Multiple Seam Mining Interactions:
Case Histories From the Harris No. 1 Mine

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ABSTRACT

The Harris No. 1 Mine, located in Boone County, WV, has been longwalling the Eagle Coalbed for over 30 years. Harris has experienced numerous interactions associated with the extensive room-and-pillar and longwall mining operations which have been conducted in the overlying No. 2 Gas Coalbed. The problems have included roof falls, excessive rib sloughage, and gateroad and bleeder entry closure. A detailed evaluation of the multiple seam experiences at Harris No. 1 Mine was conducted as part of the National Institute for Occupational Safety and Health (NIOSH) nation-wide multiple seam mining case history data base. One observation from the Harris gateroad case histories was that smaller, critically loaded, upper seam pillars seemed to cause more severe ground conditions than did wider pillars. The LaModel program was used to investigate this supposition, and the results confirmed that “critical” sized pillars do transmit the highest amounts of stress to adjacent seams. In addition, the data suggest that the probability of a major multiple seam mining interaction increases when the depth of cover is 1,000 ft or greater and when the Eagle seam pillars have a Analysis of Longwall Pillar stability factor less than 1.50.

INTRODUCTION

The National Institute for Occupational Safety and Health has recently completed a comprehensive nation-wide data base of multiple seam mining case histories. To collect the case histories, underground geotechnical evaluations were conducted at more than 45 U.S. coal mines. The data is currently being analyzed in order to ascertain the relative importance of the various contributory mining and geologic parameters responsible for multiple seam mining interactions. The ultimate goal is to provide the mining community with a design methodology for multiple seam mining which will aid in determining the likelihood of adverse interactions so that corrective measures can be taken to prevent injuries and fatalities.

During the study, 22 multiple seam case histories were collected from the Harris No. 1 Mine, more than at any other mine site. An area was deemed to be a case history if a multiple seam interaction occurred or should have been anticipated. This accumulation of such a significant number of cases over a relatively small geographic area presented an excellent opportunity to conduct a study which would evaluate the current state-of-the-art in multiple seam design. In other words, can the criteria that engineers employ to predict whether or not a multiple seam interaction will occur be used to explain Harris’ experiences?

The Harris No. 1 Mine is operated by Eastern Associated Coal Corporation which is a subsidiary of Peabody Energy. Harris is located in Wharton, WV, and began operations in 1966 (figure 1). Since then, Harris has driven and retreat mined over 60 longwall panels in the Eagle Coalbed. The No. 2 Gas Coalbed is situated approximately 200 ft above the Harris Mine workings. Both longwall and room-and-pillar retreat mining have been conducted in the No. 2 Gas. In many cases, remnant structures such as barrier pillars, isolated gateroads (gateroads which are bordered by gob on both sides), etc. that were left in the 2 Gas have caused difficult ground conditions in Harris due to downward load transfer. In other instances, upper seam structures have not noticeably impacted mining. From the mine planning perspective, the paramount question is: When will multiple seam problems occur and how severe will the interaction be? The purpose of this investigation was to shed some light on these questions by conducting detailed analyses of Harris’ experiences.

Figure 1. Harris No. 1 Mine location map.

GEOLOGIC SETTING

The topography above Harris No. 1 Mine is fairly rugged. The valleys are narrow and "V" shaped and ridges are steep and prominent. These physiographical features can cause rapid changes in cover over relatively short horizontal distances. The overburden at Harris ranges from 100 ft at the drift to slightly over 1,400 ft under the highest ridges. As is the case with most Central Appalachian coal mines, the overburden is relatively competent.

Previous researchers (1-3) have determined correlations between multiple seam interactions and the interburden competency, thickness, and number of interbeds (number of distinct rock units within the interburden); therefore, considerable emphasis was placed on obtaining core hole information as close to the case history sites as possible. The information on interburden characteristics is listed in the Appendix. As indicated in the Appendix, the interburden between the Eagle and No. 2 Gas ranges in thickness from 176 to 213 ft.

Figure 2 is a generalized stratigraphic column of the interburden between the No. 2 Gas and Eagle Coalbeds. It should also be noted that the major sandstone and shale units shown in figure 2 vary in thickness. For example, in a few of the core holes the upper two sandstone units merge into a 100 ft thick unit. The same can be said for the lower two sandstone units. These rock unit thickness variations suggest ancient stream channel activity. Usually, the interburden contains 6 distinct rock units; however, the actual number varies from 4 to 7. In general, the interburden is rather competent, with the percentage of sandstone, sandy shale, and limestone ranging from 59 to 80 percent. The coalbeds between the Eagle and No. 2 Gas shown in figure 2 have not been mined above Harris.

