GROUND CONTROL FOR HIGHWALL MINING

BY R. KARL ZIPF, JR. AND CHRISTOPHER MARK

Highwall mining continues to grow in importance as a coal production method from U.S. surface mines. It may account for as much as 4% of the total U.S. coal production, according to one recent estimate. Analysis of Mine Safety and Health Administration (MSHA) accident and injury statistics shows that, overall, highwall mining has maintained an admirable safety record. Its fatality and injury rates are comparable to those for other surface mining methods, and are significantly lower than those for underground mining.

No mining method is risk free, however. Highwall mining injuries have been associated with handling materials, slips and falls, machinery, powered haulage, and other types of incidents. But perhaps the greatest risk, to both personnel and equipment, is from ground control. The two most significant ground control hazards are rock falls from the highwall and equipment entrapment underground.

Highwall Stability

Ensuring highwall stability through proper ground control engineering is of paramount importance to safe highwall mining operations. The only fatality to occur during the last five years at a highwall mining operation was due to highwall collapse. There have also been numerous near-misses, several of which have involved extensive damage to equipment.

In the central Appalachians, where the majority of highwall mining occurs in the U.S., hillseams are the most prominent geologic structures that affect highwall stability. Hillseams (or mountain cracks) are near vertical fractures in the rock that are formed in response to natural weathering and erosion of hillsides. They extend hundreds of feet down from the surface. They typically run parallel to the hillside, but they can also extend across narrow points or ridge lines. The hazard arises when rock slabs that form along the hillseams detach and fall away from the highwall face (See Figure 1).

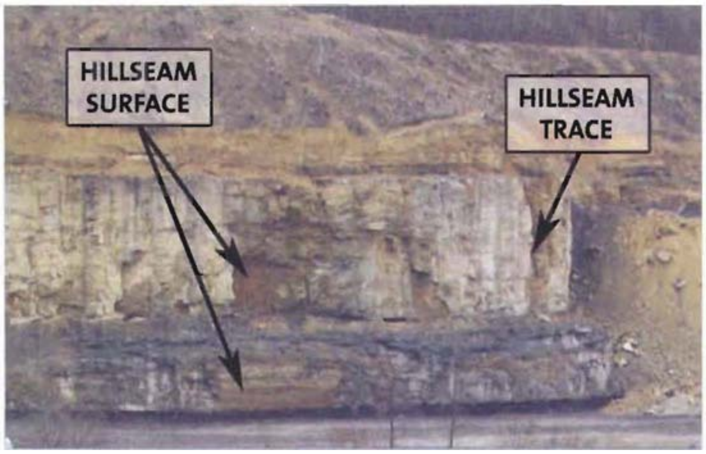

Figure I-Hillseams indicated by arrows in contour mine highwall. Note that weathering along hillseams can extend several hundred feet or more below the surface.

Unfortunately, it is impossible to control the location of hillseams or reliably detect their presence within a highwall. There are, however, a number of measures that can be taken to minimize the risk of failure associated with hillseams:

Planning-Most operators choose to skip those areas of the highwall where a prominent hillseam daylights (See Figure 2). Existence of such areas is known for several weeks in advance of highwall mining; therefore, planning engineers can adjust the layout of highwall mining panels to locate barrier pillars within areas of questionable highwall stability.

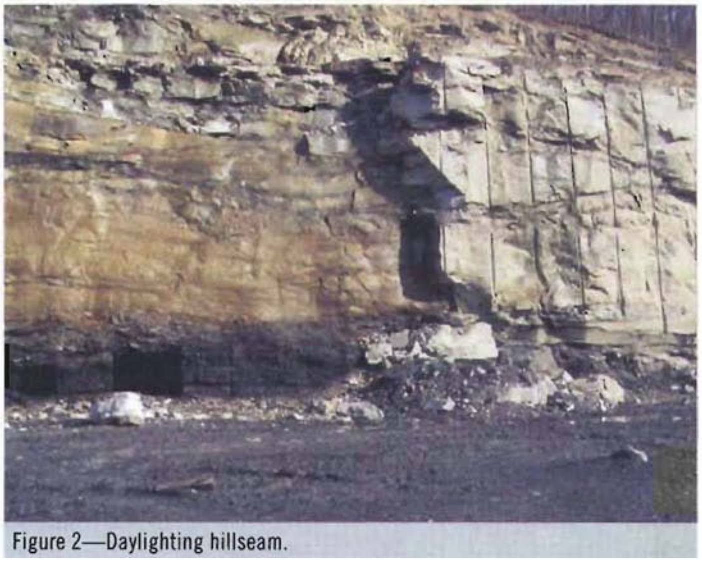

Figure 2—Daylighting hillseam.

