EVALUATION OF PILLAR RECOVERY IN SOUTHERN WEST VIRGINIA

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ABSTRACT

Pillar recovery continues to be a significant ground control hazard. During the past decade, 10 miners were killed during pillar extraction operations in southern West Virginia. Studies conducted during the past decade have identified a number of “risk factors” that can be used to evaluate pillar extraction plans:

- Cut sequence
- Final stump
- Timber or Mobile Roof Supports
- Roof bolting
- Intersection span
- Depth of cover
- Roof quality
- Age of workings

For each of these factors, rock mechanics science suggests which alternative would be expected to be more risky. For example, numerical models were used to evaluate different cut sequences, and indicated that less roof convergence occurred with the outside lift method than with the Christmas tree in the particular environment simulated. For many of the risk factors, accident statistics confirm the science. One finding was that currently almost 70% of the retreat coal in southern WV is being mined with MRS. In contrast, timber supports were used in 70% of the past decade’s pillaring fatalities. This paper discusses each of the risk factors in turn, presents the relevant accident statistics, and shows how the risk factors can be combined to estimate the overall hazard. It also addresses the use of pillar design to minimize the risk of global stability hazards including squeezes, massive collapses, and bumps.

ACKNOWLEDGMENTS

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INTRODUCTION

During the year 2001, nine roof fall fatalities occurred in the U.S. Of the nine, three occurred during pillar recovery operations.

Unfortunately, 2001 was not an unusual year. A NIOSH report issued in 1997 found that pillar recovery accounted for about 10% of all U.S. underground coal production, but was associated with about 25% of the roof and rib fatalities between 1989-96 (1). Figure 1 shows during the decade 1992-2001, there were a total of 82 roof fall fatalities in U.S. coal mines. Of these, 27 (33%) occurred during pillar recovery operations[1]. Six of the incidents (all outside West Virginia) resulted in double fatalities.

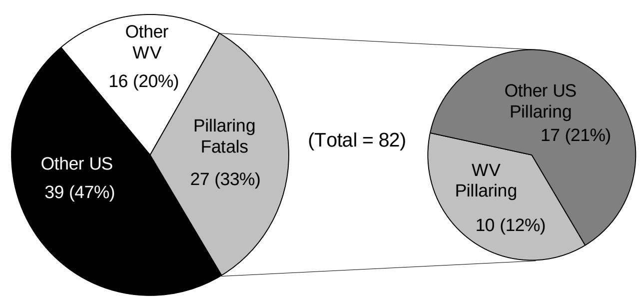

Figure 1. Ground Fall Fatalities in the U.S., 1992-2001.

This paper focuses on southern West Virginia, the coalfield with the greatest number of pillar recovery operations. Southern West Virginia was also chosen because the most complete set of data was available there. Lessons drawn from the southern West Virginia experience should be helpful to pillar recovery operations throughout the U.S. A nationwide study of pillar recovery is currently underway.

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[1]These statistics actually underestimate the number of deaths associated with pillar recovery. In two instances, one in Utah and one in West Virginia, miners were killed by shuttle cars as they attempted to flee premature roof collapses. Both fatalities were classified as “machinery” accidents.

During the past several years, the regulatory agencies and many mine operators in southern West Virginia have been very pro-active in implementing new safety technology to reduce the roof fall risk during pillar recovery. For example, the greatest concentration of Mobile Roof Supports in the U.S. is in southern West Virginia. However, the purpose of this paper is not to highlight any specific innovation or regulatory action, or to make comparisons between mining regions. Rather, it focuses on the technical ground control aspects of pillar recovery.

Pillar recovery is a complex process, and a wide variety of mining techniques are used to accomplish it. It seems evident that certain pillar recovery techniques, or certain aspects of the pillar recovery process, may be riskier than others. The goal of this paper is to isolate the most significant hazards associated with pillar recovery, so that the overall level of risk can be reduced.

PILLAR RECOVERY DEMOGRAPHICS AND ACCIDENT RATES

As part of this study, MSHA Roof Control Specialists from District 4 in Southern West Virginia were asked to provide information on pillar recovery practices in each of the mines they inspected. The data included whether the mine extracted pillars, what pillar recovery method they most commonly employed, whether the pushout was recovered, and whether the mine used Mobile Roof Supports.

The information was then linked with the MSHA accident and employment database (2) for the year 2000 (table 1). In all, information was available on mines that produced 47.6 million tons, or 83% of the total underground production in District 4 during 2000. Room-and-pillar mines that practiced pillar recovery accounted for 60% of the 47.6 million tons (three longwall mines in District 4 also engage in pillar recovery). Assuming that pillar recovery typically accounts for about one-third of the production at these room-and-pillar mines, then about 20% of the District 4 underground production comes from pillar recovery.

Table 1. Demographics of pillar recovery in southern West Virginia in 2000

Mine Grouping	Summed hours (thousands)	Summed tons (millions)	Tons/hr	Ground fall injuries/ 200 Khrs
Longwall Mines	2,940	20.16	13.88	1.50
Room-and-Pillar, Non-Retreat	1,961	8.06	4.11	1.84
Room-and-Pillar, Retreat	5,710	34.09	5.97	2.35
ALL MINES	**12,512**	**66.11**	**5.28**	**2.14**
R&P Retreat, With MRS	3,853	21.13	19.09	2.91
R&P Retreat, Without MRS	1,858	12.96	13.45	2.40

The 1997 NIOSH report found that nationwide, the roof fall risk to miners during pillar recovery was about 3 times that of miners on development. Since 1991, 38% (10/26) of all fatal underground accidents in District 4 were the result of unplanned roof falls during retreat mining. With 38% of the fatalities associated with about 20% of the production, mathematically a coal miner on a pillar recovery section in Southern West Virginia was 2.5 times more likely to be fatally injured in a roof fall than a miner on an advancing section.