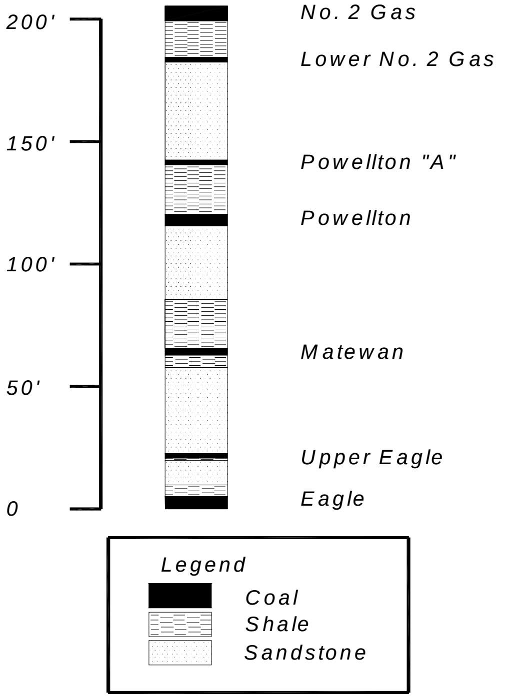

Figure 2. Generalized interburden stratigraphy.

Another factor identified in determining the magnitude of the interaction is the immediate roof rock competency (4). The shale unit shown in figure 2 directly above the Eagle Coalbed varies in thickness from 0 to 10 ft. In areas of Harris, this shale unit can either be laminated, sandy, or nonexistent (replaced by a sandstone scour). These fluctuations explain the range in Coal Mine Roof Rating (5) values from 44 to 71. These values indicate that the immediate roof rock is moderately strong to strong.

GATEROAD DESIGN AND SUPPORT

Harris began longwall operations with a 300 ft wide plow face and 40 ton walking frames in 1966. Since then, numerous technological innovations have lead to improvements in the longwall systems and gateroad supplemental supports employed. Currently, Harris is mining 3.2 million clean tons of coal per year. Gateroad pillar design and supplemental support selection have also gone through an evolutionary process at Harris based on the performance of past longwall faces and gateroads. In fact, twelve different gateroad designs which incorporated various elements of a 3-entry, 4-entry, and yield pillar designs have been tried at Harris. The gateroad system design was progressively refined and calibrated through the back analyses of previous successful and not so successful mining attempts.

The engineers at Harris utilize the novel approach of integrating the multiple seam stress transfer values obtained from the LaModel program (6) into the Analysis of Longwall Pillar Stability program (7) in order to obtain a more realistic stability factor (SF). This methodology is described in the Discussion section of this paper. For the past 5 years, Harris has been using a 3 entry gateroad system with entries on 90 ft centers and crosscuts on 140 ft centers. This system has worked well and no gateroad blockages have occurred since its usage began. Based on past experiences, during mine design Harris' engineers adhere to the following "rules-of-thumb" as much as possible: 1) the long axis of the panel to be mined should be parallel to that of the upper seam panel, 2) the future headgate should be positioned under, and as close to the center of the gob as possible, and 3) avoid advancing the longwall face under a gob/solid boundary (8).

Harris uses 5 ft full column resin bolts on 4 ft centers in the headgate entry. In the remaining gates and bleeders 4 ft full column resin bolts on 4 ft centers are standard. The roof control plan also stipulates that a minimum of 2 crib equivalents be installed every 12 ft in the tailgate. Floor heave has always been a major concern at Harris. Because conventional cribs (both 4 and 9 point) are inclined to roll out when subjected to heave, Harris began using 30 inch engineered timber supports. These supports have performed well, in that the floor tends to heave up around the supports.

The engineers at Harris also use the LaModel program to identify high vertical stress areas which are caused by deep cover, abutment loads, and/or multiple seam stress transfer. In highly stressed areas, either 2 or 4, 12 ft long cable bolts are installed in between each row of primary supports. Sometimes, additional engineered timber supports are warranted in tailgate locations. The spacing of these supports is dependent upon the expected level of stress.

CASE HISTORY ANALYSES

A detailed examination of both the No. 2 Gas and Harris No. 1 workings (figure 3) revealed 22 case histories where multiple seam interactions happened or might have been anticipated. In each case history, gateroads were driven and panels were extracted under various upper seam structures, and the outcomes are listed in the Appendix. Overburden depth, interburden thickness and composition, and additional consequential mining parameters, which are thought to determine whether or not interactions will occur (1-3) are also listed in the Appendix. Prior to the analyses, the data base was separated into two categories, gate entry workings (17 cases) or longwall face stability (5 cases) because of the major differences between the two. A rating system from 1 to 6 (see the Appendix for details) was developed to numerically evaluate the conditions or degree of interaction for each case. For the purpose of analyses, conditions 1 and 2 were combined and categorized as being a minor interaction because the interactions were barely negligible to minor. Conditions 3 through 6 were combined and designated as being a major interaction because the interactions were troublesome to major and warranted that special measures to be taken.