Inspection and monitoring-Daily inspection of the benches above the active highwall mining area is a prudent precautionary measure. A crack in a bench immediately above a highwall miner is shown in Figure 3. Simple displacement monitors may be useful for detecting movement along cracks that may precede a significant life-threatening failure. New tools, such as slope monitoring radar, may also prove useful in detecting motion of the rock slopes above active highwall mining operations.

Good blasting practice-Most surface coal miners in the central Appalachians use pre-splitting and the familiar half-barrels are routinely seen throughout the pits. Shorter delays along the face and longer delays between rows can direct more of the blast force parallel to the face, potentially doing less damage to the wall rock. In addition to pre-splitting, decreasing the burden, spacing and charge weight in drill holes close to the highwall will also decrease damage to the wall rock.

Decreasing the highwall slope angle-Decreasing the highwall slope angle from 90° (vertical) to 70°-80°, especially in areas of known hillseam concentration, could eliminate the hillseam hazard (See Figure 4). Angled highwalls are routinely employed in many Midwestern surface mines and in some

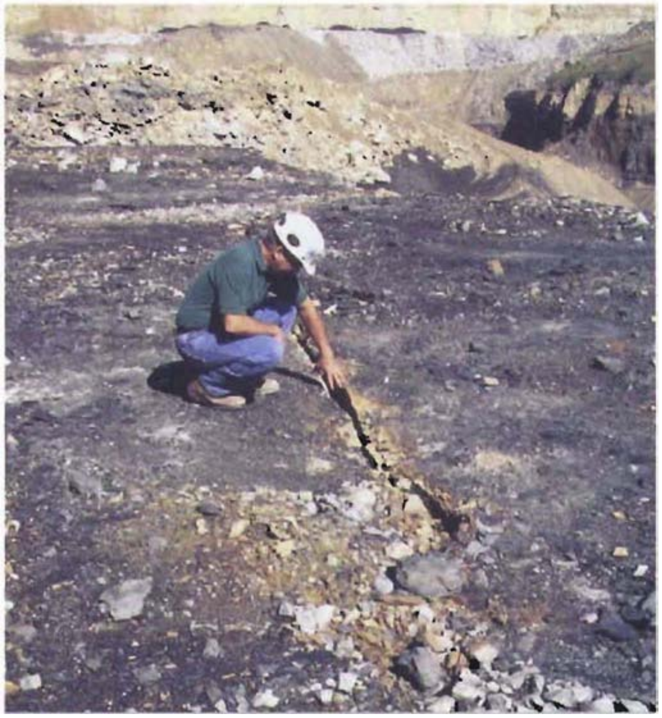

Figure 3-Crack in bench above highwall mining operation.

mountain-top removal operations. In the steep-slope contour mines of central Appalachia. they may require careful operational planning and special drilling equipment. However, the safety returns on the investment could be substantial.

Highwall stability issues are often most severe near "ridge points." Most operators protect themselves by leaving a substantial safety barrier in which no mining is conducted near ridge points (See Figure 5). The wall rock is also often fractured in the heads of the hollows beneath stream valleys, and these areas should also be avoided (See Figure 6). Many other features, including old underground works that daylight in the highwall (See Figure 7), can also be hazardous.

Equipment Entrapment

A "stuck" or trapped highwall miner, and the ensuing retrieval or recovery operation, can be extremely disruptive to the highwall mining process. Most entrapments are due to roof falls in the hole. While weak shale drawrock often falls before the hole is completed, it seldom results in an entrapment. Strong sandstone roof is less likely to fail, but when it does, it is more likely to prevent retrieval.

