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GENWAL Crandall Canyon Mine Main West Barrier Mining Evaluation

1.0 INTRODUCTION

GENWAL Resources, Inc. is planning barrier pillar mining in the Main West at the Crandall Canyon Mine. The mining plan and the coal seam depth of cover contour are shown in Figure 1. Current plans include developing four entries in the barriers north and south of the existing mains in the area west of the 1st Right/2nd North submains under cover ranging from about 1,300 ft to 2,200 ft. Barrier mining is also planned to the east between the 1st Right/2nd North and 1st North submains under generally shallower cover. Critical to the plan is potentially high-stress conditions caused by a combination of deep cover and side-abutment loads from the adjacent longwall gobs.

Agapito Associates, Inc. (AAI), conducted a geotechnical evaluation of the proposed mine plan using the displacement discontinuity code, LAMODEL, to predict (1) vertical stress, (2) convergence and (3) pillar yielding during barrier mining for entire Main West.

2.0 SUMMARY AND CONCLUSIONS

3.0 ANALYSIS

The evaluation of the proposed Main West mining plan comprised: (1) Back-analyzing retreat mining in the Section 36 panels and (2) Modeling future conditions for the proposed Main West mining plan based on the pillar strength calibrated in (1). Both models incorporated the mining geometry and sequence and variable depth of cover in the areas of interest. To provide better detail of pillar behavior, the element sizes in both models were set to 5-ft-square and the number of levels of confinement at the pillar ribs was set to 8.

3.1 Back-Analysis of Mining Conditions in the Section 36 Panels

During pillar extraction in the Section 36 panels, roof and pillar conditions at some area became critical; therefore some pillars were left to keep a safe mining condition. Most of these remnant pillars should totally or partially yield after the whole panels were extracted. These critical remnant pillar conditions were utilized in the numerical model to calibrate the pillar strength.

In LAMODEL, "method of slices" is applied to approximate the load bearing capacity of the pillars. This method assumes that the strength of any pillar element is a function of its distance from the nearest pillar rib and element size by:

$$\sigma_v = S_l[0.71 + 1.74(x/h)] \qquad (1)$$

Where:

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σ_v = Pillar stress function
S_l = In situ coal strength
x = Distance from the nearest pillar rib
h = Pillar height

Peak strain in each element is calculated by:

$$\varepsilon_v = \sigma_v / E \tag{2}$$

Where:
ε_v = Peak strain
E = Coal elastic modulus

Upon yielding, the residual stress and residual strain within a pillar element are calculated by:

$$\sigma_r = 0.2254 \times \ln(x) \times \sigma_v \tag{3}$$

and

$$\varepsilon_r = 4 \times \varepsilon_v \tag{4}$$

Where:
σ_r = residual stress
ε_r = residual strain

In this case, the in situ coal strength and elastic modulus were assumed to be 1640 psi, and 0.5×10^6 psi respectively for a 5-square-foot element. An average of 8 ft pillar height was used across the section 36 panels. The 8-level strength and strain for a typical coal pillar using equations (1) through (4) are listed in Table 1.

Figures 2 through 10 show modeling results for three mining stages in the south panel of the Section 36. The average overburden in this panel was approximately 1,700 ft. The condition before pillar extraction in the south panel was modeled as the first mining stage. At the second mining stage, pillar extraction processed half way across the panel. The third mining stage corresponded to a stage when the whole panel has been mined except several remnant pillars were left in the middle of the panel.

Figures 2, 3, and 4 show vertical stress, yielding condition, and seam convergence respectively at the first stage. At this stage, almost all the remnant pillars in the north panels have yielded. The stresses in the centers of these pillar exceeded 10,000 psi and seam convergences were more than 2 inches. All pillars within the south panels maintained stable and limited yielding occurred at some pillar ribs. Seam convergences within this panel were less than 1.6 inches and average vertical stresses within the pillars were around 3,000 psi, increasing 800 psi from 2,200 psi of in situ stress state, assuming 1.1 psi per foot stress gradient.

At the second mining stage, pillars adjacent to the gob yielded (Figure 6) and more than 2-inch-deformation occurred (Figure 7). As shown in Figure 5, excessive vertical stress larger than 10,000 psi was transferred to these frontline pillars. Based on this critical condition, subsequent deformations greater than approximately 2 inches were considered an indication of potential instabilities.

