Work Practices to Manage Bump Prone Ground

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ABSTRACT

In deep and highly-stressed coal mining, advanced design practices are used to minimize the potential for damaging events to occur. Despite these design efforts, the hazard of coal mine bumps can not be completely eliminated. This paper will review current and historic work practices used internationally to minimize the hazard to miners from mining in conditions which could produce a bump. These site specific work practices have a common base in monitoring for conditions which could result in a bump and application of controls to prevent the occurrence or minimize the severity of an event where miners are working. Monitoring practices range from purely observational to semi quantitative. Control methods attempt to initiate events in a controlled manner, absorb the energy of a potential event or reduce the potential for or magnitude of an event by altering the stress conditions of the mine workings. Building from the experiences of other coal fields, an empirical framework to manage the potential hazard of coal mine bumps can be developed to enhance the level of safety provided by prudent mine design.

INTRODUCTION

Mining-induced seismicity, when it results in damaging events to an operating mine, is also referred to as bumps, bounces, outbursts and rockbursts. These terms all describe the sudden, violent failure of the coal seam or adjacent strata that has resulted in loss of life and property in deep coal mines. Mine design practices strive to minimize the risk of injury to persons and damage to equipment and mine infrastructure from mining induced seismicity. For instance, many Utah mines have replaced bump prone pillars with yielding pillars and one uses inter-panel barrier pillars. Despite theses efforts, the hazard of mine bumps is not completely removed. Local variations in geologic structures and properties, mining practices and coal gas content can increase the risk of a bump event in an otherwise conservative mine design. Controlling this hazard requires a means to identify when and where mining conditions have changed and active measures are needed to reduce excess hazards.

While a number of control systems have been proposed and applied, none have achieved sufficient success in deep western US coal mines to be considered a viable standard practice. For instance, Agapito and Goodrich (1) maintain that “experience with de-stressing in the Utah mines has been limited to a small scale and results have been inconclusive.” Moreover, they point out that the “techniques are unpopular because they are expensive and the bump triggering potential when drilling into highly stressed areas, has caused some injuries in the past.” Iannacchione and Zelanko (2) found five reportable bumps that occurred during destressing operations, the first in the 1950’s.

One of the most systematic applications of hazard reduction methods in western longwall coal mining was conducted by one of the authors at Mid-Continent’s advancing longwall at the Dutch Creek No. 1 mine in Colorado (3). While this program was successful technically, it was not compatible with the production expectations of modern longwall mines. The significant deficit of this program was the reliance on a single, labor intensive method to identify and control potential bump hazards and the need for universal application of the system due to the mine’s design and geologic conditions.

The objective of this paper is to identify means and methods which may be adapted to a targeted approach of reducing residual bump hazard that has been primarily controlled by mine design. While bump hazard management systems must be designed for site specific conditions, the experiences gained in other mines can assist in the development of these programs.

MONITORING METHODS

Key to developing a bump hazard management program is the development of means of assessing changes in mining conditions that indicate a departure from either the foundation of the mine design or the expected response of the ground to mining. Monitoring systems can range from purely observational to active probing of the coal and adjacent strata. Following are techniques which have successfully identified high hazard areas or have otherwise revealed information that has been associated retrospectively with damaging events. Common to the application of these methods is the need to have an understanding of the expected mode of failure during a bump event if not the mechanism behind the failure. Many mines may have multiple potential modes and mechanisms of failure. Mine operators are encouraged to explore not only these methods but, armed with an understanding of the intent of the method, develop new strategies that may be better suited to their mine’s conditions.

