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Proceedings: New Technology for Ground Control in Retreat Mining

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PROCEEDINGS: NEW TECHNOLOGY FOR GROUND CONTROL IN RETREAT MINING

Compiled by Christopher Mark, Ph.D.,[1] and Robert J. Tuchman[2]

ABSTRACT

This proceedings volume contains papers presented at technology transfer seminars sponsored by the National Institute for Occupational Safety and Health (NIOSH) on New Technology for Ground Control in Retreat Mining. The seminars were conducted at five locations: Uniontown, PA (March 26, 1997), Norton, VA (April 8, 1997), Pikeville, KY (April 10, 1997), Charleston, WV (April 17, 1997), and Evansville, IN (April 22, 1997).

The papers presented here describe several new, highly practical technologies developed by the NIOSH Pittsburgh and Spokane Research Centers[3] to improve safety during pillar retreat operations. Two central issues are addressed: pillar design and mobile roof supports (MRS's).

Proper pillar sizing is essential for safe pillar extraction. The Analysis of Retreat Mining Pillar Stability (ARMPS) program and its large data base of actual mining case histories are presented. LAMODEL, a second computer program, can be used for analysis of multiple-seam and other complex mining situations. Other papers address pillar design to avoid massive pillar collapses and the proper role of coal strength testing.

MRS's have greatly improved safety where they are used for pillar line support. We studied the application of MRS's at 20 mines throughout the Eastern United States. Conclusions regarding the most effective section layouts, cut sequences, and support placements are reported. Field and laboratory tests of MRS's are also described.

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[3]The research described in these papers originated under the former U.S. Bureau of Mines prior to transferring to the National Institute for Occupational Safety and Health in 1996.

A STATISTICAL OVERVIEW OF RETREAT MINING OF COAL PILLARS IN THE UNITED STATES

By Christopher Mark, Ph.D.,[1] Frank E. McCall,[1] and Deno M. Pappas[2]

ABSTRACT

The demographics and safety record of the pillar retreat segment of the U.S. coal industry was analyzed using statistics collected by the Mine Safety and Health Administration. Pillar recovery is practiced primarily by mines in Appalachia and the Midwest. Using 1993 data, the accident rates and productivity of a large sample of pillar retreat mines were found to be similar to other room-and-pillar mines in the same geographic areas. Pillar recovery apparently accounts for about 10% of all U.S. underground production, but has been associated with about 25% of the roof and rib fatalities during 1989-96. However, of the 28 fatalities that were analyzed, only 4 occurred for which no citations were issued for violations of mining law. Nearly one-half of the fatal incidents occurred during the mining of the last lift or pushout. All four no-citation incidents occurred during the removal of the last lift during a "Christmas tree" extraction sequence.

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ANALYSIS OF RETREAT MINING PILLAR STABILITY (ARMPS)

By Christopher Mark, Ph.D.,[1] and Frank E. Chase[2]

ABSTRACT

The prevention of pillar squeezes, massive pillar collapses, and bumps is critical to safe pillar recovery operations. To help prevent these underground safety problems, the Pittsburgh Research Center has developed the Analysis of Retreat Mining Pillar Stability (ARMPS) computer program. ARMPS calculates stability factors (SF) based on estimates of the loads applied to, and the load-bearing capacities of, pillars during retreat mining. The program can model the significant features of most retreat mining layouts, including angled crosscuts, varied spacings between entries, barrier pillars between the active section and old (side) gobs, and slab cuts in the barriers on retreat. It also features a pillar strength formula that considers the greater strength of rectangular pillars. The program may be used to evaluate bleeder designs, as well as active workings.

A data base of 140 pillar retreat case histories has been collected across the United States to verify the program. It was found that satisfactory conditions were very rare when the ARMPS SF was less than 0.75. Conversely, very few unsatisfactory designs were found where the ARMPS SF was greater than 1.5. Preliminary analyses also indicate that pillar failures are more likely beneath sandstone roof and that the ARMPS SF may be less meaningful when the depth of cover exceeds 230 m (750 ft).