Many trapped highwall miners also result from seam rolls and undulations that may cause tight spots. Where poor surveying or machine guidance results in crossed holes, the excessive span created may also cause an entrapment. When a highwall miner does get trapped, there are several options for recovery. In order of increasing difficulty, they are surface retrieval (pull it out), surface excavation, or underground recovery.

Surface retrieval is by far the least complicated option. Many operators have built special devices to hook onto separated equipment in the hole. The operator pulls on the trapped highwall mining equipment with anything available such as the launch vehicle, dozers, loaders or haul trucks. The major hazards associated with surface retrieval are the tight cables and connectors used during the pull.

Excavating from the surface can be a very safe option, but it may be necessary to remove 100,000 cubic yards of rock to reach the trapped machine. Furthermore, during excavation, the trapped equipment is likely to become damaged due to nearby blasting.

Underground recovery is arguably the most hazardous and essentially requires the set up of a small underground coal mining operation. MSHA requires the operator to submit a recovery plan to the District Manager that must be reviewed and approved prior to beginning the underground recovery.

Interviews with MSHA roof control specialists suggest that in 2003, between 10 and 15 highwall mining systems became seriously trapped and could not be pulled out of the hole. Each one required a substantial retrieval effort such as underground recovery, surface excavation or a major surface retrieval. There were about 60 highwall mining operations in the U.S. in 2003, so at that time, the odds were about 1 in 4 that a highwall miner would become trapped during that year and required a major recovery/retrieval effort.

Design of Web and Barrier Pillars

MSHA recognizes the ground-control-related safety concerns associated with highwall mining and requires each highwall mining operation to develop and follow 'an appropriate highwall ground control plan, which addresses the web spacing and other measures necessary to safely conduct the high rates of recovery.' Proper pillar design is essential to maintain highwall stability and to prevent entrapments. The results of one large pillar failure is shown in Figure 8. In this case, 30 to 50 web pillars failed suddenly, which caused substantial rock fall from the highwall. The rock fall was sufficient to completely bury a 110-ton haul truck. Fortunately no one was in the pit when this failure occurred. Another area where web pillar failure led to large rockfalls from the highwall is shown in Figure 9. The web pillar collapse also trapped the highwall miner which required several months' effort to recover.

The National Institute for Occupational Safety and Health (NIOSH) has developed the Analysis of Retreat Mining Pillar Stability-Highwall Mining (ARMPS-HWM) computer program to help mine planners with this process (See box on page 28).

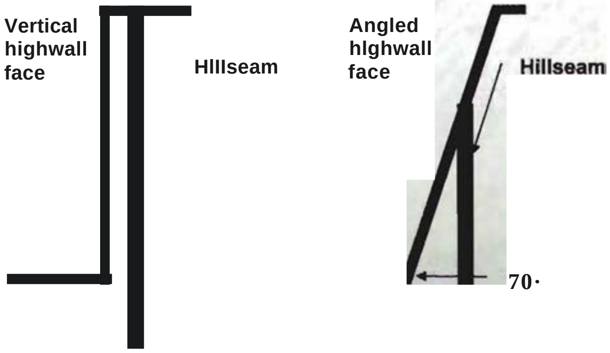

Figure 4-Vertical highwall containing hillseam (left) and 70' highwall with hillseam (right).