Face Observations

One of the most basic means of assessing potential local hazards is consistent systematic observations of face conditions for a change from nominal experience. While informal observations may raise awareness there is a potential for rationalization and inexperience to minimize perceived risks. The process of systematically recording key observations allows correlation of and trending of observations to minor events and provides a basis to pursue more active monitoring methods. Critical observations should be based on the expected strata behaviors identified in the mine design process. Observed conditions which have been associated with abnormal loading of the face or pillars that should be considered are:

- *Lagging of the cave line*: Any delay in caving or increase in distance from the pillar line to cave has the potential to change the behavior of the adjacent face or pillars
- *Characteristics of the cave:* A cave that changes from small debris to larger blockier sizes may indicate a localized increase in immediate roof strength that can impact load transfer. A change in cave material size can also reduce bulking of the cave and increase the span from the face to where the gob can support overlying strata.
- *Variation in distance between yielding of chain pillars and/ or floor heave and the face:* A mining area should develop a relatively predictable relationship between face position and pillar yield as reflected by rib spalling or closure of the mine opening such as floor heave. Changes from this norm require investigation of the reason for the variation. In particular a sudden reduction in magnitude of yield behavior may indicate stored energy.
- *Change in shield loading cycles:* Sudden changes in shield loading magnitude or location of cyclic loading may indicate changes in the overburden’s behavior. Absent an explanation, a reduction in shield loading should be considered stored energy.
- *Changes in spalling behavior of the face or rib:* A decrease in spalling of the face or pillar ribs can, absent a structural explanation, indicate a localized area of stronger or more brittle coal prone to sudden failure.
- *The appearance of red dust and/or slickensides at the coal/ roof or floor interface:* A bump resulting in coal ejected into the mine opening is the expression of a loss of cohesion within portions of the seam or between the seam and the roof or floor. A highly stressed zone will show signs of minor failures in the form of red dust or polished rock surfaces as the coal resists extrusion in addition to more obvious expressions of these features after a major bump.

Geologic Investigations

During the design process a stratagraphic model of the geology above the coal seam is developed. This model represents nominal conditions that the mining area will influence as extraction progresses. While the process of developing this model is generally not` precise it does make assumptions about the thickness and properties of the strata that can influence the performance of a mine design. An understanding of the the sensitivity of the mine design to variations from this model will enable an operator to identify what observations are necessary to assure that the mine design remains valid. In the near seam geology damaging events have been associated with:

- Sandstone channels (4)
- Faults (5; 6)
- Seam rolls (2)
- Changes in coal composition (7)

Collecting these observations typically requires the services of a geologist with assistance from mine operations personnel. Stewart (6**)** describes the use of information collected during roof bolting to develop roof hazard maps that would also provide information for this purpose. Current NIOSH research is investigating remote monitoring methods for identifying gross changes beyond the bolting zone and investigation of other potential geologic hazard markers.

Seismic Monitoring

The use of seismic monitoring systems has been applied to coal mining in a number of forms, from local micro seismic to regional systems, and to varying degrees of success. Currently, systems rely on trained specialists to process waveform data and provide accurate locations and magnitudes of events. Some system providers offer data processing services to reduce the burden. While not a predictive tool, once a pattern of normal seismic behavior is established these systems can be used to identify changes from that norm that would warrant additional monitoring of the hazard potential of mining areas (8). Seismic monitoring has also been a resource for post event analysis to provide input into future mine designs. The use of mining induced seismicity as an input to tomographic analysis of hazard potentials surrounding the mining face is an area of current applied and basic research (9).

Holub (10) describes the use of seismic monitoring to evaluate hazard potential of mining areas in deep Czech coal mines and the development of a quantifiable threshold of seismic energy, above which proactive control measures are mandated. The establishment of thresholds, whether empirically or theoretically derived, is the foundation of a formal hazard management system.

Probe drilling

A method of identifying highly stressed zones in the coal face and pillars that has seen success in softer coals is probe drilling using small diameter (<50mm) bores. The concept behind this method is to develop a micro excavation in the coal seam and observe the seam’s reaction to the excavation. Yielded coal normally surrounds deep mine openings. The peak ground pressure is carried in a stress abutment well behind the rib surface. Since yielding increases coal permeability, the yield zone is degassed as well as de-stressed forming a gas pressure abutment. For example, Varley (3) discusses using drill holes to locate gas and stress abutments (figure 1). Bräuner (7) provides a more extensive discussion, based on experience with softer Ruhr coal of Germany.