The same NIOSH report found that the roof/rib non-fatal injury rate was generally lower in pillar recovery mines than in other room-and-pillar mines. In District 4, for example, the retreat mine rate was 1.37 while the non-retreat rate was 1.64 (1). In 2000, however, the retreat mine roof/rib injury rate was 2.75, while the rate at other room-and-pillar mines was 1.84.

ROCK MECHANICS OF COAL PILLAR RECOVERY

When pillars are first developed, they must carry the entire weight of the overburden. If they are adequately sized, a new equilibrium is established, and ground control consists primarily of securing the immediate roof above the entry.

Pillar removal disturbs the equilibrium and creates an inherently unstable situation. Man-made supports cannot carry the full weight of the overburden. The roof is subjected to new stresses and deformations. The ground will cave in, the only question is when. Ground control means keeping the roof up until the miners have completed their work and left the area.

Prior to 1988, 30 CFR 75 drew a distinction between "full" and "partial" pillar recovery. Full pillaring was defined as extraction that allows total caving of the main roof, while partial pillaring left sufficient coal in place to support the main roof. However, many pillar plans fall between these two extremes, and the distinction can be blurred and confusing. This language was removed when the roof control regulations were revised and implemented in 1988.

A different approach is proposed in this paper. The goal is to achieve a safe and stable working area for the miners involved in pillar extraction, whatever pillar recovery method is used. This is achieved by minimizing the "risk factors" associated with different elements of the pillar recovery process. Risk factors are divided in two main groups:

- *Global Stability: Prevention of section-wide pillar failure.*
- *Local Stability: Prevention of roof falls in the working area.*

GLOBAL STABILITY RISK FACTORS

Proper pillar design is the key to ensuring global stability. There are three main types of pillar failure, each of which requires its own approach.

Pillar Squeezes

Squeezes occur when the pillars are too small to carry the loads applied to them. As the loads are gradually transferred, the adjacent pillars in turn fail. The results can include closure of the entries, severe rib spalling, floor heave, and roof failure. The process may take hours or days, and can cause an entire panel to be abandoned.

The Analysis of Retreat Mining Pillar Stability (ARMPS) program can be used to help size pillars to carry both development and abutment loads (3). ARMPS has been calibrated by back-analysis of hundreds of pillar recovery case histories. The database has recently been expanded to include more deep-cover cases, and new design guidelines have been proposed (see figure 2 (3)).

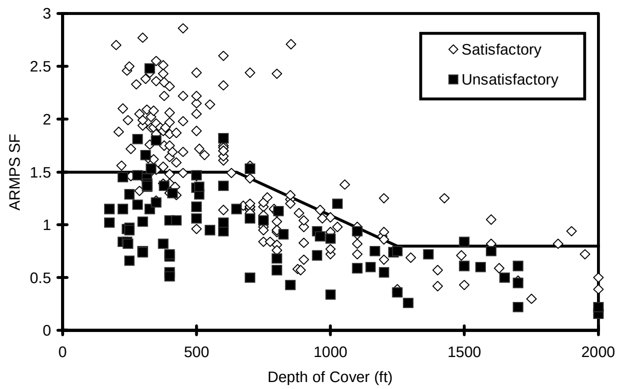


Figure 2. Suggested ARMPS Stability Factors, based on an expanded case history data base (3).

Massive Collapses

Massive collapses are pillar failures that take place rapidly and involve large areas. One effect can be a powerful, destructive airblast. Of fourteen massive collapses that have been documented since 1980, all but two have occurred in southern West Virginia. They have caused several injuries but, miraculously, no fatalities.

Data collected at the failure sites indicate that all the massive collapses have occurred where the pillar width-to-height (w/h) ratio was 3.0 or less, and the ARMPS SF was less than 1.5. Such conditions occur most often in worked-out areas where pillars have been split. Guidelines for preventing or containing massive collapses have been published (4). These guidelines have been largely implemented in southern West Virginia since 1998, and no documented massive collapses have occurred since then.

Pillar Bumps

Bumps are sudden outbursts of coal and rock that occur when stresses in a coal pillar cause it to rupture without warning, sending coal and rock flying with explosive force. Of the 172 bumps included in the NIOSH coal bump database that extends back to 1950, 54 (31%) occurred in southern West Virginia. The most recent incident there was a double fatality in the Beckley seam nearly 10 years ago. Pillar retreat mining or barrier splitting accounted for 50% of the bumps in the nationwide database. Nearly 95% of the bumps occurred at depths greater than 1,000 ft (5).

Research has shown that bumps are much less likely when barrier pillars isolate each new panel from the abutment loads transferred from nearby gob areas. At depths of greater than 1,000 ft, Chase et al. (3) suggest that properly designed barriers can enhance pillar line stability. Special extraction techniques, such as the thin pillar method, can also be helpful.

LOCAL STABILITY: PRIMARY RISK FACTORS

Global stability is a necessary, but not sufficient, condition for creating a safe working area. Local stability depends on a number of factors, of which the following four are most critical.