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PREVENTING MASSIVE PILLAR COLLAPSES IN COAL MINES

By Christopher Mark, Ph.D,[1] Frank E. Chase,[2] and R. Karl Zipf, Jr., Ph.D.[3]

ABSTRACT

A massive pillar collapse occurs when undersized pillars fail and rapidly shed their load to adjacent pillars, which in turn fail. The consequences of these chain-reaction failures can be catastrophic. One effect of a massive pillar collapse can be a powerful, destructive, and potentially hazardous airblast. Thirteen recent massive pillar collapses have been documented in West Virginia, Ohio, Utah, and Colorado. Data collected at the failure sites indicate that all of the massive collapses occurred where the pillar width-to-height (w/h) ratio was 3.0 or less and where the Analysis of Retreat Mining Pillar Stability Factor was less than 1.5. The unique structural characteristics of these pillar systems apparently result in sudden, massive pillar failures, rather than the more common slow "squeezes." The field data, combined with theoretical analysis, provide the basis for two partial-extraction design approaches to control massive pillar collapses. These are the *containment* approach and the *prevention* approach; practical examples are provided of each.

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PILLAR DESIGN AND COAL STRENGTH

By Christopher Mark, Ph.D.,[1] and Timothy M. Barton[1]

ABSTRACT

A comprehensive data base was created that includes more than 4,000 individual uniaxial compressive strength test results from more than 60 coal seams. These data were compared with 100 case studies of in-mine pillar performance from the Analysis of Retreat Mining Pillar Stability (ARMPS) data base.

Statistical analysis found no correlation between the ARMPS stability factor of failed pillars and coal specimen strength. Pillar design was much more reliable when a uniform coal strength of 6.2 MPa (900 psi) was used in all case histories. The conclusion is that laboratory testing should *not* be used to determine coal strength for ARMPS.

Other analyses provided evidence of why laboratory strength does not correlate with pillar strength. The data showed clearly that the "size effect" observed in laboratory testing is related to coal structure. The widely used Gaddy formula, which predicts a significant strength reduction as the specimen size is increased, was found to apply only to "blocky" coals. For friable coals, the size effect was much less pronounced, or even nonexistent. Laboratory tests do not account for large-scale discontinuities, such as roof and floor interfaces, which apparently have more effect on pillar strength than small-scale structure.

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A NEW LAMINATED OVERBURDEN MODEL FOR COAL MINE DESIGN

By Keith A. Heasley[1]

ABSTRACT

In the past, numerous boundary-element models of stratified rock masses have been proposed using a homogeneous isotropic elastic overburden. In this paper, it is postulated that a laminated overburden model might be more accurate for describing the displacements and stresses in these stratified deposits. In order to investigate the utility of using a laminated overburden in a boundary-element model, the fundamental mathematical basis of the laminated model is presented and graphically compared with the fundamental behavior of homogeneous isotropic elastic overburden and with field data. Specifically, the stresses and displacements surrounding an idealized longwall panel as determined from the laminated overburden model are presented and compared with results from the homogeneous isotropic overburden and with measured abutment stress data. Additionally, the remote displacements and surface subsidence as calculated by the laminated overburden model are compared with homogeneous isotropic calculations and with measured subsidence data. Finally, the new laminated boundary-element program, LAMODEL, is used to model the underground stresses and displacements, the topographic stresses, and the interseam interactions at a field site. The results of this investigation show that the laminated overburden is more supple, apt to propagate displacements and stress further, and better able to fit observed data than the classic homogeneous isotropic overburden. Ultimately, it is suggested that the laminated model has the potential to increase the accuracy of displacement and stress calculations for a variety of mining situations.