A series of XY scatter plots were generated in order to examine the various mining and geologic parameters for correlations. Figure 4 indicates that 6 out of 7 of the major interaction gateroad workings cases occurred when Harris' depth of cover was 1,000 ft or greater and the Analysis of Longwall Pillar Stability Factor (ALPS) was 1.5 or less. Further, figure 5 points out that 5 out of 7 of the major interaction cases occurred when the No. 2 Gas ALPS

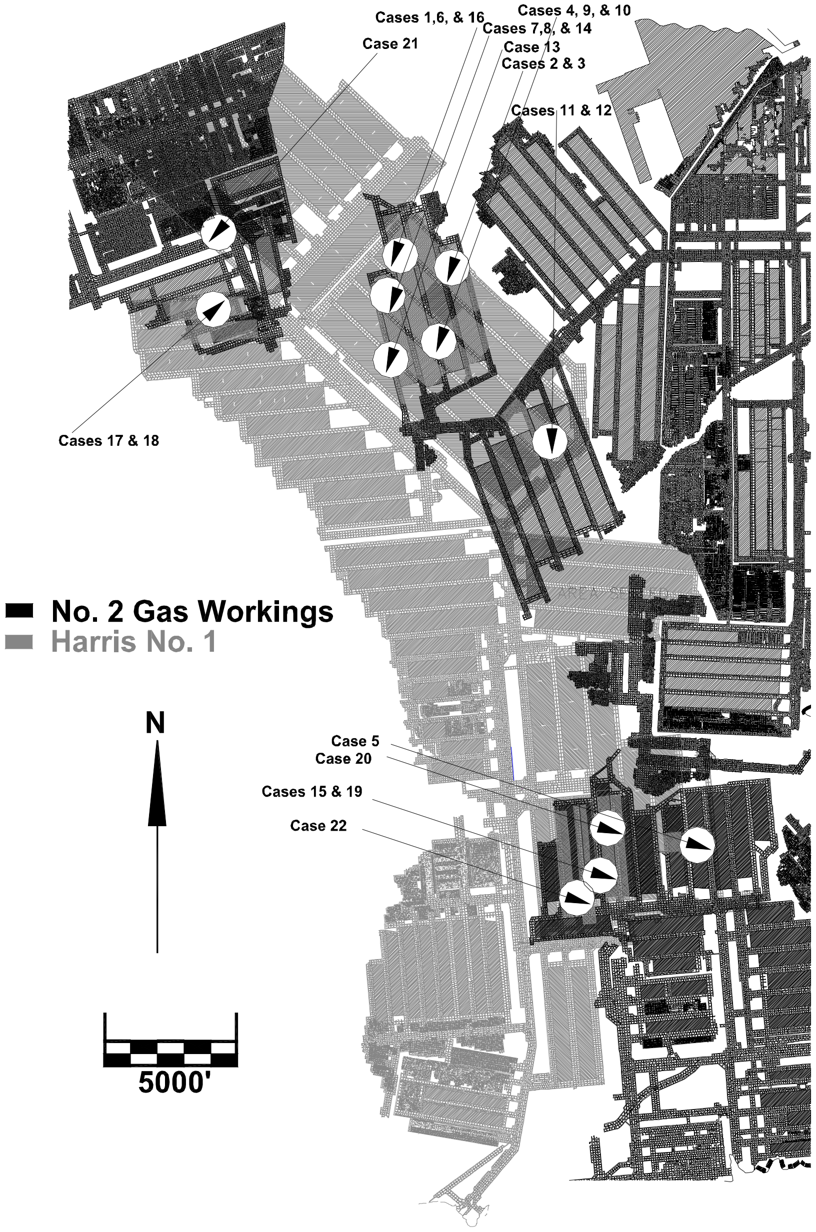

Figure 3. No. 2 Gas workings superimposed on Harris No. 1 Mine.

SF was less than 1.0 and the depth of cover was 1,000 ft or more in Harris. Finally, figure 6 illustrates a weak correlation between problematic cases and a No. 2 Gas overburden/interburden ratio of 3.9 or greater. As for the five longwall face stability cases, the only parallels that could be drawn were that the depth of cover was primarily 1,000 ft or greater, and the immediate roof rock was enerally relatively weak. Upper seam pillar design did not appear to be an issue; however, both it and the findings mentioned in this section warrant additional examination and discussion.