Cut Sequence

By far the most popular methods of pillar recovery used today are those that require no additional roof bolting during retreat. A study of representative roof control plans from mines nationwide found that 50% used some form of Christmas tree sequence, 42% used outside lifts, and 23% used some type of three-cut plan (figure 3). In contrast, split-and-fender and pocket-and-wing plans were in place at only 19% and 8% of the mines, respectively (7). Note the total percentage is greater than 100% because many mines use more than one sequence.

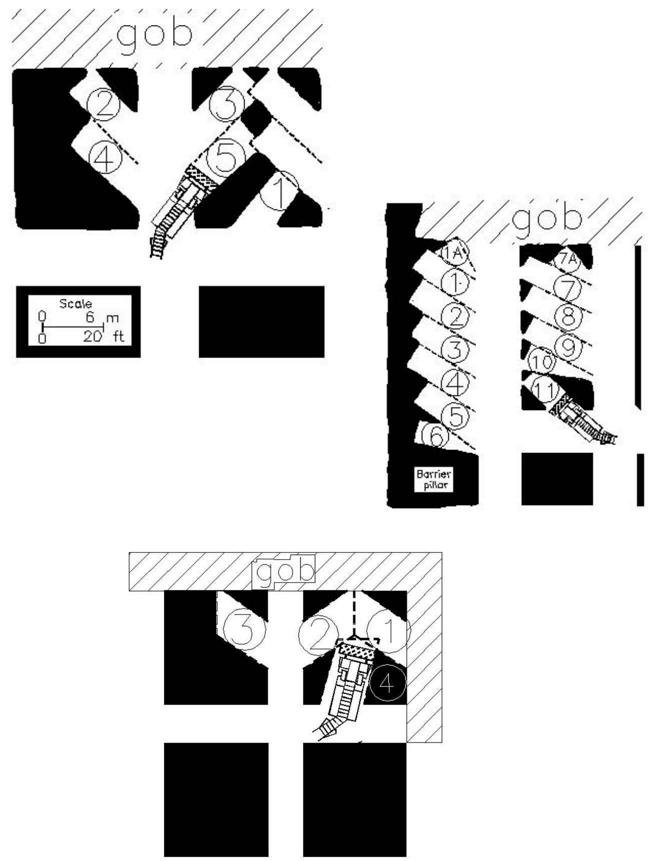
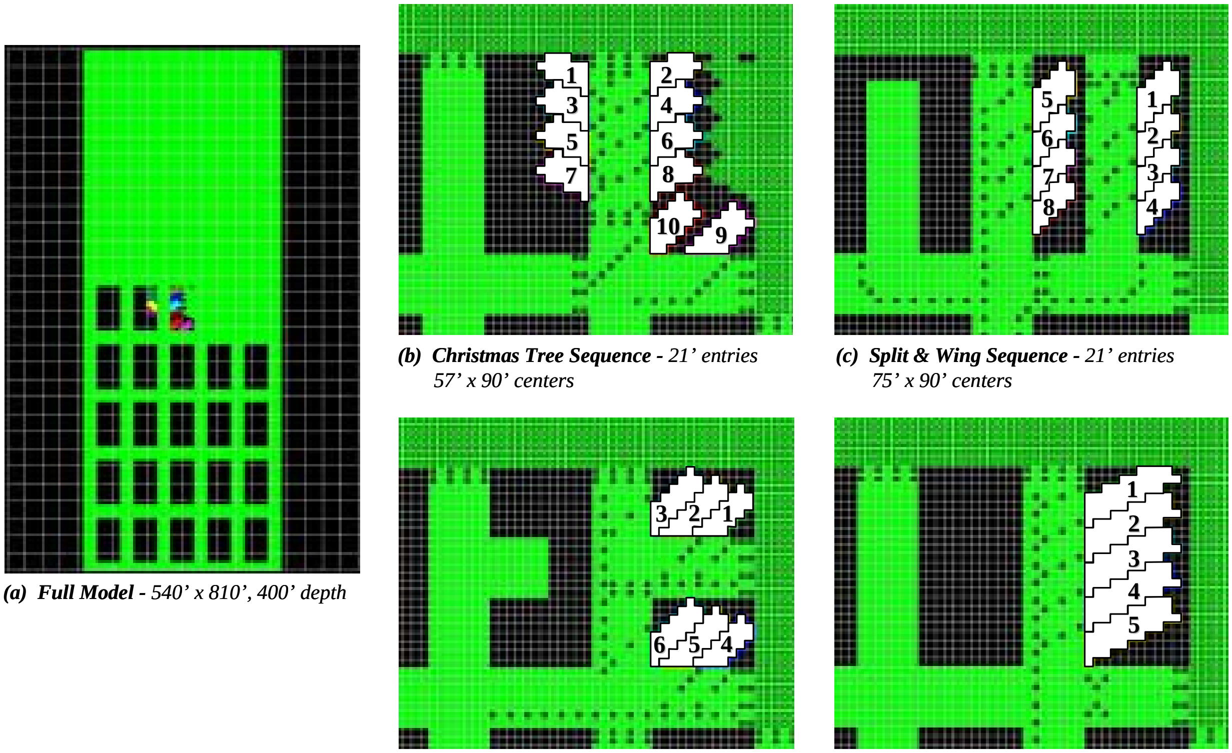


Figure 3. Common cut sequences used in the eastern U.S. Top: Christmas tree. Middle: Outside lift. Bottom: Three cut.

