GATE DESIGN KEY TO BUMP CONTROL

Bump-related fatalities in the Appalachian coalfields spur investigation by U.S. Bureau of Mines

Full extraction retreat mining, during both longwall and room-and-pillar operations, leads to the concentration of stresses in nearby support pillars. When this occurs at great depth and between unyielding roof and floor strata, portions of these highly stressed pillars often fail rapidly and violently. Such failures, commonly referred to as bumps, vary from minor vibrations without significant strata movement, to notable earth tremors that may eject thousands of tons of coal and rock into the workings.

Following a rash of bump-related fatalities and injuries in the Southern Appalachian coal region in 1984 and 1985, an investigation of the geology, mining methods and engineering parameters at five bump-prone sites in West Virginia and Virginia was conducted by the U.S. Bureau of Mines. This study confirmed that stiff, competent strata, together with the high stresses generated by retreat mining, were a common factor to all five operations.[1]

This result was viewed in the light of a previously conducted evaluation on extraction sequences used to control bumps during room-and-pillar retreat mining at McDowell Co.'s Olga mine in West Virginia.[2] It was these combined findings that resulted in on-site investigations to determine if gate road design could be used to control bumps.

Two different gate road designs, located within the Pocahontas No. 3 seam on Island Creek Coal property, were evaluated using two detailed instrument arrays and in-mine observations. The state-of-the-art instrumentation arrays consisted of stainless-steel, borehole platened flatjacks used to indicate changes in pillar stress, coal extensometers for measuring pillar dilation, convergence stations for measuring roof-to-floor closure, a differential roof-sag indicator, and a differential floor-heave indicator. A permissible data acquisition system was employed to continuously monitor coalbed stress (Fig. 1) and roof-to-floor convergence in hazardous areas.

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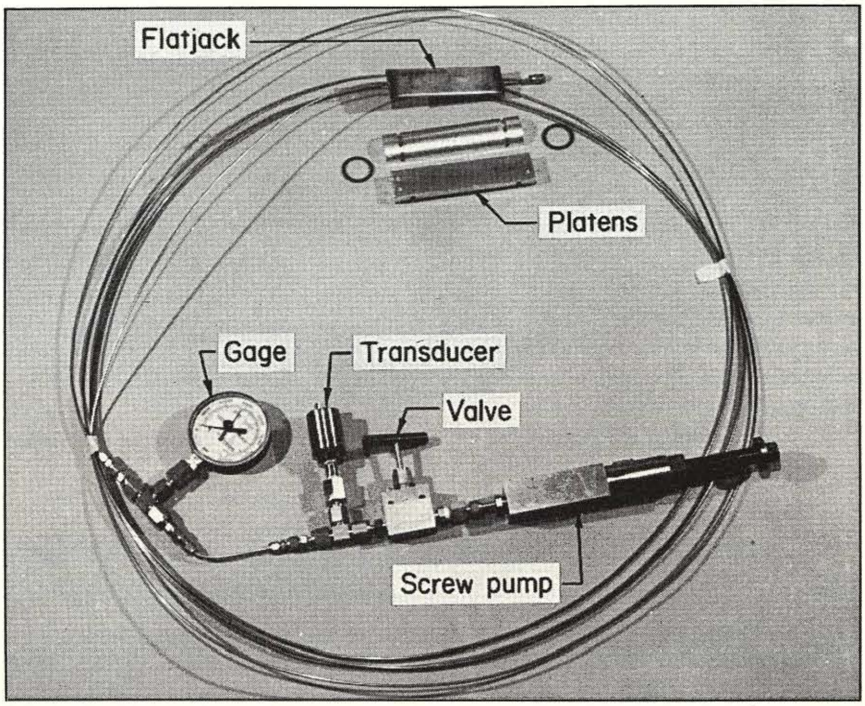

Fig. 1—Borehole platened flatjack configuration equipment that is used to monitor rock movements which proceed bumps.