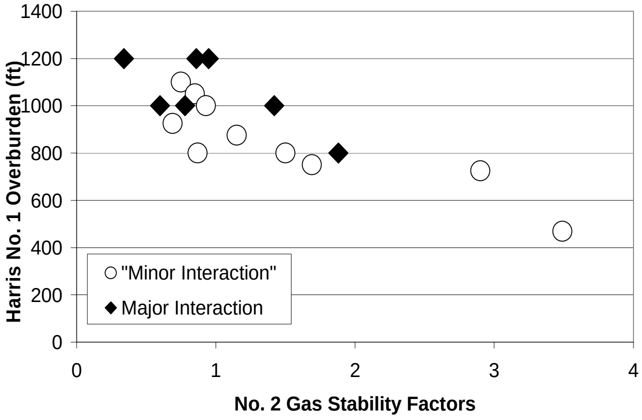

Figure 5. Relationship between degree of interaction and the No. 2 Gas ALPS stability factors and Harris No. 1 overburden.

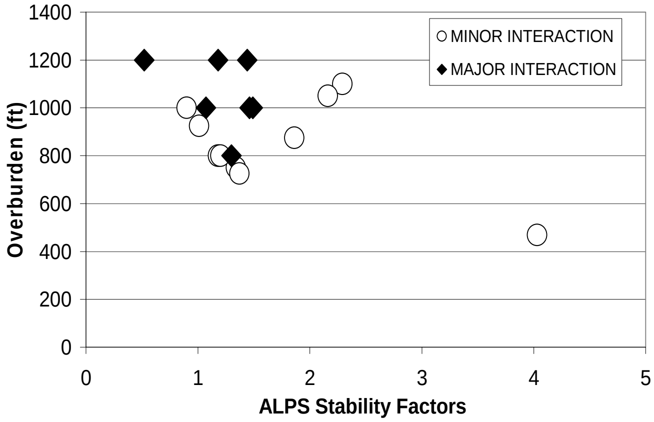

Figure 4. Relationship between degree of interaction and the Harris No. 1 ALPS stability factors and overburden.

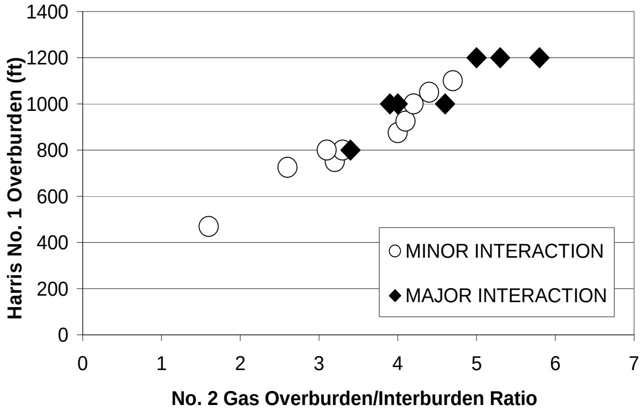

Figure 6. Relationship between degree of interaction and the No. 2 Gas overburden/interburden ratio and Harris No. 1 overburden.

UPPER SEAM PILLAR DESIGN

As indicated in the previous section, most of the multiple seam interaction problems in Harris' gate entries occurred when the upper seam ALPS SF's were less than 1.00. At first, it might seem counter-intuitive that smaller upper seam pillars would cause more severe stress conditions in an underlying seam than would wider pillars. However, a consideration of the load distribution in the upper seam pillars provides an explanation. Essentially, three load distributions are possible, as shown in figure 7:

- A) illustrates a small, yielded pillar that carries a relatively small load;
- B) illustrates a wide pillar, with localized high stress zones near the ribs but a lightly loaded core, and,
- C) illustrates the load distribution of a "*critical pillar*," with a highly loaded core.

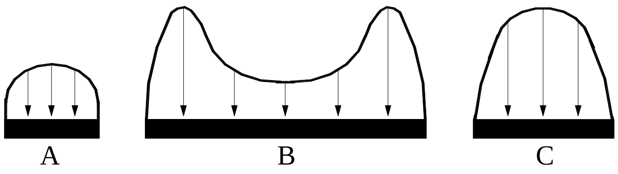

Figure 7. Pillar loads distribution diagrams:
(A) yielded (B) wide (C) critical

The critical pillar would result in the most severe "footprint" on the lower seam, because it produces an intensified downward "point load" type of stress transfer to the underlying workings. The wide pillar may carry a larger total load, but because that load is distributed over a much larger area, its effect on the lower seam is less noticeable. A good analogy would be the imprints that a petite woman in high heels might make in wet sand compared with those made by a sizeable football player wearing tennis shoes.