The information provided by the MSHA Roof Control Specialists indicates that the Christmas tree method is nearly universal for high-extraction pillar recovery in southern West Virginia. With the Christmas tree method accounting for at least 90% of high extraction pillar recovery, it is not statistically significant that 9 of the 10 pillar mining fatalities between 1992-2001 occurred on Christmas tree sections. In 7 of these incidents, the miners were in compliance with the approved roof control plan when the fatality occurred.

Outside of West Virginia, just 2 of the 11 fatal incidents occurred where a full Christmas tree plan was being used. In several other incidents, however, the mines employed 3-cut plans with lifts taken left and right from the same entry. There was only one fatality where an outside lift plan was used. Data on the prevalence of the different pillaring methods outside of southern West Virginia is not yet available, so the significance of these numbers cannot be determined.



***(a) Full Model** - 540' x 810', 400' depth*

***(b) Christmas Tree Sequence** - 21' entries 57' x 90' centers*

***(c) Split & Wing Sequence** - 21' entries 75' x 90' centers*

***(d) Pocket & Fender Sequence** - 21' entries 57' x 90' centers*

***(e) Outside Lift Sequence** - 21' entries 57' x 90' centers*

Figure 4. Computer model of retreat cut sequences.

From a rock mechanics standpoint, it makes sense to compare the Christmas tree to the outside lift method. Christmas tree plans are characterized by cuts being taken from both the left and the right pillars, while with outside lifts only one pillar is mined at a time[2]. Comparing just these two methods, the Christmas tree plan would be expected to be more risky than outside lifts because:

- Wider unsupported spans are mined;
- More time is spent at the same location (to complete both the right and left lifts), and;
- The operator of the remote controlled continuous miner (CM) may stand in a non-optimum location for either the left or the right lifts (see section below on "Operator Positioning").

The basic advantage of the outside lift plan is that operator always has a solid pillar at his back. It also has some disadvantages, however:

- It can't be used in wide pillars without leaving large remnant fenders of coal (and wide pillars may be required to meet global stability requirements in thick seams or under deep cover), and;
- It usually employs deeper cuts, making the CM more difficult to extract if it is trapped while extracting a lift by a roof fall or rib roll.

[2]The three-cut plans that are popular in some coalfields come in many varieties. Some resemble the outside lift, others employ left and right cuts like the Christmas tree. The percentage of coal recovered also varies widely, depending on the initial size of the pillar and the width and depth of the cuts. Because of the wide variety, the term "three cut" is not very descriptive, and specific plans must be evaluated on an individual basis.

To provide some further insight into the influence of the cut sequence on ground stability, the boundary element numerical model (BESOL) was used to compare four common pillar recovery plans in an identical mining environment (a 400-ft depth of cover and a 5-ft seam height). The mining methods evaluated were the Christmas Tree, Split and Wing, Pocket and Fender and Outside Lift. The particular pillar/opening geometries, cut sequences and timber supports (placed during each cut) used in each model were based on actual plans used by mines in southern West Virginia. Figure 4 depicts the general model geometry and the cut sequences used to simulate each of the pillaring plans.

Figure 5 shows convergence contours for each of the four mining methods after roughly one-third of the coal has been extracted. The 0.2-foot convergence level has been highlighted for reference purposes. The convergence data generated represents gross movement of the main roof/floor and higher levels would be indicative of increased potential for a roof fall.

- *Split & Wing* – Because of the substantial yielding of the narrow fenders, the 0.2-foot convergence contour engulfs the entire split and extends well into the intersection outby where the lifts are being taken.
- *Pocket & Fender* – The 0.2-foot contour level engulfs the entire work area and extends down the entry to a point just short of the intersection.
- *Christmas Tree* – The 0.2-foot convergence contour extends outby the last cut into the work area of the next cut.
- *Outside Lift* – The 0.2-foot level remains within the last cut taken.