Under purely load driven conditions, the coal will close around the auger rod producing more cuttings per unit of advance than would be produced by drilling an unstressed block. The volume of cuttings produced will increase substantially when a highly stressed abutment is probed. If the gas content of the coal is sufficient, a precursor indicator of gas discharge from the hole can be observed as drilling offers a means for pressurized gas contained in the coal pores to escape. A third indicator of location of the stress abutment is the production of audible noise in the form of micro-seismic events. The distance from the face or rib to

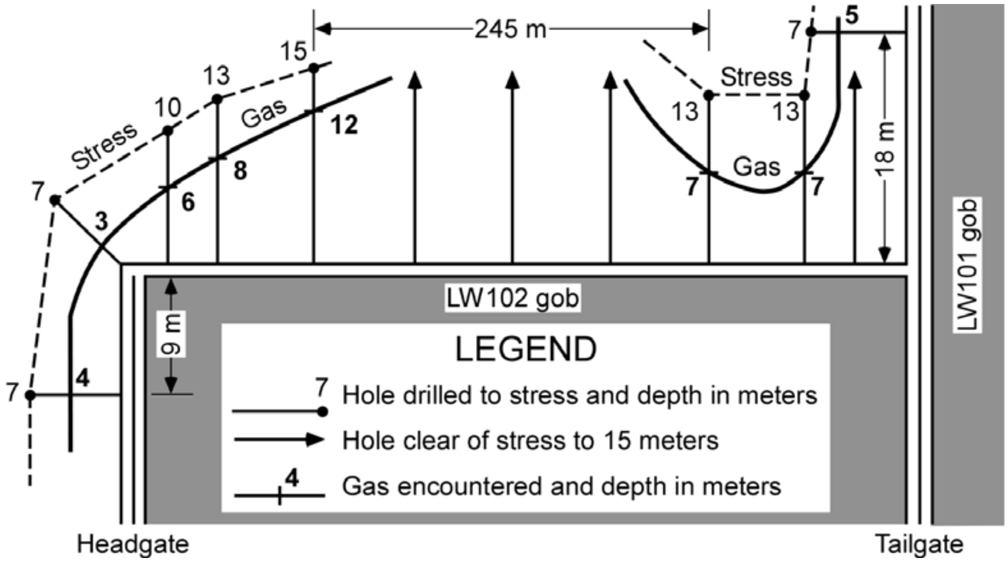

Figure 1. Stress and gas abutments located by drilling (3)

the high stress zone determines the relative hazard. An empirical relationship has been established (3; 7) to identify the minimum distance to the highly stressed zone:

$$S=XM+A \qquad (1)$$

Where S is the critical distance to the high stress zone, X is a site specific variable typically between 2 for pillars and 3 for faces, M is the mining height, and A is the expected advance in the direction of the bore before retesting. In application of this method, the drilling observations that would reflect the location of the high stressed zone are site specific and should be developed by systematic testing of stable and at risk areas.

Though probe drilling has been successfully used in a number of mines to define bump hazards or evaluate the post development yield of chain pillars (11) there is no implicit guarantee of universally applicability. Pillar and face loading which is not progressive but relatively rapid and cyclic may be absent during probe drilling but appear between test intervals. Bump mechanisms originating outside the seam, often referred to as shock bumps (12; 5), may have no predictive expression within the seam prior to the event.

HAZARD CONTROL METHODS

Once an area with an increased bump hazard has been identified through a well designed monitoring program, a suitable reaction to identified hazards must be employed to protect workers and property. Internationally a variety of control measures have been deployed to respond to bump hazards with varying degrees of success and economic impact. Locations where intact, highly stressed coal with gas at high pressure is at or just behind the face can generate an outburst of coal and gas. Control methods are designed to initiate yield in such locations or, insulate the miner from the hazard.

A number of methods have been developed for pursuing this goal. These include drilling, volley firing, hydro-fracturing, and water infusion (before or during mining). As with monitoring strategies, application of bump control methods requires a basic understanding of the potential modes of failure and mechanisms driving the hazard(s). Mine operators can build from these experiences to develop their own site specific strategies to reduce the risk of a damaging bump event.