LaModel, a displacement-discontinuity boundary element program was used to evaluate the hypothesis described above. The models were run using standard default parameters and yield zones. Figure 8 displays the basic layout of the two mine designs which were modeled. In the Harris design case, a three entry longwall gate entry development section (oriented from top to bottom on figure 8) was driven on 120 ft entry and crosscut centers in a 6 ft high reserve. The pillars had an ALPS SF of 3.07 and the depth of cover was 1,200 ft. A three entry isolated gateroad system (oriented from left to right on figure 8) was then situated 200 ft above Harris. The crosscut center spacing in the No. 2 Gas remained constant at 140 ft. The entry centers were varied from 30 to 180 ft in 10 ft increments for each LaModel run and the mining height was 6 ft. As illustrated in figure 8, the No. 2 Gas and Harris workings are situated perpendicular to one another so that four pillars were stacked in the center of the LaModel grid. Figure 8 also displays the LaModel analysis results for a No. 2 Gas gateroad system with 60 ft wide pillars. Figure 8 clearly shows that the multiple seam stress transfer magnitudes in Harris are the highest beneath the isolated gateroads. Conversely, the de-stressing effects of the overlying gob are also evident in figure 8.

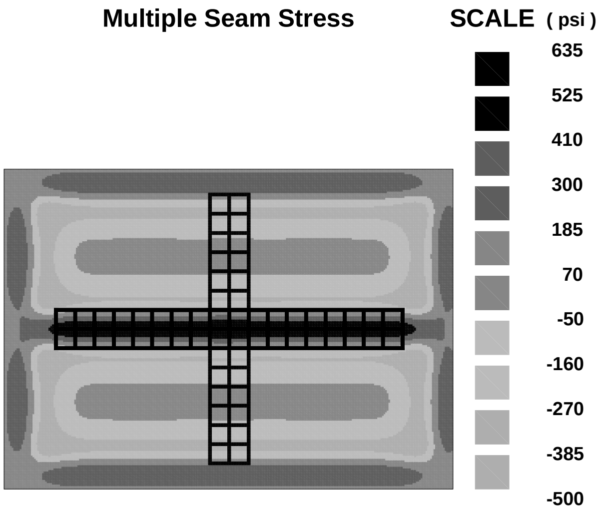

Figure 8. LaModel output for 60 ft wide No. 2 Gas pillars.

Figure 9 displays the peak multiple seam stress transfer value and the ALPS SF for each pillar width modeled. Figure 9 illustrates the wide range in multiple seam peak stress transfer values which are dependent on the width of the pillar. When analyzing figure 9, the multiple seam stress transfer curve appears to have three distinct regions that correspond to the three upper seam load distributions shown in figure 7. The peak or "critical" multiple seam stress transfer values occur when the chain pillars in the upper seam are in the 50 to 90 ft range. The models indicated that the cores of these pillars were all heavily loaded. On the left side of the critical pillar region, the models showed that the stresses in the cores of smaller, upper seam pillars were much lower than for the critical pillars. The smaller the pillar, the lower the peak stress, and the less the multiple seam stress experienced in the lower seam. On the right side of the critical pillar region, as the upper seam pillars get wider, they distribute their load more evenly. The result is a steady decreasing trend in downward stress transfer as the pillar width is increased up to around 130 ft. Once the pillar reaches a certain width, there is essentially no interaction between the two high-stress zones at the ribs and the peak stress transfer levels out at approximately 350 psi.

DISCUSSION

For want of a better adjective, the term "critical" was used to describe the pillars whose size transferred the highest multiple seam stress values. Obviously the word critical conjures up different meanings depending on whether you are designing deep cover gateroad yield pillars or mining in bump prone ground conditions. However, from a multiple seam aspect, the LaModel analyses indicate that critically-sized upper seam pillars can increase the lower seam pillar stresses substantially. In this study, the LaModel results were used to calculate the average stress increase in a Harris tailgate pillar system caused by isolated No. 2 Gas gateroads on 80 ft wide entry centers. The calculated average multiple seam pillar stress was 396 psi, which is approximately equivalent to increasing the depth of cover by 360 ft. Therefore, a Harris tailgate system which was initially designed for 1,200 ft of overburden and having a conservative ALPS SF of 1.23 was, in actuality, being subjected to cover loads equivalent to 1,560 ft of overburden which effectively reduces the ALPS SF to 0.88. This example emphasizes the importance of both estimating and incorporating multiple seam stress transfer into the pillar design process. It implies that wider pillars with higher ALPS SF's should be employed; however, gateroad developmental constraints also need to be considered. The engineers at Harris are currently using this methodology to design gateroad pillar systems and, based on past experiences, an ALPS SF in the 1.0 to 1.2 range (taking into account the additional multiple seam stress) has been determined to provide satisfactory results. It should be noted that the stress transfer values and critical pillar dimension widths previously mentioned are case specific and will vary depending upon the input parameters.