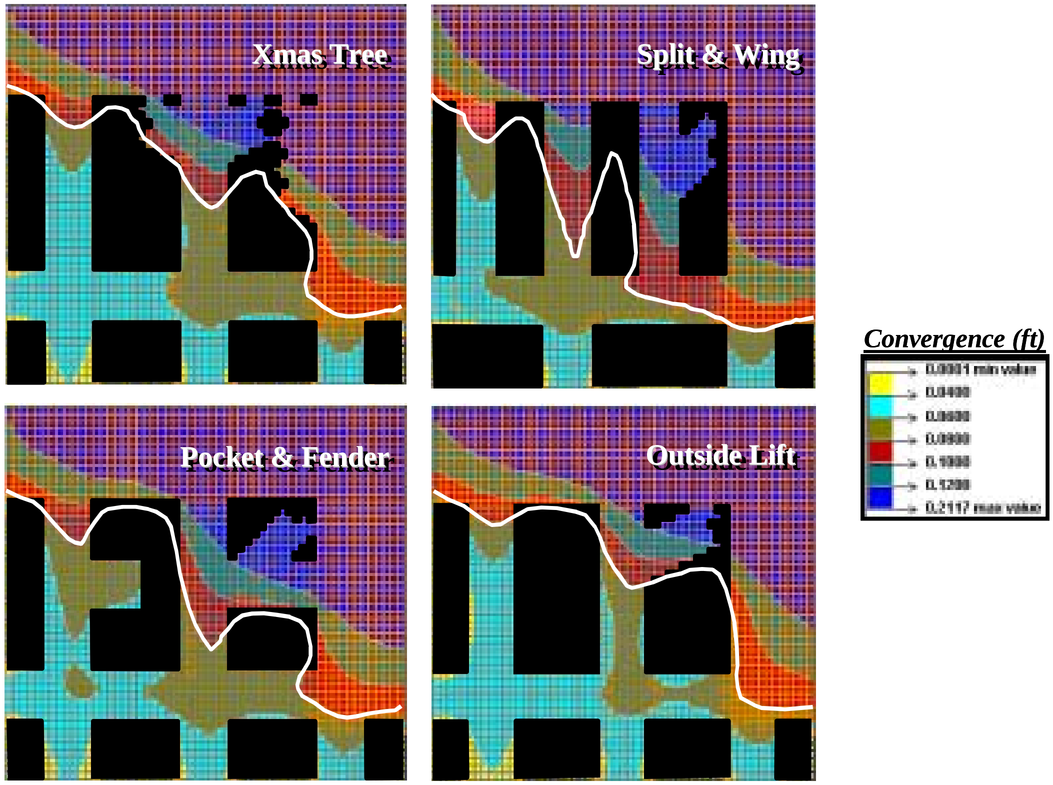


Figure 5. Roof convergence contours after several cuts. The 0.2 ft cut contour is highlighted in white.

In this particular scenario, the outside lift method appeared most likely to result in stable ground conditions. In general, the models indicate that high stress develops in the fender(s) being mined, that properly sized fenders withstand the stresses developed, and that undersized fenders yield prematurely - allowing gob pressures to override them and cause elevated convergence in the work area.

Final Stump or Pushout

The final stump is a critical element in roof control during pillar recovery. While in place, it helps protect the active intersection, which is generally the weakest link because of its wide span. Once the stump is removed, or is made too small to provide support, the intersection may become unstable, like a chair with one leg removed.

Between 1992 and 2001, 6 of the 21 nationwide pillar recovery fatalities occurred during extraction of the pushout or last lift. All but one of these incidents occurred in West Virginia. In other words, 50% of the West Virginia fatals involved the last lift. Since the final lift accounts for far less than 50% of the total time required to recover a pillar, this is clearly a very high-risk activity.

Traditionally, miners have been reluctant to leave the final stump because they were concerned that stumps in the gob would inhibit caving and cause a squeeze. Recent experience seems to indicate that fears about leaving stumps might have been exaggerated. In most cases, it appears that the optimum pillar extraction plan may be one that purposely leaves a final stump sized to provide roof support without inhibiting caving. Guidelines for sizing the final stump were recently published (6), and are summarized in table 2.

Table 2. Guidelines for sizing the final stump (7)

Seam Height (ft)	Stump size (ft)*
4	8.5
6	9.5
8	10
12	10.5

*Cut-to-corner distance (see figure 6).

For a stump to perform its function, it must not be cut any smaller than needed. Plans that specify a set number of lifts can result in undersized stumps if actual pillar dimensions are smaller than expected. A better practice is to specify the cut-to-corner distance (figure 6). Foremen can use spray paint to mark the stump dimensions on the rib as a guide to the CM operator.

Using the outside lift sequence for illustration, the numerical model shows what can happen as mining approaches the last lift. While maximum intersection convergence occurs when the pushout is mined (all coal support is removed) a critical increase in intersection convergence, with a corresponding potential for roof failure, can occur earlier in the sequence if the outby end of the pillar totally yields. Figure 7 shows that once cut 4 is taken, the final stump yields and the 0.2-ft convergence level suddenly propagates well into the intersection. Subsequent mining of the pushout (cut 5) would take place beneath roof that might already be unstable. Under the right circumstances, this condition could be expected with any pillar recovery cut sequence.

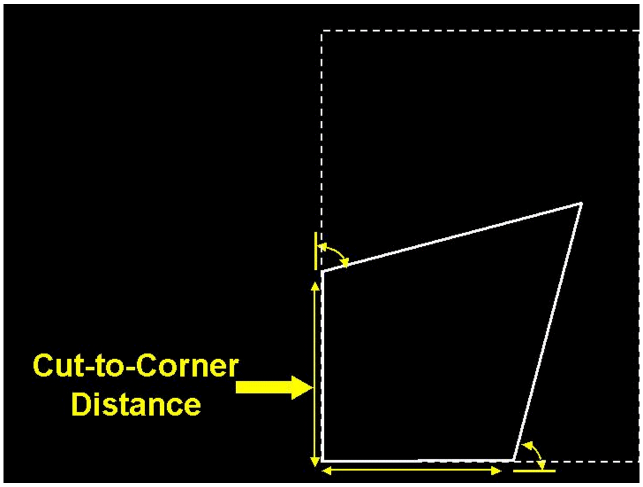


Figure 6. Cut-to-corner distances for the final stump (6).

Mobile Roof Supports vs. Timbers

Traditionally, timber posts provided supplemental support for pillar recovery. More than 100 roadway, turn, and breaker posts can be required to extract a single pillar. As supports, timber posts have a number of disadvantages:

- Setting them exposes miners to roof falls. During the past decade, two miners have been killed while setting posts, both of them in West Virginia;
- They have limited load-bearing capacity. A typical 6-inch diameter hardwood post can carry about 50 tons, but most actual posts have flaws and are even weaker;
- They have limited convergence range. Wood posts can break after only 1-2 inches of roof-to-floor convergence, and their post-failure strength is almost nil, and;
- Their weight and bulk result in material handling injuries, particularly in high coal.