In addition to methods to reduce or eliminate the likelihood a damaging event will occur, supplemental protective measures can be utilized to provide a greater amount of protection should the control measures not completely remove the hazard. These protective measures include efforts to protect miners from ejected debris and operational adjustments within a cutting cycle. Caution must be exercised to not rely solely on these protective measures to ensure the safety of miners.

PROTECTIVE MEASURES

Protection from Ejected Debris

The use of personal protective measures to prevent mine workers from being struck by ejected debris during a bump has become a standard component of U.S. ground control plans where there is a risk of bumps. These measures vary by location but in general consist of administrative controls, protective equipment worn by miners, energy absorbing barriers on the longwall face and barriers wrapping gate pillars.

- Administrative controls focus on limiting the number of persons in the face area during high potential phases of mining such as cutting the gates. While this has been recognized as reducing the exposures it is prone to human error with tragic consequences (13).
- The use of personnel protective equipment such as helmets with face shields, protective vests, knee and shin guards have become an accepted part of deep longwall mining. While these protections have no doubt reduced the number of injuries from smaller events, they have limited ability to afford protection from much larger events.
- Barriers to absorb the energy of ejected material on the longwall face include shields erected on the shearing machine to deflect material ejected from the face above the shearing machine frame and guards, often constructed of belting and/or steel mesh, connected from the shield

canopies to the face conveyor via chains. In development headings, starting a cut with the continuous miner drum high on the face and cutting down can take advantage of the mass of the head for protection from ejected coal as the face is relieved. These barriers offer protection from most debris ejected during small events but are likely incapable of withstanding the energies of the largest bump events. (13).

- The intent of wrapping gate road pillars is to contain the debris ejected from these pillars during the sudden failure of a bump event. These measures currently used in U.S. coal mines involve bolting screening material to the coal rib with vertical supports between the roof and floor on close spacing (~0.6m centers) to contain the pillar rib mesh should the bolts fail. The vertical supports used vary from timbers to yieldable steel posts. Should the bump include significant floor heave or large lateral movement of the pillar there is significant risk the vertical supports could be dislodged. While containment of pillars is widely used in rock burst prone mines internationally, there is a distinct difference in approach. Pillar containment systems are designed to withstand the estimated energy and movement of a large event. These designed systems provide a means to yield in all directions while developing an ultimate strength capable of withstanding a severe event (14) without failure. The most significant difference between these systems and those currently used in U.S. mines is the use of wire rope lacing, designed to allow the ribs to expand without rupture as reinforcement to rib mesh. While some mines have experimented with wrapping wire rope around a pillar, it is not clear a similar level of engineering design was used.

Cutting Cycle Adjustments

The execution of any design can influence the potential to bump. Adjustments within the mining cycle can avoid sudden loading of mine structures through control excavation speed, depth and timing.

Room and pillar mining offers the greatest potential for variations in cutting sequence to result in a bump. Turning a crosscut and thus creating a pillar one or more cuts behind the face can reduce the potential for bumps during the crosscut. During retreat operations, attention should be paid to sustaining a cave line, avoiding steps or overly large remnant pillars. The use of remote control of shuttle car conveyors, which allow the operator to be outby the machine during loading, in addition to remote control continuous miners can remove all miners from proximity to the face during cutting.

Longwall mining offers little flexibility and provides some assurance that mining sequence and geometry will produce a sustainable cave line. Within longwall mining the cutting cycle can be altered to minimize personnel exposures and attempt to relieve energies in smaller increments.

- The web and speed of the cut can be reduced with some mines taking as little as 0.5 m per pass in bi-directional cuts.
- The face can be cut in one direction only, allowing more time between passes for stresses to equilibrate.
- Only a portion of the seam can be cut on a pass, typically the center in the first pass toward the tailgate. The pass is completed by taking the roof and floor coal on the return pass to the head gate. The concept, attributed to the Sunnyside mine in Utah, is the center cut pass can be made without operators near the shearing machine and the large kerf created by the center cut reduces the hazard for the return pass where operator proximity and attention to the cutting drums is greater.
- To reduce the potential for a lagging cave to contribute to the hazard, some mines use a cutting sequence where one or both of the gates are snaked in advance of the face line.
- Any combination of the above as conditions warrant.