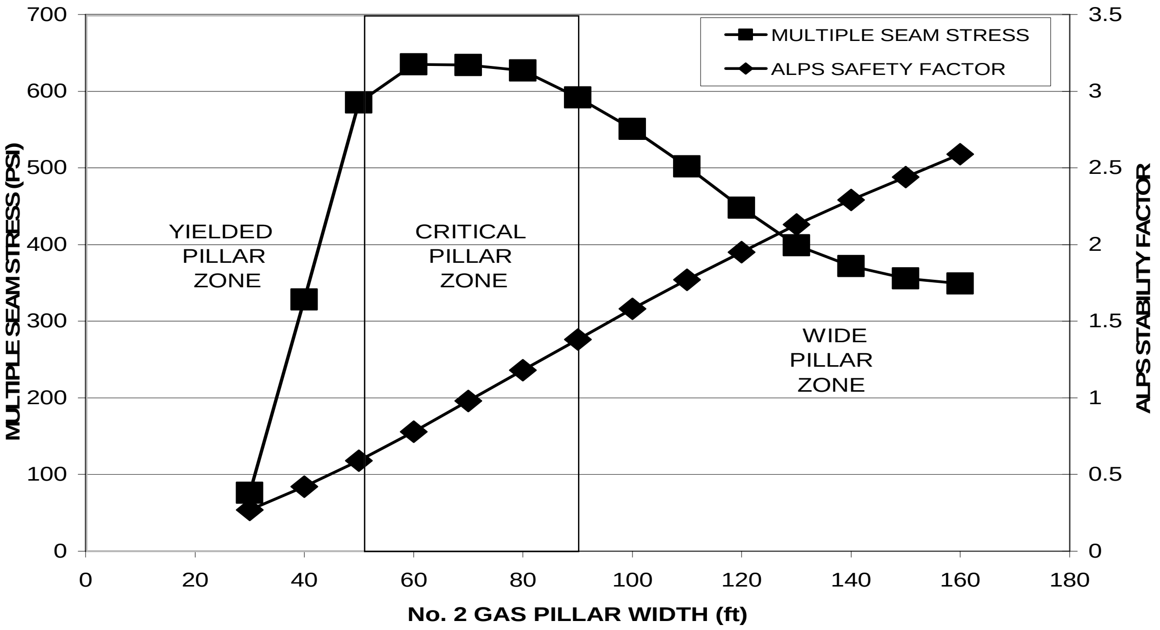

Figure 9. Peak multiple seam stress transfer values and the ALPS SF's for modeled pillar widths.

As stated in the case history analyses section, 6 out of the 7 major interactions occurred when the Harris depth of cover was 1,000 ft or greater and when the ALPS SF was less than 1.50 (figure 4). The cover relationship is noteworthy, in that, most operators maintain that there is a correspondence between multiple seam interaction difficulties and overburden. Typically, operators state that troubles generally begin occurring at roughly 800 ft of cover. Essentially, it takes a certain amount of cover load to cause downward load transfer problems. One possible explanation for the higher cover value at Harris may be interburden competency. It is conceivable that the three sandstone units which comprise 59 to 80 percent of the interburden are bridging, and therefore dampening the downward load transfer. As for the Harris ALPS SF's, figure 4 suggests that the probability of a major interaction occurring decrease as the stability factor increases. The same can be said for the No. 2 Gas ALPS SF's. As shown in figure 5, 5 out of 7, or 71 pct of the major interaction cases occurred when the No. 2 Gas ALPS SF was less than 1.0 and the depth of cover was 1,000 ft or more in Harris. Based on the above mentioned findings, a certain amount of concern and supplemental support are probably warranted when dealing with deep cover and lower upper and lower seam ALPS SF's. Like the old longwall adage goes, "it is better to be safe than be shut down." (It should be noted that multiple seam stress transfer values were not taken into account when determining the ALPS SF's listed in the Appendix or shown on the figures.)