For all of these reasons, both MSHA and NIOSH have advocated the use of Mobile Roof Supports (MRS) for pillar recovery. MRS are shield-type support units mounted on crawler tracks (figure 8). They were first employed in West Virginia in 1988, and more than 100 units were in use in the U.S. by 1997 (7). The advantages of MRS are that they:

- Are operated remotely, at some distance from the pillar line;
- Have a support capacity of 600 of 800 tons per unit, and are employed in pairs or sets of four;
- Can maintain their load even if the roof moves downward more than a foot, and;

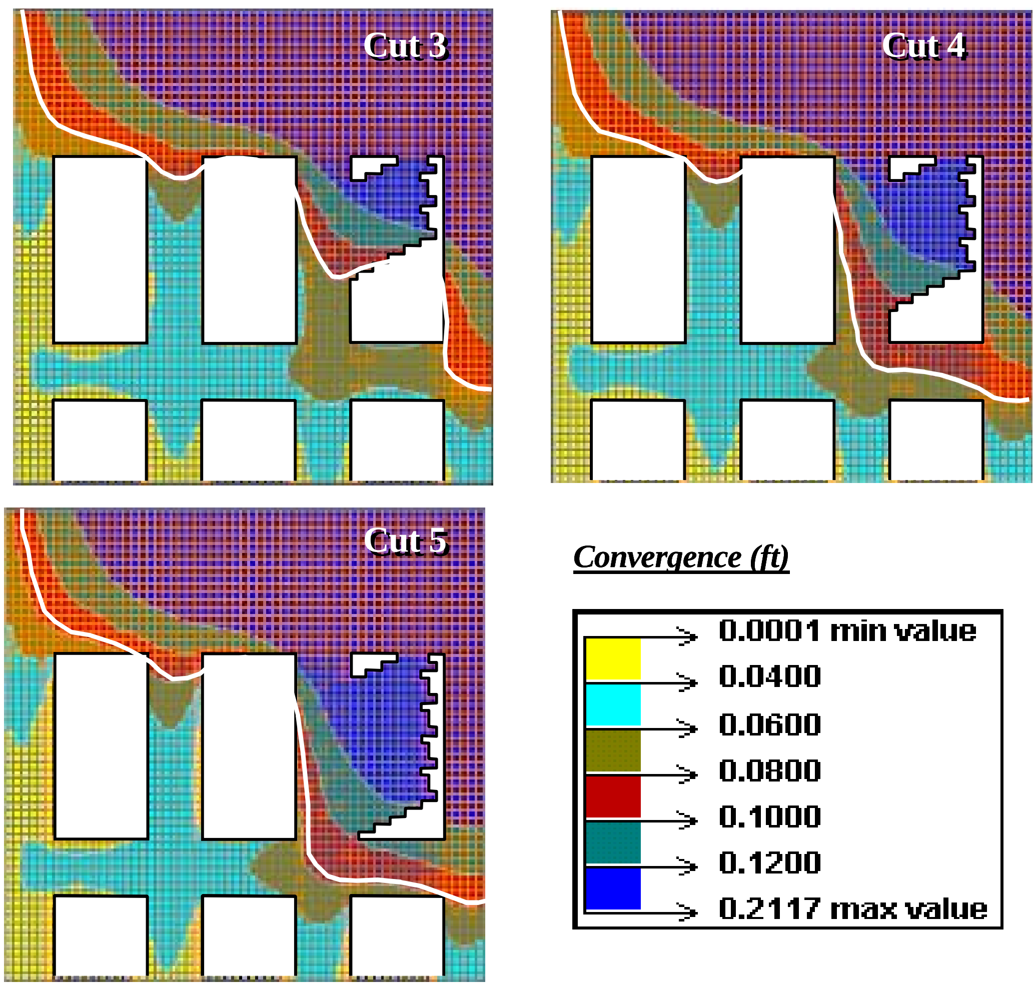


Figure 7. Roof convergence as mining approaches the final stump.
The 0.2 ft cut contour is highlighted in white.

• Eliminate most material handling.

Figure 8. A Mobile Roof Support (MRS).

Two disadvantages are their cost and the resulting necessity to recover them if they are trapped by a rock fall.

The statistics now seem to justify the enthusiasm for MRS. In the past 10 years, three of the 10 West Virginia pillar recovery fatalities occurred where MRS were being used[3]. Our study found that in 2001, MRS mines accounted for 69% of all the manhours in southern West Virginia retreat room-and-pillar mines. Extrapolating backward, a conservative assumption is that between 45 and 50% of the pillar recovery manhours since 1992 were on MRS sections. Using these data, it appears that a miner on a timber section has been about two times as likely to be fatally injured than a miner protected by MRS.

Using MRS can be a highly effective means of reducing the risk of pillar recovery. However, they must be employed properly. The pillaring plan should show the proper location for MRS during each lift, and the plan should be carefully followed. If the pushout is recovered, four MRS should be used, and at least two of them should be located directly in the intersection. MRS should always be moved in pairs, one canopy length at a time, so that they can support each other.

One disadvantage of MRS is that their operating range is limited to seams thicker than approximately 42 inches. Figure 9 shows that in southern West Virginia, the vast majority of mines in seams thicker than 52 inches already use MRS. But of the 54 mines who reported a seam height of 52 inches or less, only 7 were using MRS. In these thin seam mines, a timber plan that requires an adequate number of posts installed at the proper times and in the proper locations is essential.