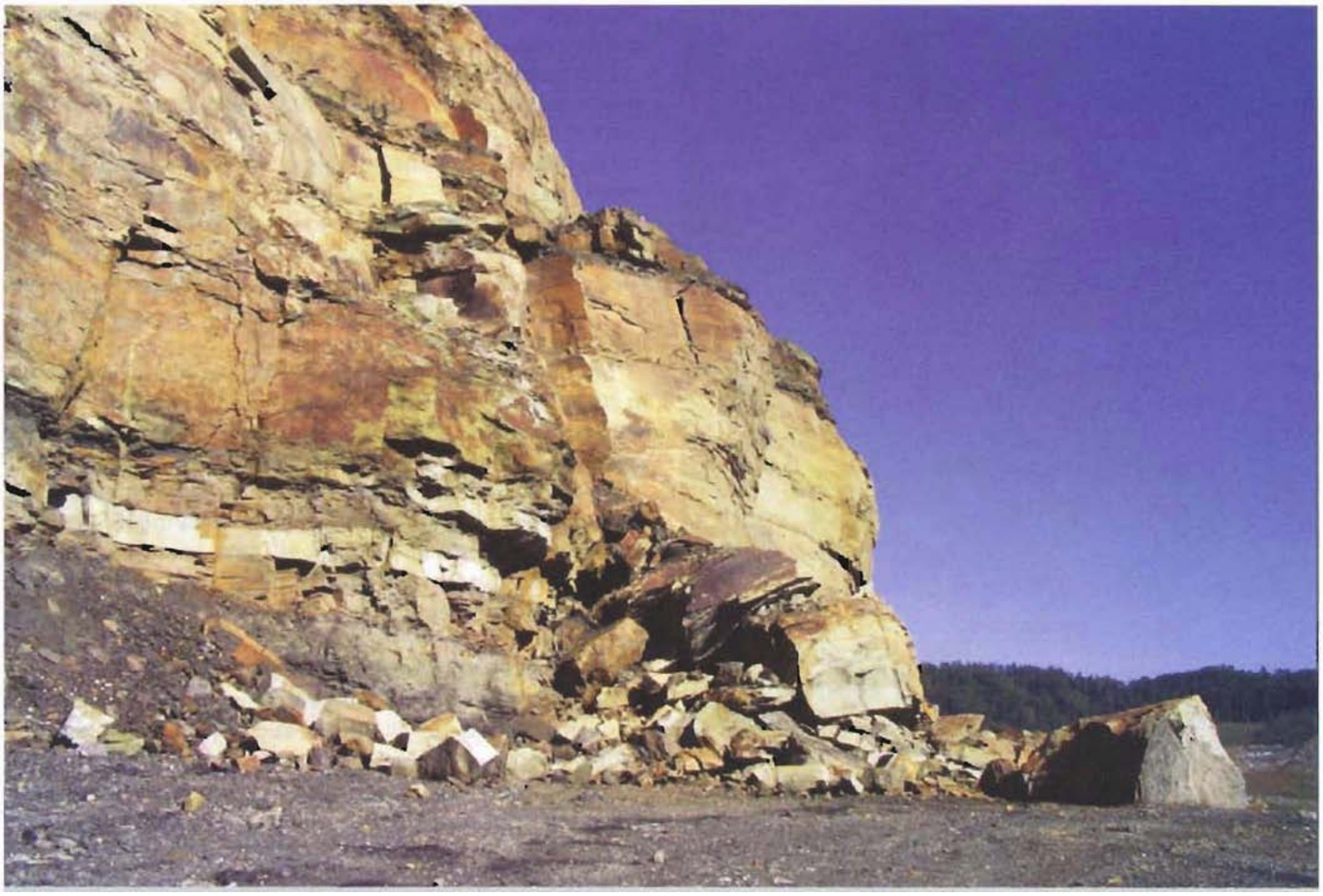

Figure 5-Ridge points with hillseams can lead to large rockfalls in highwall mining.

Special Ground Control Issues

At least 20% of *the* highwall mining operations expect *to* encounter old auger holes somewhere on the property, according *to* a recent analysis of MSHA highwall mining ground control plans. A typical highwall mining web and barrier pillars containing pre-existing auger holes is shown in Figure 10. Although these auger holes may only penetrate the highwall 100 ft or so, they substantially weaken the web pillars directly beneath the highwall. Conventional coal pillar strength formulas, like ARMPS-HWM, do not apply directly to *this* situation.

NIOSH researchers used numerical models to estimate *the* strength of highwall mining web pillars containing pre-existing auger holes. These calculations for a range of practical auger mining geometries indicate *that* the strength of a highwall mining web pillar containing auger holes is 25% to as little as 15% of the solid web pillar strength.