Figure 8, 9, and 10 show vertical stress, yield condition, and seam convergence respectively for the stage three. It was noted that the pillars adjacent to the gob had significantly yielded and that deformations across the remnant pillars were more than 2 inches in most parts.

Above analysis showed that the modeling results were consistent with the actual conditions at the section 36 herringbone panels. The coal strength data listed in Table 1 were then considered as reasonable values to represent the section 36 area and the Main West area. Table 2 lists the other parameters chosen for the models.

3.2 Modeling the Proposed Main West Mine Plan

Figure 11, 12, and 13 show the model area including Main West barrier pillar, one and half mined out longwall panels. Symmetric conditions were applied to four boundaries in order to simulate the area including panels 11, 12, and13 and the whole Main West area. The overburden depth across the model varied from about 1,600 ft up to 2,200 ft. As shown in Figure 11, the stress within barrier pillar was about 2,000 psi in the center of the pillar and over 4,000 psi along the south pillar boundary. Side-abutment stress reached as high as 30,000 psi along the north pillar boundary due to the extraction of longwall panel 12. High vertical stress over 3,000 psi was predicted around the rib of each main pillar. As shown in Figure 12, these high stresses have caused pillar rib and corner yielding, which was consistent with field observation. In the mains, deformations were usually below 1.2 inches.

Figure 14, 15, and 16 show vertical stress, yielding condition, and vertical displacement respectively after the east barrier pillar has been mined. The pillar dimension was planned to be 70 ft by 60 ft with 20 ft wide entries. 130 ft wide coal seam was left between the planned mining area and longwall panel 12. The average overburden of the planned mine area was about 1,700 ft. The results showed that apparently higher vertical stress concentrated on these pillars than the main pillars, which caused more pillar yielding. However, all these pillars had large elastic cores to keep them stable. The maximum deformation at crosscuts was less than 1.4 inches.

Figure 17, 18, and 19 show vertical stress, yielding condition, and seam convergence respectively after mining through the barrier pillar using the above mining plan. The overburden depth across this mining area varied from 1,600 ft up to 2,200 ft. As shown in Figure 17, there was no significant vertical stress transferred to the pillars under deep cover, since most vertical stress were concentrated over the remnant barrier pillar. Figure 20 shows vertical stresses along cross section through the center of the pillars 320ft to the west boundary of the model before and after mining. It illustrates that large vertical stress was shifted to the north boundary of the barrier pillar after Panel 12 mined out and that the planned pillars dodged away from the high side-abutment loading. In addition, it was noted that the planned barrier mining transferred very little load to its adjacent mains, which would not affect the stability of main entries. All planned pillars had rib yielding but with large elastic cores (Figure 18) and underwent reasonable deformations (Figure 19). Figure 21 compares deformations along a main entry and a planned entry. The plot illustrates that deformation of the planned entry was higher than the deformation of the main entry, and that the deformations within both of them were all below 1.4 inches.

Table 1. LAMODEL Pillar Strength Classification

LAMODEL input element classification	Distance into pillar, ft	Avg strength of each element, psi	Peak Strain	Residual Strength, psi	Residual Strain
I	2.5	2059	0.004	425	0.017
H	7.5	3845	0.008	1746	0.032
G	12.5	5631	0.012	3206	0.047
F	17.5	7417	0.016	4785	0.062
E	22.5	9203	0.019	6459	0.077
D	27.5	10989	0.023	8209	0.092
C	32.5	12775	0.027	10025	0.107
B	37.5	14562	0.031	11896	0.122

Table 2. Input Parameters for LAMODEL

Parameters for LAMODEL	Value
Overburden	
Deformation Modulus of Roof Rock (psi)	2,000,000
Poisson's Ratio of Overburden	0.25
Lamination Thickness of Overburden, ft	25
Unit Weight of Overburden (lb/ft^3)	158
Coal	
Elastic Modulus of Coal (psi)	470,000
Poisson's Ratio of Coal	0.34
Strain Hardening Gob	
Intial modulus, psi	100
Final modulus, psi	76,000
Final stress, psi	4,000
Gob height factor	1
Poisson's Ratio of Gob	0.25