ORIGINAL DESIGN FAILINGS

The original design of gateways, as employed in the developments for panels 6 and 7, used a 218-ft-wide, yield-abutment-yield configuration with the yield pillars on 50-ft centers, the abutment pillars on 100-ft centers and all crosscuts on 100-ft centers (Fig. 2). By using this configuration, the 80-ft by 30-ft pillars yielded on the headgate pass of the face, thereby eliminating their potential to bump. These yielded pillars then effectively shielded workmen from any coal thrown out from the 80-ft square tailgate abutment pillar, if they happened to bump during the subsequent tailgate pass.

In the first study area, abutment pillar bumps began to occur adjacent to the tail drive within the panel 6 development gate road after 3,650 ft of the 6,000-ft-long panel had been extracted. Fig. 2 illustrates the location of the bump area, labeled *A*, as well as the overburden depth, the thickness of the immediate siltstone

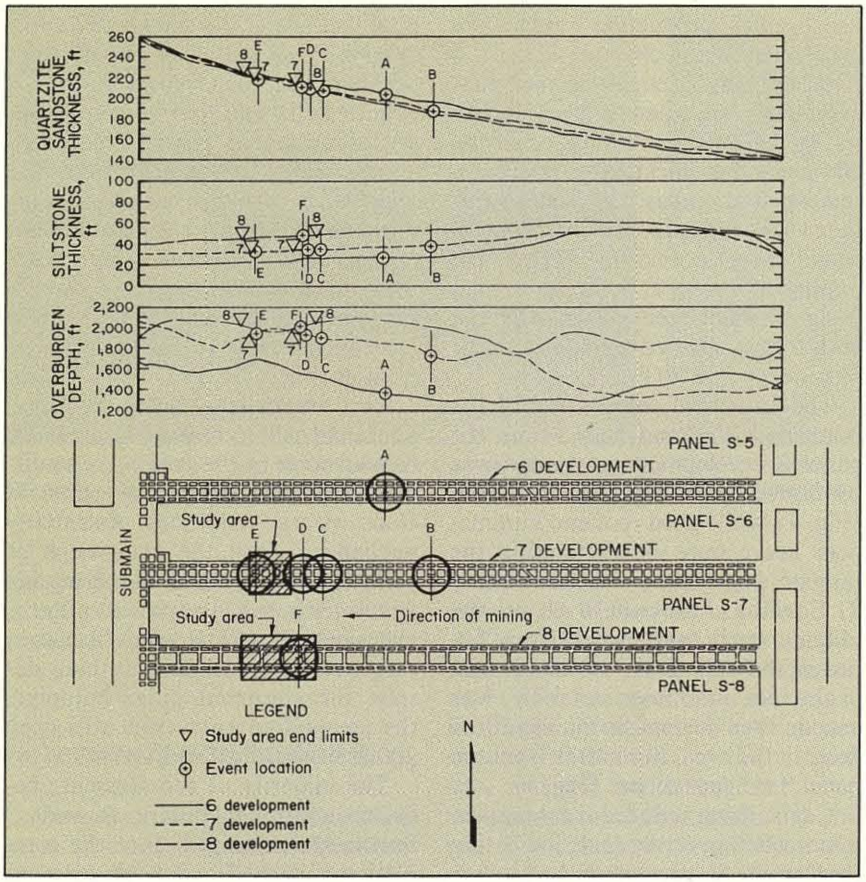

Fig. 2—Superjacent strata conditions over the 6, 7 and 8 development gate roads showing the location of bump.

roof, and the thickness of the quartzite main roof over the 6, 7 and 8 development gate roads.

Only slight face instability was observed on the tailgate corner of the mined panel, and despite the fact that dramatic coal displacements were observed within the tailgate, no coal was disturbed in the actual headgates themselves—in this or any of the bumps investigated.

When bump *A* occurred, the shearer was cutting coal near the tail side, and although the face crew felt the shock wave released by the bump, they were uninjured. Ventilation equipment located at the mouth of the panel 6 development over 2,000 ft away, however, was affected.