Data analyses also indicated that there was no relationship between the degree of interaction and the percentage of competent interburden. The same can be said for the interburden thickness/number of beds ratio. Conversely, there was a weak correlation with immediate roof rock competency. Generally, the Coal Mine Roof Rating (CMRR) was higher for the minor interaction cases. Another weak association previously indicated was the overburden/interburden thickness ratio value of 3.9. As a rule-of-thumb, problems generally do not occur until this ratio reaches 7 or 8. However, critically sized pillars may be an overriding factor in this particular situation.

CONCLUSIONS

The most significant findings of this investigation was that the size of the remnant upper seam structure can influence the extent of the multiple seam interaction. More specifically, this study suggests that smaller critically loaded upper seam pillars are more likely to cause lower seam ground control problems than are wider pillars. The LaModel program was used to examine this supposition and the results verified this premise.

This investigation also demonstrated how effective a tool LaModel is in determining multiple seam stress transfer magnitudes. Once this value is obtained, it can be incorporated into the ALPS or ARMPS programs to obtain a more realistic stability factor.

The back analyses of 17 gateroad case histories at Harris No. 1 indicate that the probability of a major multiple seam mining interaction occurring increases when: 1) the depth of cover is 1,000 ft or greater, 2) the upper seam pillars are critically loaded, and 3) the Eagle seam pillars have a non-adjusted ALPS SF (excludes multiple seam load transfer) less than 1.50. In areas where these criteria are met, Harris engineers have mitigated problems through pillar design modifications and the installation of supplemental support. Based on past experiences, the engineers at Harris have determined that an adjusted ALPS SF in the 1.0 to 1.2 range provides satisfactory results.

Finally, the analyses also identified a weak correlation between the degree of multiple seam interaction and the immediate roof rock competency (CMRR) and the overburden/ interburden thickness ratio. However, no relationship between the degree of interaction and the percentage of competent interburden or the interburden thickness/number of beds ratio was evident. This may be attributable to the lack of variability in this site specific data base. Possibly, the conclusions drawn from the analyses of the nation-wide multiple seam mining data base will concur with previous researchers' findings.

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REFERENCES

1. Holland, C.T. Effects of Unmined Seams of Coal by Mining Seams Above and Below. Proc. WV Academy of Science, 1947, p. 113-132.

2. Stemple, D.T. A Study of Problems Encountered in Multiple-Seam Mining in Eastern United States. MS Thesis, Virginia Polytechnic Institute and State University, Blacksburg, 1956, 188 pp.

3. Haycocks, C., M. Karmis, and B. Ehgartner. Multiple-Seam Mine Design. Paper in Proceedings of the International Symposium on Ground Control in Longwall Coal Mining and Mining Subsidence-State of the Art. AIME, 1982, pp. 59-65.

4. Luo, J., C. Haycocks and M. Karmis. Gate Road Design in Overlying Multiple Seam Mines. SME Preprint 97-107, 1997, 11 pp.

5. Molinda, G.M. and C. Mark. Coal Mine Roof Rating (CMRR) a Practical Rock Mass Classification for Coal Mines, USBM IC 9387, 1994, 83 pp.

6. Heasley, K.A. Numerical Modeling of Coal Mines With a Laminated Displacement-Discontinuity Code, Ph.D. Thesis, Colorado School of Mines, 1998, 187 p.

7. Mark, C. Pillar Design Methods for Longwall Mining. USBM IC 9247, 1990 p. 53.

8. Hsiung, S.M. and S.S. Peng. Design Guidelines for Multiple Seam Mining, COAL MINING, Part I, 24 (9), Sept. 1987, pp. 42-46 and Part II, 24 (10), Oct. 1987, pp 48-50.