HAZARD REDUCTION MEASURES

Water Infusion/Fracturing

The distinction between hydro-fracturing and water infusion is somewhat confused in reported trials. In some cases, both terms have been applied to the same operation. Hydro-fracturing is distinguished by a few large fractures created over a relatively short time span. Water infusion is a more general softening through an increase in pore pressure, moisture content and generalized fracturing. The increase in moisture content affects coal physical properties. Bräuner (7) comments on the distinction as follows:

> "If the situation is critical already, high pressures are applied for hydraulic fracturing. If the stresses allow [drilling of] deep holes, the fluid pressure is kept low and acts for a longer time. This is to make the coal break successively instead of violently."

Bräuner also emphasizes that de-stressing operations should begin at the sides of the stressed zone and progress into more highly stressed material rather than start in the middle. Finally, he reports that burst control methods have beep applied in the Ruhr Coalfield (Germany) since the 1960's and found to be highly effective. Bräuner also reports that increasing the moisture content of Ruhr coal from 1 to 5% resulted in a 60-70% reduction in uni-axial compressive strength and a 40-70% reduction in elastic modulus. In addition, Bräuner observed a transition from violent (dry) to ductile (saturated) failure mode. Borehole-bursts, in the laboratory or field, are mechanically similarly to rib bursts. In addition, Bräuner reports on laboratory borehole-burst tests that found:

1. "Borehole-bursts occurred in almost all types of hard coal
2. having more than 10% volatile matter.
3. No borehole-bursts were observed when such coal had been
4. saturated with water."

Yuguang (15) discusses similar practices in China. Bump potential is evaluated using drill cutting volume, water content and micro-seismic monitoring. Two protective measures are described. First, the extraction of a protective seam, preferably an overlying seam with low bump potential. Second, water infusion, both before mining and with face advance. In both cases, the water reduces seam strength and elasticity which moves the pressure abutment deeper into the coal rib.

Water infusion has also been applied to dust and methane control. For instance, Jackson and Merritts (16) describe water infusion of coal pillars for dust control at the Kenilworth Mine in Utah. Infusion reduces dust during mining and proved useful to extinguish a burning pillar, apparently ignited by frictional heating along a shear plane during a pillar bump.

Varley (3) describes favorable results obtained by the infusion of 28 MPa water through 30m deep holes drilled from the tailgate on 30m centers (figure 2). Application times range from 3 to 20 days, ceasing when flows rise to 400lph. This method was frustrated by ground conditions, particularly floor heave near the face of the advancing longwall, limiting access to the panel ahead of the face. Drilling of large diameter (100mm) holes was the least successful method, leaving intact sections of face capable of outburst.

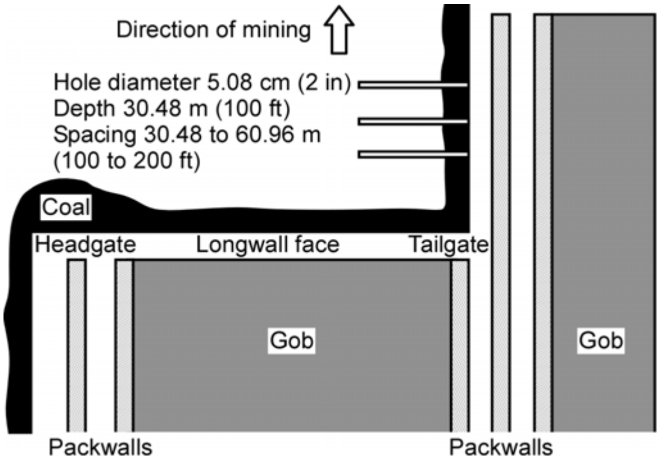

Figure 2. Water infusion holes in the rib of an advancing longwall (17).

Haramy et al. (17) echo Varley's conclusions, and discuss many of the same trials. However, they refer to Varley's water infusion as hydraulic fracturing of the seam and caution that "fracturing a very large and highly stressed area causes loads to be redistributed and may create bursts conditions elsewhere in the mine."