Tailgate abutment pillar bumps, similar in magnitude to bump *A*, occurred during the extraction of panel 7 (Fig. 2). They began, however, approximately 450 ft earlier in the panel extraction with the occurrence of bump *B*. As the mining of panel 7 progressed, the tailgate abutment pillars began bumping 500 ft in advance of the longwall face. These failures transferred load onto panel 7, thus initiating bumps on the tailgate corner of the longwall panel.

Two of the face bumps, *C* and *D*, were significant events that affected normal operations. These events occurred after panel 7 was extracted to 4,240 ft and 4,430 ft, respectively. (A plan view of bump site *C* is presented in Fig. 3.) In bump *D*, the panline was lifted and thrust toward the gob, while in the *C* and *D* bumps approximately 40 ft of the coal rib of panel 7 was thrown into the tailgate.

A visual inspection of pillar conditions in the tailgate indicated that the load bearing capacity of abutment pillars *A* to *F* had been destroyed by bump *B* prior to the occurrence of face bump *C* (Fig. 3). The smoke-free entry between pillars *B* and *I* was completely closed by abutment pillar *B*'s bumping, thus making travel along this entry virtually impossible.

The area containing abutment pillars *G*, *F* and *E* was found to have experienced floor heave (Photo 1) between abutment pillars *E* and *F*. Since the posts were not broken, as would have been the case if roof-to-floor convergence had occurred, it can be deduced that the main overburden load was supported by panel 7, and consequently, that the abutment pillars had not been deformed or forced into the floor.

After the *D* bump, the tail of the face was kept 10 ft in advance of the head in an attempt to decrease the stress concentration on the tail by redistributing stresses toward the head. Also after this bump, the shearer was operated remotely when mining near the tailgate corner of the panel. In this way the panel was completed without any further face bump delays. The absence of further incidents in the panel could not be conclusively attributed to changes in procedures or on tailgate design.

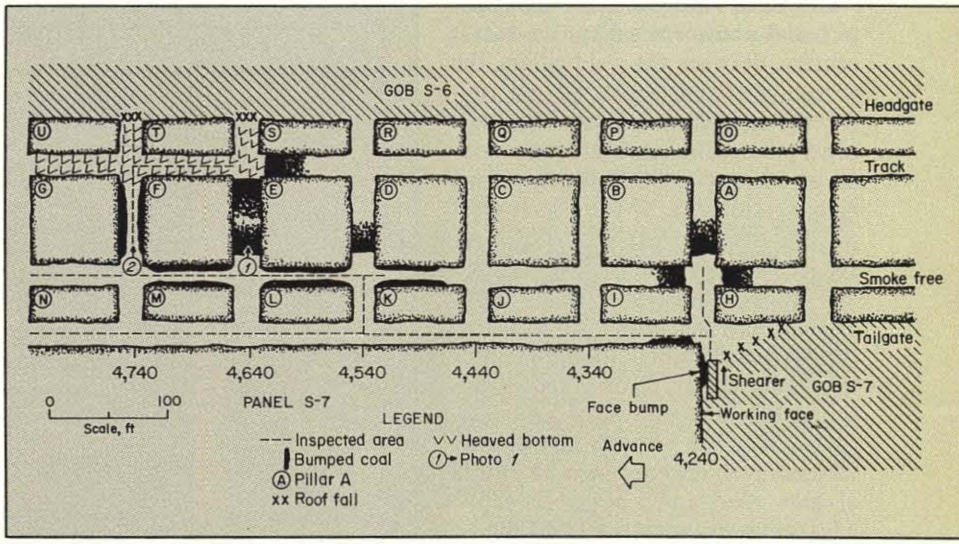

Fig. 3—Plan view of bump C within the panel 7 development gate road showing the extent and location of bumped coal.

Photo 1—Condition of crosscut between pillars E and F showing bump fall out.