Roof Bolting

Longwall mine operators recognize that headgate and tailgate entries will subjected to abutment loads during retreat mining, and will therefore require *extra* roof bolting. Unfortunately, pillar recovery sections have sometimes been considered "short term," and therefore candidates for a lower density of roof support. In fact, increasing the roof bolt support in many cases can be the simplest way to reduce the risk of roof falls during pillar recovery.

[3]The MRS were only implicated in the fatality in one of these instances. In the other two cases, broken roof bolts were considered the primary cause.

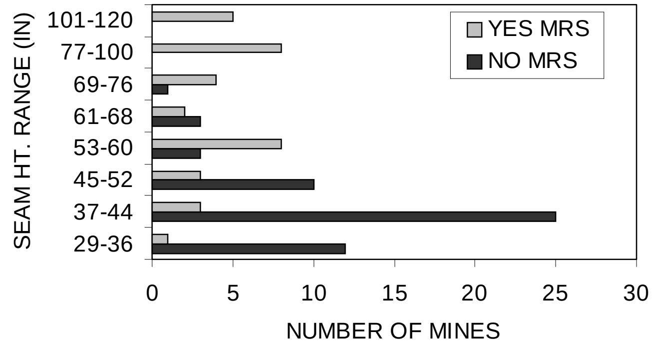


Figure 9. Distribution of MRS by seam height in southern West Virginia.

The failure of roof bolt systems has been a factor in a number of recent pillaring roof fall fatalities, including:

- *Broken roof bolts, sheared by roof movement, were found in three incidents (two of them in WV);*
- *Missing heads and plates, cut off by the CM, were found in two incidents (one in WV), and;*
- *Bolts were too short and missed their normal anchorage in sandstone when the underlying shale thickened in one WV incident.*

There is no widely accepted method for designing roof bolt patterns for retreat mining, though the Analysis of Roof Bolt Systems (ARBS) method can be a good starting point (8). In general, depending on the roof strata and other factors, the effectiveness of roof bolt systems for pillaring can be improved by using:

- *Longer bolts that build a thicker beam or anchor in better quality roof;*
- *Stronger bolts, using larger diameter rod or higher grade steel, that are less likely to break from rock movement,*
- *Extra intersection support such as cable bolts, and/or;*
- *Point anchor resin-assisted bolts that can provide warning of high loads (while fully grouted bolts may break along their lengths without warning).*

Another advantage of supplemental roof bolt support for pillar recovery is that bolts can be installed well outby the pillar line, before the ground is affected by the high stress environment.

OTHER RISK FACTORS

Roof Geology

Weak rocks like shale, mudstone, and coal, are more likely to be fractured and damaged by abutment stresses on the pillar line. They are also more likely to contain slips, slickensides, horsebacks and other discontinuities that have contributed to many pillar line fatalities.

Weak roof normally requires a higher level of roof bolting. Leaving a final stump for roof support is also more critical where the roof is weak. Every effort should be made to identify major discontinuities before mining and apply supplemental support. It may be necessary in some cases to avoid pillaring certain areas where hazardous roof features are known or suspected.

Intersection Span

Intersections are the Achilles heel of coal mine ground control. Research has shown that an intersection is 8-10 times more likely to collapse than an equivalent length of entry or crosscut. Even a seemingly small increase in the intersection span can greatly reduce stability, because the rock load is proportional to the *cube* of the span (10). Intersection hazards are most acute where the roof is weak.

Maintaining stable intersections is essential to safe pillar recovery. This can be accomplished by:

- Minimizing the entry width;
- Reducing the number and depth of turnouts;
- Using longer and/or stronger bolts in the intersections;
- Leaving an adequate final stump, and;
- Installing extra standing support (MRS or roadway posts) in the intersection if the final stump is extracted.

Depth of Cover

Greater depth means higher stress, both vertical and horizontal. During the past decade, approximately 30% of the pillar recovery fatalities have occurred in the relatively small number of mines where the depth of cover exceeds 750 ft. It seems that because global stability is harder to achieve at depth, the roof is more likely to be unstable. Proper pillar design is critical to successful mining at deep cover, but deep cover also magnifies the importance of all the other risk factors.

Multiple Seam Interactions

Many U.S. coal reserves occur where previous mining has been conducted above or below. The problem is particularly acute in the Central Appalachian coalfields, which includes southern West Virginia. Localized high stress zones can occur either above or below old works, and subsidence can damage the roof hundreds of feet above abandoned gob areas. In recent years, at least two pillar line fatalities appear to have been influenced by multiple seam interactions. Zones of potential interactions should be carefully mapped in the planning stage, and pillar recovery should be avoided where severe interactions are anticipated.

Recovery of Older Pillars

In many mines, pillars in old workings constitute substantial coal reserves. Such pillars can present an attractive target for extraction. Unfortunately, in many cases those pillars were not designed with pillar recovery in mind. Their dimensions may be inappropriate or irregular, and entry and intersection spans may be too wide. Most importantly, the roof bolting may be inadequate, and the roof rock may have degraded over time. Supplemental bolting is often required, particularly in intersections, to prepare old works for pillar recovery.