DeMarco et al. (18) discusses face de-stressing near the tailgate of the 9th East Panel at the Castle Gate No. 3 Mine with "face and tailgate high-pressure hydro-fracture holes." This method was discontinued as the mine progressed from 600 m (2000 ft) of overburden to areas with shallower overburden – that did not include the Castlegate Sandstone. That is, the Castlegate was eroded over some mining areas. However, "the complicated nature of panel loading" led DeMarco et al. to state that any judgment of de-stressing program success was "speculation." However, bumps, including a severe bump that halted mining for several days, did occur as mining re-entered deep overburden without de-stressing. The mine was idled in April 1989 after occurrence of several additional bump events (19).

Routine gate road pillar infusion has been used at the Elk Creek Mine, operating under 760m of overburden in Colorado's North Fork Valley. Randy Litwiller, Elk Creek mine manager, describes drilling infusion holes in gate road pillars 100 meters or more ahead of the longwall face to a depth less than half the width of the pillar. (20) Once a pillar begins to yield the infusion holes are pressurized using the face support hydraulic supply. The infusion increases the yielding of the pillar, reducing the occurrence of damaging bumps. The location and direction of bumps are controlled by infusing only one side of the pillar.

Cave Management

Controlled yielding of strata around deep longwall panels can also be important. Haramy et al. (21) review depths and geologic characteristics of Utah and Colorado mines operating under strong roofs. Haramy et al. show that a stronger roof correlated with more periodic loading of shields and suggest the need for induced caving by hydraulic fracturing, large-hole blasting, and water infusion.

Dubinski and Konopko (22) describe bump control practices in deep Polish mines including the weakening of strong strata above, but not adjacent to, the coal seam by "torpedo" blasting. In this method large charges of explosives, up to 150 kg, are detonated in the target strata above longwall panels and development headings (30 kg). Holub (2007) describes similar practices in deep Czech coal mines.

Dvorsky and Konicek (23) describe preconditioning of massive sandstone and conglomerate strata above a "hard coal" longwall panel in the Czech Republic. Blast holes are positioned to create a break line above a barrier pillar separating the panel from a previously mined pillar to the south, and to break up strata above the longwall to ease gob formation. A tectonic fault north of the east-west trending panel suggests that these blasts would relieve high north-south stresses as well.

Dubinski and Konopko (22) further describe the use of directional hydraulic fracturing to both establish a break line for the cave and to alter a massive strata into a layered member better able to cave progressively rather than cyclically. The authors also describe the use of water infusion to soften sandstone members in the roof by up to 60% when clay is present.

Hayes (24) and Mills et al. (25) discuss hydro-fracturing of a 30m thick conglomerate roof at Moonee Colliery, Australia. The conglomerate is prone to sudden failure over wide areas, creating windblast hazards. The panel design intends the conglomerate remain intact, bridging the 100m panel by resting on 35m wide chain pillars. Caving is induced by hydraulic fracturing via holes drilled from the shields, and pressurized after the longwall has advanced beyond the holes. These fractures initiate smaller caving events, limiting the length of immediate roof behind the shields.

Water infusion of strong strata might also have promise since the strength of some sandstone has been shown to depend on moisture. McCarter and Wilson (26) report the softening and weakening of a variety of sandstones with increasing moisture content. Saturation effects on uni-axial strength effects vary from none to a roughly 30% reduction, depending on sample characteristics. They also describe how vibration characteristics can be used to assess moisture content.

Shimada et al. (27) describe hydraulic fracturing of strong roof over a longwall panel in the Miike Colliery, Japan to control air blasts from sudden caves that have injured miners. The panel is off shore, 500 m below sea level, where barrier pillars between panels were introduced to control subsidence. Shimada et al. also report on significant softening and weakening of coal and coal measure rock with introduction of wetting (water infusion), including reductions of strength in Miike sandstone of 30 – 50% (Figure 3).