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RETREAT MINING WITH MOBILE ROOF SUPPORTS

By Frank E. Chase,[1] Allen McComas,[2] Christopher Mark, Ph.D.,[3] and Chester D. Goble[4]

ABSTRACT

Mobile roof supports (MRS's) are shield-type support units mounted on crawler tracks. MRS's are used during retreat mining and eliminate the setting of roadway, turn, and crosscut breaker posts that are required during pillar recovery operations. Mobiles are a more effective ground support than timbers, and their usage enhances the safety of section personnel and reduces material handling injuries. MRS usage is rapidly increasing, and approximately 40 U.S. coal mines have successfully employed this relatively new technology. This paper addresses the practical aspects of MRS usage in underground coal mines.

During this study, nearly one-half of the U.S. mines that have utilized mobiles were visited. This report depicts the more common pillar extraction methods that operators have found successful. The "Christmas tree" and outside lift methods are described and illustrated. Roof control plans that do not require breaker posts or allow pillar extraction with fewer than four mobiles are also examined. In addition, operators' experiences with setting pressures, loads, and rates of loading during pillar extraction are addressed. Mining and support strategies to more effectively control hillseams, weak roof, and gob overrides are also discussed.

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MONITORING MOBILE ROOF SUPPORTS

By Kenneth E. Hay,[1] Stephen P. Signer,[2] Michael E. King,[3] and John K. Owens[4]

ABSTRACT

Researchers from the Spokane Research Center conducted a field study to assess the safety of remotely controlled mobile roof supports (MRS's) in a retreat pillar mining operation. Data were collected to provide the Mine Safety and Health Administration with criteria needed to develop guidelines for MRS use and to determine if precursors could be identified that would alert miners to imminent roof falls.

Two test sites at which two different support methods—MRS's and posts—were used were monitored to obtain information on entry stability. Pressure transducers and string potentiometers were installed on all four MRS's to obtain loading and displacement information. Roof bolt load cells, sonic probes, extensometers, and survey targets were installed in the surrounding entries to obtain information on ground behavior.

Results showed a larger increase in roof bolt loading and roof movement when MRS's were used, especially in the intersection area. Roof bolt loads in the entries showed decreases when the MRS's were set and increases of up to 11.1 kN (2,500 lbf) when the MRS's were unloaded. Unloading of one MRS in a pair did not significantly increase load on the other. MRS's 1 and 2 usually had the higher loads; these loads increased as the pillars on each side were being mined. MRS 3 normally had lower loads than 1 and 2; however, it also experienced some very high loads when in the last position near the pushout. MRS 4 usually had the lowest loads, primarily because it was located near the solid pillar that was not being mined.

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FULL-SCALE PERFORMANCE EVALUATION OF MOBILE ROOF SUPPORTS

By Thomas M. Barczak[1] and David F. Gearhart[2]

ABSTRACT

Two mobile roof supports (MRS's), one manufactured by J. H. Fletcher and Co. and one manufactured by Voest-Alpine Mining and Tunneling, were evaluated under controlled load conditions in the Strategic Structures Testing Laboratory at the Pittsburgh Research Center. A unique load frame, called the mine roof simulator, provided a realistic simulation of mining conditions by inducing vertical, horizontal, and lateral loading on the support. The purpose of these tests was to determine the performance capabilities and limitations of the supports and to investigate factors that influence the measurement of loading and loading rate. An evaluation of the support design and load conditions that can cause support failure or loss of support capacity is presented relative to the laboratory tests. In general, lateral loading perpendicular to the longitudinal axis of the canopy is most severe, although horizontal loading in the direction of the longitudinal axis of the canopy can also produce critical loading is some cases. The tests indicate that both setting force and leg pressure measurement are influenced by the staging of the leg cylinders. The implications of these factors on load rate measurement are evaluated. Differences in design philosophy between the two supports are identified and related to support performance. The difference in leg design, two- versus three-stage, had the most impact on support performance. Safety issues pertaining to support operation and maintenance are also discussed. Lastly, MRS capacity and stiffness characteristics are compared with those of conventional timber supports.

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