APPENDIX

Harris No. 1 Case History Data Base

Case	H	h	LC	SF	INT	COMP INT %	No. 2 Gas h	LC	SF	H/ INT	INT/ # Beds	Angle	CMRR	Rating and Comments
1	750	6.6	TGL	1.34	180	62	6.0	ISO	1.69	3.2	25.7	33	54	(1) No problems were encountered while crossing under isolated gateroads.
2	925	6.3	TGL	1.01	180	62	6.0	ISO	0.69	4.1	25.7	33	54	(1) No problems were encountered while crossing under isolated gateroads.
3	469	6.6	HGL	4.03	180	62	6.0	BL	3.49	1.6	25.7	33	54	(1) Headgate was driven under bleeder entries without any problems. Panel was recovered without gateroad cribbing.
4	875	6.7	HGL	1.86	176	59	6.0	HGL	1.15	4	25.1	32	63	(1) No problems were encountered during gateroad advance or panel retreat under gateroad pillars.
5	725	6.8	TGL	1.37	199	72	6.5	BL	2.90	2.6	33.2	0	47	(1) Gateroads were successfully driven under longwall bleeder entries the entire length of the panel.
6	800	6.8	TGL	1.18	180	62	6.0	ISO	1.50	3.3	25.7	33	54	(2) Additional gate entry cribbing was required while crossing under isolated gateroads.
7	1000	6.1	TGL	0.90	193	74	6.0	ISO	0.93	4.2	32.2	33	56	(2) Additional gate entry cribbing was required while crossing under isolated gateroads.
8	1100	6.2	Dev	2.29	193	74	6.0	ISO	0.75	4.7	32.2	33	56	(2) Poor ground conditions required cable bolting on development while crossing under isolated gateroads.
9	800	6.8	TGL	1.20	193	74	6.0	ISO	0.87	3.1	32.2	33	56	(2) Additional gate entry cribbing was required while crossing under isolated gateroads.
10	1050	7.2	Dev	2.16	193	74	6.0	ISO	0.85	4.4	32.2	33	56	(2) Poor ground conditions required cable bolting under isolated gateroads.
11	1000	7.1	TGL	1.07	201	80	6.0	ISO	0.60	3.9	50.3	25	44	(3) Tailgate entries located below isolated gateroads experienced several roof falls. Numerous tensioned cable bolts were installed on 4 foot centers.
12	1200	7.3	TGL	0.52	201	80	6.0	ISO	0.34	5	50.3	25	44	(3) During face recovery, tailgate entries situated below isolated gateroads experienced excessive floor heave and roof falls.
13	1200	6.9	HGL	1.18	176	59	6.0	BL	0.95	5.8	25.1	32	63	(4) During panel recovery, 500 ft of tailgate closed.
14	800	6.1	TGL	1.30	180	62	6.0	BL	1.88	3.4	25.7	33	54	(4) During panel recovery, 1200 ft of the headgate entry heaved closed.
15	1000	6.3	HGL	1.49	199	72	6.5	ISO	0.78	4	33.2	0	47	(5) During panel recovery, the tailgate squeezed closed under a headgate.
16	1000	6.2	BL	1.46	178	71	6.0	BL	1.42	4.6	35.6	58	71	(5) During panel recovery, 750 ft of a 4 entry bleeder system squeezed shut.
17	1200	5.8	HGL	1.44	192	66	6.0	BL	0.86	5.3	32	76	44	(5) The headgate squeezed closed beneath bleeder entries after panel extraction.
18	1181	6.8	LW Face	N/A	192	66	6.0	ISO	0.73	5.2	32	14	44	(2) Two feet of face heave occurred while mining under isolated gateroads.
19	1000	6.7	LW Face	N/A	199	72	6.5	ISO	0.69	4	33.2	0	47	(2) Two feet of face heave occurred while mining under isolated gateroads.
20	675	7.6	LW Face	N/A	199	72	6.5	ISO	1.77	2.4	33.2	0	47	(2) Two feet of face heave occurred while mining under isolated gateroads.
21	1200	5.7	LW Face	N/A	178	79	5.1	LC2	15.86	5.7	44.5	63	62	(5) Longwall face went on squeeze under a gob/barrier pillar boundary.
22	1200	6.6	LW Face	N/A	213	71	6.5	BL	1.22	4.6	35.5	90	44	(5) Roof falls and weight on the face halted recovery under bleeder/gob boundary.

Legend

Angle	Intersection Angle
BL	Bleeder Loading
CMRR	Coal Mine Roof Rating
COMP	Competent
DEV	Development Loading
H	Mining Height (ft)
h	Overburden (ft)
HGL	Headgate Loading
INT	Interburden Thickness (ft)
ISO	Isolated Loading
LC	Loading Condition 2 (ARMPS)
LC2	Loading Condition
LW	Longwall
N/A	Not Applicable
SF	Stability Factor
TGL	Tailgate Loading
# Beds	Number of Beds in Interburden
%	Percentage

Rating Scale

1	Panel was developed and retreat mined with little or noevidence of multiple seam interactions.
2	Panel was developed and retreat mined with minor to moderate floor heave (less than 2 feet) and/or rib sloughage (less than 4 feet). Infrequent roof falls may also have occurred.
3	Panel was developed with minor difficulties. On retreat, pillars were occassionally abandoned due to roof falls and/or heavy pillar loading.
4	Panel was developed with greater difficulties and several pillars were lost on retreat due to adverse conditions.
5	Panel was extremely difficult to advance and could not be retreat mined.
6	Ground conditions necessitated that the panel be abandoned on development or deteriorating conditions over time closed the section