Vasarhelyi (28) analyzes moisture versus strength relationships for 35 British sandstones from 21 locations and found a best-fit equation of $USC_{saturated} = 0.759\ UCS_{dry}$ with an R^2 of 0.906. Chen and Hu (29) report substantially larger strength reductions for weak sandstones in Taiwan. These two studies identify the

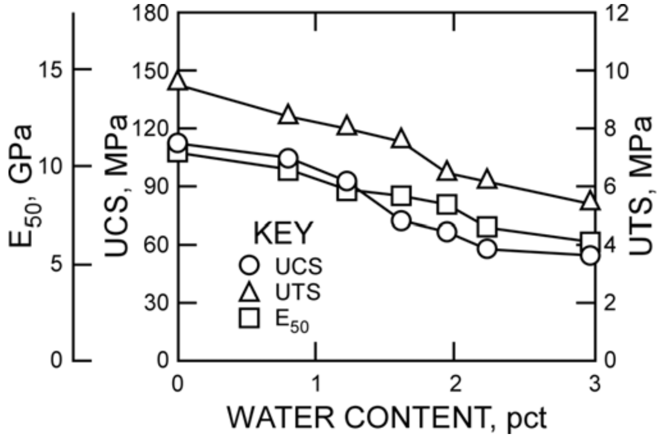

Figure 3. Change of Miike sandstone properties (27)

potential to utilize water infusion to reduce the strength of strong bridging strata where it presents a local hazard to a portion of a mine. The other significant result is the potential for localized natural changes in moisture content of strata, such as may be found near prominent joints or faults, to alter the caving behavior of a normally strong member.

Ray et al. (30) reports softening of Indian coal measure rock, particularly sandstones, with water infusion, in the laboratory. Fine-grained sandstones with a clay content of 13.6% showed the least response after 3 days of saturation, with a strength reduction of 10% over a dry sample. Increasing grain size and/or clay content showed an increased impact (50% reduction for medium-grained sandstone and 60% reduction for fine-grained sandstone with 27.4% clay). A reduction in strength of nearly 80% was attained for coarse-grained sandstone with 23.1% clay content. Further reduction in strength was noted in some sandstones, as the saturation time was extended from 3 to 7 days. Based on these results, Ray et al. argue that water infusion of sandstones could be used to improve caving over longwall panels.

The impact of water infusion might be heightened by addition of small concentrations of various chemicals that affect the zeta potential (the electric potential across the solid-liquid interface) which may further decrease tensile strength (31). This phenomenon has been studied mainly for drilling applications, but may also apply to natural and induced changes in the caving characteristics of massive strata. The phenomenon may also explain failure of apparently strong bridging strata that is exposed to ground water.

De-stress Drilling

De-stress drilling is simply piercing highly-stressed coal with drill holes that, ideally, induce yielding of the surrounding coal, moving highly-stressed zones away from the mining face. The process must remove enough material to induce yield in a highly stressed zone that is then mined and the process repeated. Verification that the hazard is removed requires subsequent probe drilling. Experience in Europe and elsewhere indicates holes 100 mm and smaller in diameter are unlikely to initiate dangerous bumps.

Iannacchione (2) reports on the use of de-stress drilling using very large (61 cm) holes at the Gary mine in West Virginia. This practice was discontinued due to initiation of large damaging bumps. Iannacchione also reports the Olga mine, also in West Virginia, found success in using 100 mm holes to relieve stress in coal ribs. Olga used the 100 mm holes to probe for pressure abutments and, when encountered de-stress the zone through removal of coal by holding the drill depth at the abutment.

Varley (3) reports the drilling of large diameter (100 mm) holes was the least successful method for control of the hazard of bumps on a longwall face, leaving intact sections of face capable of outburst. Mid Continent Resources did use large diameter drilling to de-stress development faces as an alternative to volley firing but experienced several injuries when drilling did not fully remove the hazard (32).

Osamu & Katsuhiko (33) report using numerous small diameter (50 mm) holes to gradually yield a highly stressed zone in a longwall panel gate at the Miike mine in Japan. Probe drilling on progressively closer spacing was continued until results indicated the zone of interest had been relieved. While labor intensive, this method may have merit for mines with infrequent exposures to bump hazards.

