obtain a full-sized laminated RFRI card, contact Lou Prosser (412–386–4423, LProsser@cdc.gov), or Anthony T. Iannacchione, Ph.D., P.E. (412–386–6581, AIannacchione@cdc.gov), NIOSH Pittsburgh Research Laboratory, P.O. Box 18070, Pittsburgh, PA 15236–0070.

RFRI Chart 1.—Defect categories for determining the RFRI in underground stone mines

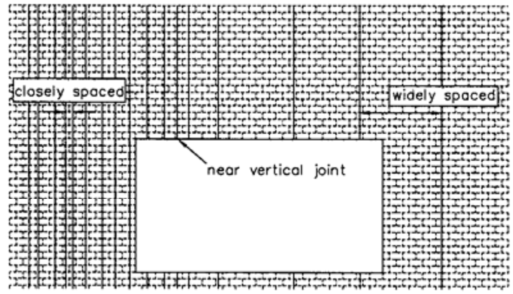
Grouping	Category	Parameter	Assessment Value	Weight	Category Value
Geologic factors	1 – Large angular discontinuities	None	1	1	
		One strong contact	2		
		One weak contact	3		
		More than one strong contact	4		
		More than one weak contact	5		
		Unknown	3		
	2 – Joint frequency	None	1	1	
		Widely spaced (>3 ft)	2		
		Moderately spaced (1–3 ft)	4		
		Closely spaced (<1 ft)	5		
		Unknown	3		
	3 – Roof layer thickness and bedding contact strength	Massive (>3-ft layers)	1	1	
		Strong bedding contacts in immediate roof (0–3 ft)	2		
		Weak bedding contact(s) in immediate roof (0–3 ft)	3		
		Rock layers 1–3 ft with weak bedding contact(s)	4		
		Thin layers (<1 ft) with strong bedding contact(s)	4		
		Thin layers (<1 ft) with weak bedding contact(s)	5		
		Unknown	3		
Mining-induced failures	4 – Shear rupture sur-face(s)	None	1	2	
		Small shear (cutter <3 ft)	3		
		Large shear (cutter >3 ft)	5		
		Unknown	3		
	5 – Joint sepa-ration	None	1	2	
		Noticeable or measurable	5		
		Unknown	3		
	6 – Lateral strata shifting	None	1	2	
		<1 inch of offset or partial vertical drill hole offset	3		
		>1 inch of offset or complete vertical drill hole offset	5		
		Unknown	3		
	7 – Vertical strata separa-tion	None	1	2	
		Slight (barely detectable)	3		
		Significant (>0.2 inch)	5		
		Unknown	3		
Roof profile	8 – Roof rock debris on floor	None	1	2	
		Slight (widely spaced)	2		
		Moderate	4		
		Significant (continuous)	5		
		Unknown	3		
	9 – Roof shape	Smooth	1	1	
		Intermediate	3		
		Rough	5		
		Unknown	3		
Moisture factors	10 – Moisture/ ground water inflow	None	1	1	
		Damp roof	2		
		Drippers	4		
		Steady flow	5		
		Unknown	3		
Sum of all category values …………………………………………					
Multiply by 1.11 …………………………………………					
Microseismic activity adjustment: No microseismic clustering, subtract 5; clustering, add 25; 0 if unknown …………………………					
Roof deformation rate adjustment: No roof deflection movement, subtract 5; constant deflection, add 15; accelerating deflection, add 30; 0 if unknown …………………………					
RFRI …………………………………………					

RFRI Chart 2. —Illustrations of parameters associated with the 10 defect categories.

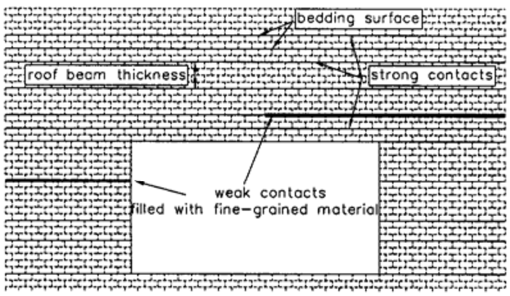
No. 1 – Large angular discontinuities



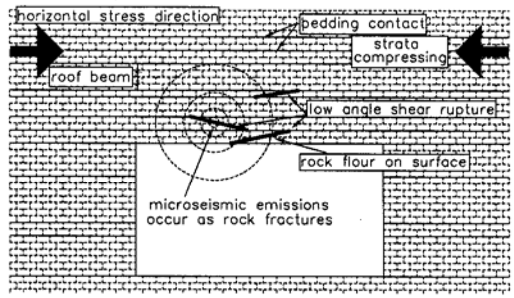
No. 2 – Joint frequency



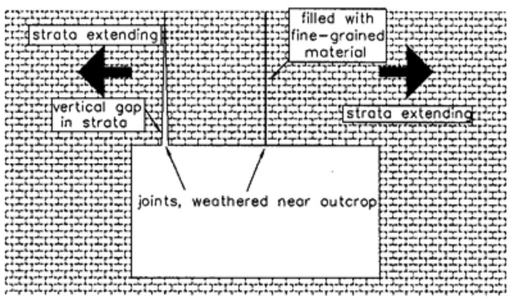
No. 3 – Roof layer thickness & bedding contact strength



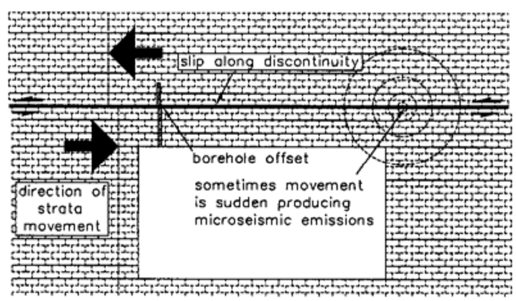
No. 4 – Shear rupture surface(s)



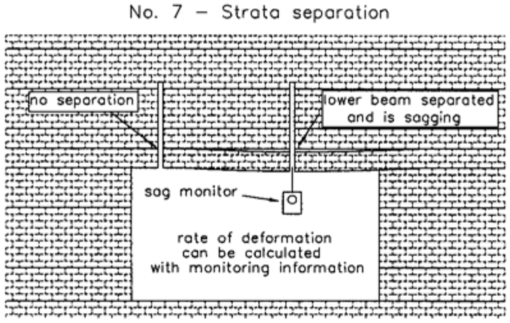
No. 5 – Joint separation



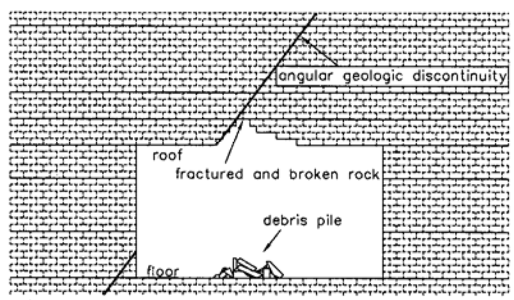
No. 6 – Lateral strata shifting



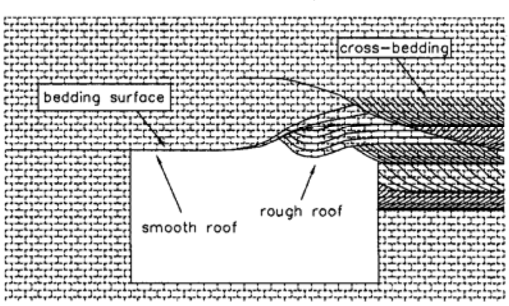
No. 7 – Strata separation



No. 8 – Roof rock debris on floor



No. 9 – Roof shape



No. 10 – Moisture/Ground water inflow