Bump *E*, which centered on the tailgate abutment pillar, occurred after 4,860 ft of panel 7 had been extracted. This bump is significant in that it marks the return to tailgate abutment-pillar failure adjacent to the longwall face, and the end of face bumps. This change in location and the magnitude of the bump events may have been due to the proximity of the barrier pillars that were left to protect the submain entries from gob abutment loading.

DESIGN YIELDS IMPROVEMENTS

Following the experiences suffered on the previous panels, the mine modified the yield-abutment-yield configuration for the panel 8 development gate road in an attempt to improve ventilation between active and inactive gobs, to enhance entry stability and to control tailgate bumps. This new 238-ft-wide design consisted of yield pillars on 40-ft centers and abutment pillars on 140-ft centers. Between the yield pillars, the crosscuts were driven at 60° on 100-ft centers, whereas between the abutment pillars, the crosscuts were driven at 90° on 2,000-ft centers. This layout resulted in 20-ft by 80-ft yield pillars on either side of a 120-ft by 180-ft abutment pillar (Fig. 2).

The larger abutment pillars in this new design were intended to carry the applied abutment loads, and thus to prevent ground stresses from overriding the longwall face. Gauna reported that the new design required the mining of fewer entries per length of gate road and improved section advance rates, but slightly decreased the extraction ratio due to the leaving of a larger pillar in the gob.[3] Continuous miner production rates were unaffected by the change.

It has long been recognized that overburden thickness is a major factor in determining bump-proneness, and since this thickness is similar in the two study areas, the likelihood is that the tailgate bump problem would have developed during the mining of panel 8 if the gate road design had not been altered from the design that allowed bumps to occur in panels 6 and 7 (Fig. 2).

The structural competence of the immediate roof and floor within the panel 8 development gate road was confirmed by the conditions at site F (Fig. 4), while good roof and minimal floor heave were encountered in the tailgate adjacent to the face (Photo 2). Spalling of the panel 8 rib into the tailgate entry was evident over approximately the first 40 ft in advance of the face and minor instability was encountered during the mining of the face, in the area 20 to 40 ft from the panel 8 tailgate corner (Fig. 4).

Coal cutting induced cracking and minor spalling of the face, indicating that stress readjustment had taken place, but this was slight when compared to that encountered on face bumps *C* and *D*. The tailgate entry 200 ft in advance of the face was undisturbed by the mining taking place in panel 8.

Heaved floor occurred at and behind the face in the smoke-free entry (Photo 3), as well as in the crosscut between abutment pillars *A* and *B* (Photo 4). In addition to this, bumping of abutment pillar *A* occurred approximately 100 ft behind the face (Fig. 4). It therefore seems probable that the 120-ft by 180-ft abutment pillars, when subjected to high abutment zone stresses, form a solid column that punch into the mine floor, causing the floor to fail in a brittle fashion (Photo 3).

The smoke-free entry and the abutment pillar crosscut located 200 ft in advance of the face, were undisturbed by the mining of panel 8. Good strata conditions, essentially unchanged since the completion of panel 7, were observed in the smoke-free entry between abutment pillar *C* and yield pillar *G*. Roof-to-floor convergence data confirmed that, despite the abutment pillar bumping, the smoke-free entry was still open 200 ft behind the face.

The majority of the crosscuts between abutment pillars *B* and *C* remained unchanged since the completion of panel 7 and displayed minimal floor heave. The last 15 to 20 ft of the crosscut on the gob side experienced approximately 15 in. of floor heave during the mining of panel 7. Remarkably enough, similar floor-heave behavior was noted in the track entry and the yield pillar crosscuts.