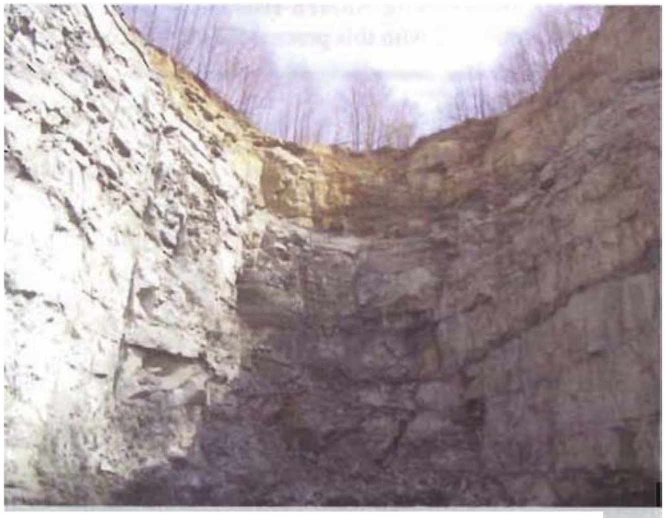

Figure 6-Heads of valleys may be more fractured and can lead to stuck highwall miners.

Figure 7- Old underground works daylighting in highwall can pose ground control hazards.

Figure 8-Site of massive web pillar collapse resulting in highwall slope failure. Photograph was taken from adjacent spoil pile. Highwall is about 150 ft high. A 110-ton coal haulage truck is buried in rockfall debris.

At least one operator is currently filling the old auger holes with cement to strengthen the web pillars and improve recovery. The NIOSH modeling indicates that cement fill can be effective, but only if the cement is stiff enough to provide the necessary confinement to the auger webs.

Many U.S. highwall mining operations recover multiple seams in very close proximity to one another. In the east, this situation can arise when a thick seam splits into thinner seams. In western mines, certain very thick seams can exceed the

ARMPS-HWM

The Analysis of Retreat Mining Pillar Stability-Highwall Mining (ARMPS-HWM) computer program is based on extensive research into instances of highwall mining pillar instability and pillar collapses in underground mines. ARMPS-HWM uses the same pillar strength and pillar load formulas that are employed in the familiar ARMPS program, but the method has been streamlined to apply specifically to highwall mining.

ARMPS-HWM addresses the following issues:
- The number of holes between barrier pillars;
- The size of the individual web pillars;
- The size of the barrier pillars, and
- The stability factor of the overall design.

Important input design parameters are the highwall miner hole width, the mining height, and the overburden depth. The program can be used in either the "analysis mode," in which the user specifies the pillar widths to be evaluated, or in the "sizing mode," in which ARMPS-HWM suggests the pillar sizes.

The program is simple to install and easy to use. It contains extensive Help files that provide more background on the research upon which they are based. The Help files also contain suggestions for highwall mining through old auger holes and for close proximity multiple-split highwall mining.

To obtain free copies of ARMPS-HWM and other NIOSH ground control software, visit www.cdc.gov/niosh/mining and look for ground control software. Alternatively, you may request it from Kim Mitchell, NIOSH Pittsburgh Research Laboratory, Cochrans Mill Rd.• P.O. Box 18070, Pittsburgh, PA 15236-0070; E-mail kmitchell@cdc.gov; Tel: (412) 386-6552, Fax: (412) 386-6891.

Figure 9-Highwall collapse site.

Figure 10—Highwall miner web and barrier pillars with old auger holes.

working height of the highwall miner, and a multiple seam mining approach may be used.

Multiple seam mining becomes most problematic when the interburden thickness between seams decreases to less than about one highwall miner hole width (10 to 12 ft). In one instance, the lower seam split was mined first, followed by partial backlilling of the pit and mining of the upper seam split. A weak, laminated interburden ranging in thickness from 4 to 10 ft separated the two splits. Catastrophic collapse (or domino failure) of the web pillars occurred that resulted in this extensive highwall failure.

The best solution to prevent this type of failure from occurring is to carefully stack upper and lower seam web and barrier pillars. Attaining proper stacking of web pillars is simple at the start of a hole, but without on-board guidance systems there is no guarantee that stacking will be maintained deep within the holes. Maintaining proper stacking of barrier pillars is more practical owing to their greater width. In conjunction with carefully aligned 'barrier pillars, limiting the number of highwall miner holes to about five will also lessen the possibility of web pillar collapse and highwall failure in these close proximity multiple seam highwall mining situations.

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