Non-Uniform Pillar Dimensions

Pillar recovery is safest when a routine can be developed and strictly followed. Developing panels with uniformly sized pillars, which facilitates a controlled and orderly extraction procedure, is strongly recommended. Where pillars are different sizes, whether by design or because of poor mining practice, "improvisation" is often necessary. In such cases, plans that call for a fixed number of lifts can result in a final stump that is too small. Requiring specific minimum cut-to-corner distances can help ensure that a properly sized final stump is left in place.

Odd-sized pillars can also result in oversized intersection spans. Pre-mining surveys should be completed to identify such hazards, and resupport may be necessary.

Continuous Haulage

Continuous haulage systems can result in improved productivity, particularly in thin seam operations. Unfortunately, they have several disadvantages for pillar recovery. In normal operations, the haulage system works out of the center entry intersection. The pillars must be retreated from both sides towards the middle, resulting in a pillar point (figure 10). Also, the center entry is often mined wider to accommodate the equipment, and the center entry intersections are particularly vulnerable to roof falls. Finally, the haulage system is more difficult to withdraw quickly if a hazard develops.

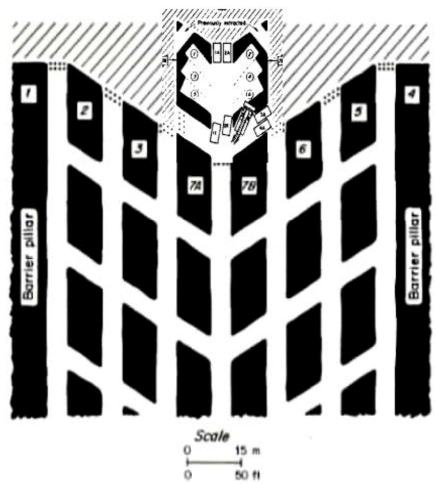


Figure 10. Pillar point created by mining with continuous haulage.

One partial solution was developed by a West Virginia mine after a fatality. An extra bridge was added to the haulage system, which then allowed it to be worked from the outby intersection. Then the entire row of pillars could be worked from right to left, eliminating the pillar point. It is also helpful to flatten the angles out as much as possible.

Operator Positioning

In more than half of the recent pillar recovery fatalities in West Virginia the victim was the CM operator or helper. According to MSHA's Program Policy Manual, "Investigation of a few of these [fatal roof fall accidents that occurred during pillar recovery operations] revealed that miners were occupying work locations inby the mining machine while coal was being mined or loaded. This practice should be discouraged, recognizing that recently mined coal pillars reduce the amount of support in these areas." With regard to 30 CFR 75.221, Roof Control Plan Information, the Policy Manual states that "work procedures and location of miners while coal is being mined or loaded should be incorporated into the roof control plan as part of the description of the mining system utilized during pillar recovery."

The pillar line is a dangerous place, and miners should never congregate there. Ideally, the operators should be outby the three-way intersection created by the lift at all times. Training and retraining may be necessary to prevent bad habits from developing.

CONCLUSIONS

Pillar recovery continues to be one of the most hazardous activities in underground mining. Global stability, achieved through proper pillar design, is a necessary prerequisite for safe pillar recovery. Local stability means preventing roof falls in the working area. It is achieved by minimizing the "risk factors" described in this paper.

The Risk Factor Checklist (Appendix) can be used to identify potential problem issues for specific pillar plans. The more questions on it that can be answered with a "yes," the less risky the plan is likely to be. The checklist does not weight the individual risk factors, nor is it necessarily a comprehensive list. It is simply a tool to help mine planners evaluate the overall level of risk, and possible ways to reduce the risk.

The Roof Control Plan is essential to every underground coal mine, but nowhere is it more important than in pillar recovery. Pillaring leaves little tolerance for error, and mistakes can be deadly. Roof Control Plans must be carefully drawn up to address the site-specific conditions, and then carefully implemented and followed. Both miners and foreman involved in pillar extraction should be trained to know and understand the plan.

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APPENDIX. - PILLAR RECOVERY RISK FACTOR CHECKLIST

Local Stability Risk Factors (Primary)

- **Cut sequence**: Is an outside lift sequence being used?
- **Final stump**: Is an adequate final stump consistently being left in place?
- **Support:** Are Mobile Roof Supports being used?
- **Roof bolts**: Is extra roof support used in intersections?

Global Stability Risk Factors

- **Pillar Design**: Is the ARMPS SF adequate to prevent a squeeze?
- **Collapse Prevention**: If the ARMPS SF<2.0 and the pillar w/h<4.0, either on advance or in the worked-out area, have steps been taken to prevent a massive pillar collapse?
- **Barrier Pillar Design**: If the depth of cover is greater than 1000 ft, are stable barrier pillars (SF>1.5 to 2.5) being used to separate the panels?

Other Risk Factors

- **Roof geology**: Is the roof at least moderate in strength?
- **Intersection span**: Have entry widths and turnouts been minimized?
- **Multiple seam interactions**: None anticipated?
- **Depth of cover**: Less than 650 ft?
- **Block size**: Are the blocks uniform in size?
- **Age of workings**: Is the development less than 1 year old?
- **Continuous haulage**: None?

Note: The Risk Factor Checklist can be used to identify potential problem issues for specific pillar plans. The more questions on it that can be answered with a "yes," the less risky the plan is likely to be. The checklist does not weight the individual issues, nor is it necessarily a comprehensive list. It is simply a tool to help mine planners evaluate the overall level of risk, and possible ways to reduce the risk.