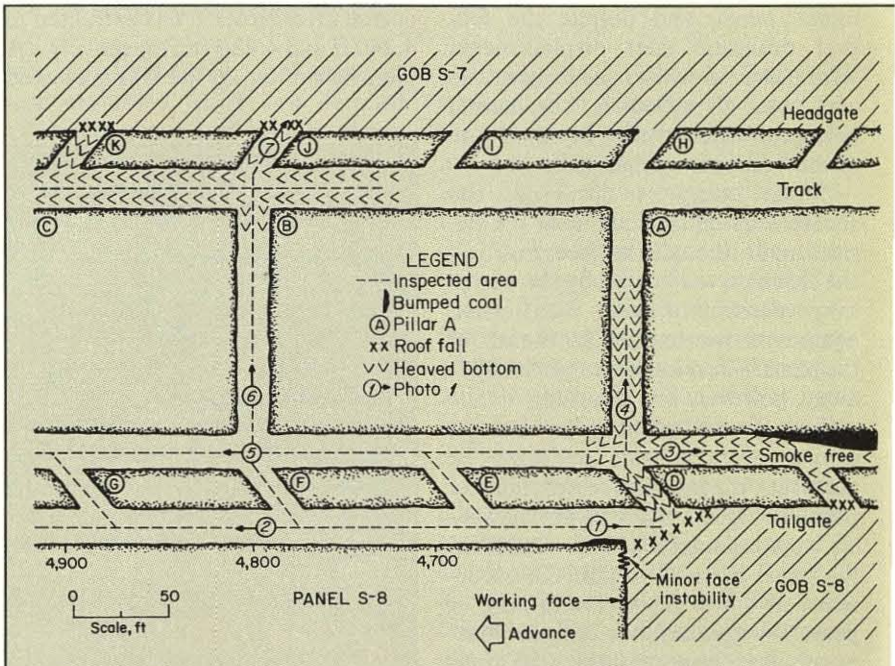

Fig. 4—Plan view of conditions at site F, within the panel 8 development gate road showing the extent and location of disturbance.

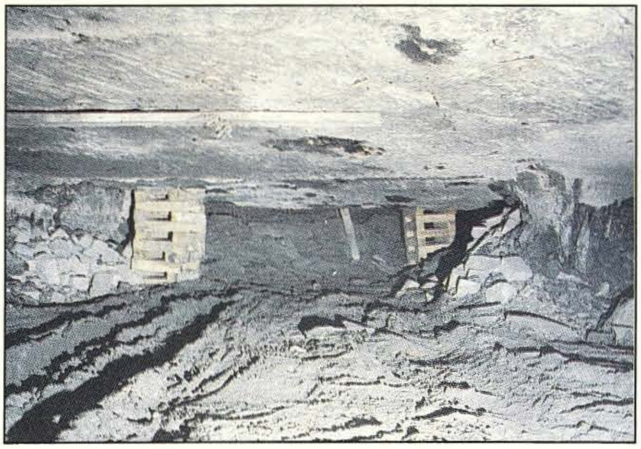

Photo 2 – Good roof and floor conditions at tail shield following alteration of the gate design.

Photo 3 – Brittle failure of bottom in smoke-free entry adjacent to mining of panel 8.

The good roof conditions directly adjacent to the panel 7 gob were representative of the entire study area.

INSTRUMENTATION RESPONSE

Analysis of the changes in coalbed stress revealed that the yield pillars in both designs failed during the extraction of the headgate panel. Roof-to-floor convergence, coal extensometer response and changes in coalbed stress effectively isolated the timing of abutment pillar failure in both gate road designs. The 80-ft square abutment pillars within the panel 7 development study area, which partially failed after the headgate pass was completed, reached their maximum load-bearing capacity 1,000 ft in advance of the tailgate pass, and began bumping 500 ft in advance of the longwall face. This sudden transfer of load to panel 7 resulted in further bumps on the tailgate corner of the longwall face.

The 120-ft by 180-ft abutment pillars within the panel 8 development study area reached their maximum load bearing capacity 200 ft in advance of the mining of the tailgate pass and did not bump until they were approximately 100 ft into the gob. Thus, the new design effectively shielded panel 8's working face from excessive loading. This was confirmed by analyzing the changes in coalbed stress that occurred at the tail side edge of panel 8, as well as the lack of face bumps during the panel's advancement.