De-stress Blasting

De-stress blasting or volley firing is used to trigger failure at a known and safe time. This method uses smaller holes and small charges that shake and fracture the coal while leaving it in place (figure 4). A number of charges are fired simultaneously (a volley), increasing the likelihood that a dynamic failure will be initiated in a relatively controlled setting.

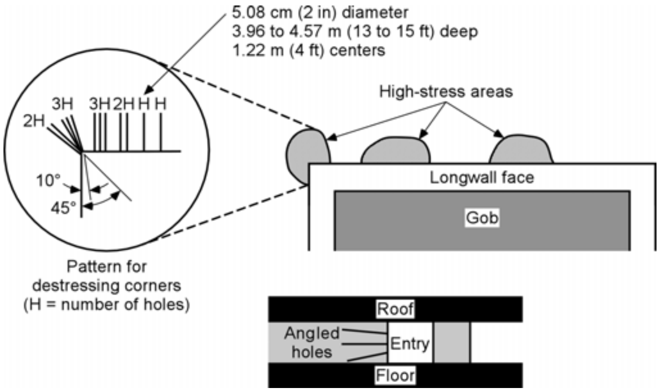

Figure 4. Volley firing scheme for an advancing longwall (17).

Varley (3) describes stress relief efforts at the Dutch Creek #1 Mine (Colorado) advancing longwall operation. The efforts focus on areas identified as posing an outburst threat, based on response to drilling. Varley finds the most effective means of distressing a mining face is drilling and blasting of the face (volley firing). The downside of this approach is the necessary halting of production and evacuating the face for a shot. The method does protect miners from induced outbursts. Success depends on two considerations. First, the blast must be designed to fracture in place, rather than pull the coal using relatively small charges. Second, care must be taken to avoid mining beyond the de-stressed zone.

Agapito et al. (34) discuss burst control methods in the Book Cliff and Wasatch Front coal fields in Utah. They mention de-stressing as a method for minimizing stresses at the face induced by mining of adjacent panels. However, they assert that this method has “not yet demonstrated satisfactory results under continuous operating conditions” and “can be hazardous if not properly implemented." Moreover, "use of de-stressing in the Price area mines has been limited to the Castlegate No. 3 Mine where it was applied unsuccessfully." Agapito et al. report that "it was deemed hazardous by miners who tried it, due to bursts induced by drilling."

IMPACT ON OPERATIONS

The implementation of bump hazard management practices will have an impact on mine operational budgets and staffing. A common element in programs described by the various authors is the need for an organizational structure, often including a site champion, to coordinate the design expectations, monitor results and control activities of the effort to manage bump hazards. Little information is available on the cost implications of bump management systems. Anecdotal evidence suggests that US mines which have implemented universal systems, to every face or panel, have not been viable economically over the long term. Information on reportable incidents and production available from MSHA (32) indicate that implementation of universal management systems did not impact the production rates of mines (Dutch Creek #1, Castlegate #3) as compared to periods of uncontrolled bumps. The production interruptions, costs and injuries avoided by implementation of universal bump management systems are not measurable. Anecdotal evidence suggests application of control methods to a limited high hazard area, such as at the Elk Creek Mine, has the potential for success in U.S. mines.

SUMMARY

Prudent management of mining in bump prone ground requires a systematic approach including an understanding of the mechanisms, monitoring for conditions indicating an increase in potential for a bump to occur and active means to control the hazard. Control efforts should be directed by monitoring to reduce the hazard with protective measures and hazard reduction measures as described. Internationally, a wide array of means of identifying and assessing hazard potentials and implementation of active controls has been developed. Though similar in approach, these systems are essentially site specific and can only be transported to another coal district or mine on careful examination of the relative properties or mechanisms the system evaluates or attempts to control. Control methods must be carefully selected to ensure a greater hazard is not created. Despite the site specific nature of these systems they do offer mines a basis for developing a method to improve the safety and perhaps productivity of an operation at risk of damaging bumps. Lessons learned include the need to be systematic in the application of a control program with clearly defined action levels. Controls measures, when indicated, should be initiated outby the suspected hazard area and seek to move the hazard inby. Finally, active control measures require verification that the bump hazard has been removed through monitoring or assurance the potential energy has been relieved.

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