The average change in abutment pillar stress, as induced by the headgate pass monitors, was approximately 6,000 psi for both gate designs. The yielding of the inner core of the 120-ft by 180-ft abutment pillars, however, occurred long after the yielding of the 80-ft square abutment pillars.

Coal extensometers demonstrated that the abutment pillars of both designs formed a 12- to 15-ft wide yield perimeter zone. Coalbed stress instrumentation also indicated that the depth of the yield zone was 15 ft. It is suggested by this study that 15 ft is the width of the yield zone in Pocahontas No. 3 coalbed pillars at ultimate strength, and that this width did not significantly change when the two-dimensional size was increased. Therefore, any increase in pillar size should result in a direct increase in confined core size.

Based on the 15-ft-wide confinement zone, the ratio of maximum stress core area to original pillar area for the 80-ft square and 120-ft by 180-ft abutment pillars is 0.39 and 0.63, respectively. This 62% increase in functional bearing area per footage of gate road, reduced abutment pillar stress and deformation, and mitigated load transfer to the tailgate corner of panel 8 has resulted in

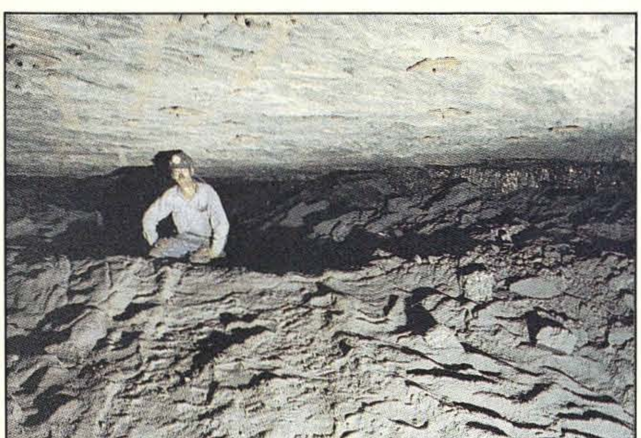

Photo 4 – Conditions in abutment pillar crosscut adjacent to mining of panel 8.

Photo 5 – Good strata conditions at the edge of panel 7 and gob 200 ft in advance of the mining of panel 8.

the successful elimination of the face bumps that had occurred when using the original gate road design.[4]

THE BOTTOM LINE

The superior performance of the panel 8 development gate road design compared to the previous design was confirmed by in-mine observation and instrumentation response. Under worst case conditions, the 120-ft by 180-ft tailgate abutment pillars did not begin to bump until they were approximately 100 ft into the gob. The previously employed 80-ft square tailgate abutment pillars bumped 500 ft in advance of the face, thus allowing load transfer to the mined panel. Furthermore, the new design greatly reduced the intensity of tailgate abutment pillar bumps when they did occur. In this way, the 120-ft by 180-ft abutment pillars, within the panel 8 development gate road, shielded panel 8 from the excess loads that caused the face bumps at the tailgate corner of panel 7.

The improved gate road design will permit high extraction, retreat longwall mining through bump-prone conditions, with the minimal risk of destructive face bumps. Insight into what determines the ultimate strength of coal pillars and the effects of yield zone confinement at pillar failure have further advanced the current knowledge of bump prevention based on longwall gate road design. □

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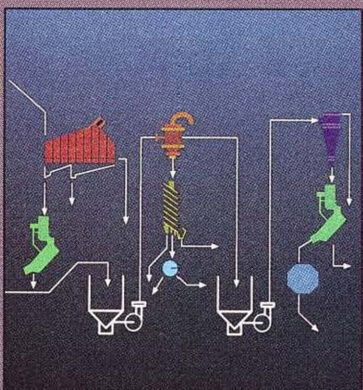
Cover Story



COAL PREPARATION

To satisfy tough market demands, coal producers strive to offer a wider range of higher quality products. Coal preparation is the means to that end. New process control schemes and on-line coal analysis now drive many of the improvements in preparation, as two articles in this issue describe. Also, the editors report on cyclones—critical machines in nearly every preparation plant flowsheet.

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