

Study of Peripheral Fractured Zones at the Sides of Roadways in Underground Coal Mines in New South Wales by Seismic Methods

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SUMMARY A study of the depth and degree of fracturing at the sides of pillars and continuous ribs in roadways was conducted at two underground coal mines in New South Wales, using the seismic refraction method and a modified form of the uphole method. The equipment basically included a sledge hammer (with a device attached to provide the origin times of the generated seismic impulses), 3-component borehole geophone assemblies and a 12-channel oscillographic recorder with the facility of enhancing signals by stacking their repetitions.

In the seismic refraction method, four geophone assemblies were installed within short horizontal boreholes at approximately mid-seam height and the travel of P-waves generated along the line of the spread were recorded.

The modified uphole method recorded the travels of P-waves generated near the mouth of a longer horizontal borehole to the successively different positions of a geophone assembly within that hole.

The depths of the fractured zones were determined by analysing the time-distance plots of the travels of the P-waves. The degree of fracturing within such a zone was considered to be indicated by the ratio of the determined P-wave velocity in the fractured zone and that in the (inner) intact zone or coal specimens in the laboratory.

The depths of the fractured zones determined from the refraction method were less than the corresponding ones from the uphole method, the latter being closer to the findings of other investigators.

1. INTRODUCTION

Compressive stress fields exist below the ground surface due to the weight of the overlying rock mass and sometimes, additional tectonic causes. When an excavation is made below ground, the existing stresses are redistributed, with concentrations developing in the rock material at the peripheries of the excavations. If the stress concentrations or 'abutments' exceed the rock strength, failure or fracturing of the material occurs and the abutments shift to intact rock farther from the excavation.

In underground mines, 'pillars' i.e. large unmined blocks of the mineral deposit are often left either temporarily or permanently, to support the rock mass surrounding the excavations. A logical approach to the optimum design of pillars would require a knowledge of the support capability of their peripheral fractured zones as well as, the more intact core inside. For this reason, studies of such fractured zones were conducted at a site each in two underground coal mines in New South Wales and are outlined here.

2. SEISMIC STUDY OF PERIPHERAL FRACTURED ZONES IN PILLARS AND CONTINUOUS RIB-SIDES

The study of fractured zones at each site, was conducted in a pillar and the continuous ribside forming the opposite sides of a roadway.

Seismic methods were used for the study, because they provided comparatively simple means of determining the depths of the fractured zones as well as, the degree of fracturing therein. The methods were based on the transmission of P-waves generated by impulsive blows from a sledge hammer. S-waves could also have been used, but for the difficulty in generating them.

2.1 Seismic Recording System

The seismic recording system used, consisted of the following:

- i) A 6kg sledgehammer with a triggering device attached to the shaft, for generating the P-waves and providing their origin times;
- ii) 4 of 3-component geophone assemblies (each containing an orthogonal configuration of 1 vertical and 2 horizontal units of 7.5Hz natural frequency, 300ohms coil impedance and 0.635 critical damping) for installation in 37mm diameter horizontal boreholes using expansion-shell anchors;
- iii) ES-1200 (Nimbus Instruments, U.S.A.) battery-operated 12-channel oscillographic recorder (modified for use in 'non-gassy places' in coal mines) with the facility of stacking the repetitions of signals for enhancement;

- iv) 6-core screened cables for connecting the geophone assemblies to the recorder;
- v) Hollow steel rods for installing a geophone assembly within a borehole at the proper depth and orientation and subsequent retrieval.

2.2 Sites of Investigations

The investigations were conducted at the West Cliff and Coal Cliff Collieries. Both the collieries belong to Kemplab Coal and Coke Pty Limited, and are located in the Southern Coalfield of New South Wales and produce predominantly high quality coking coal from the Bulli seam.

At West Cliff Colliery, the Bulli seam is 2.5 - 3m thick and lies at depths of 450-480m. The roof of the seam is usually medium grained sandstone and the floor is strong shale.

The Bulli seam at Coal Cliff Colliery is 1.5-3.5m thick and lies at depths of 350-400m. Generally, the roof of the seam is a layer of mudstone overlain by medium grained sandstone and the floor is grey shale.

The work of the investigations at the sites was mostly carried out at the weekends, when the background seismic noise from the mining activities were less.

2.3 Study of Fractured Zones at West Cliff Colliery

The location of the study at West Cliff Colliery was at one of the intake roadways of the retreating longwall panel 1. The results of the study have been detailed elsewhere (Bhattacharyya and Belleza, 1986) and are only summarised in Tables I and II.

2.4 Study of Fractured Zones at Coal Cliff Colliery

The location of the study at Coal Cliff Colliery was a pillar and the continuous ribside opposite in the 3-heading development panel 281 shown in Figure 1.

2.4.1 Application of the seismic refraction method

The positions of the geophones at the mid-seam horizon are indicated a G1-G4 in Figure 2. The position of the seismic impulses generated along the appropriate lines of geophones are denoted by the numbers 1-13. Eight repetitions of the seismic signals generated from each of those positions were recorded with stacking. The recordings were transcribed on the photo-sensitive paper using different drive speeds. The seismograms were then developed by exposing to the light of a miner's cap lamp. Later, a protective spray was applied to the paper records.

2.4.1.1 Time-distance plots of the arrivals of seismic waves and determination of their velocities

Examination of the seismograms (ignoring cross-talk) from the four geophone assemblies indicated four different arrivals. The time-distance plots of those arrivals and the velocities determined from the appropriate lines of best fit shown in Figure 3 (as an example) suggested the following:

- i) velocity V_1 , related to the arrival of P-waves to a geophone by the direct path;

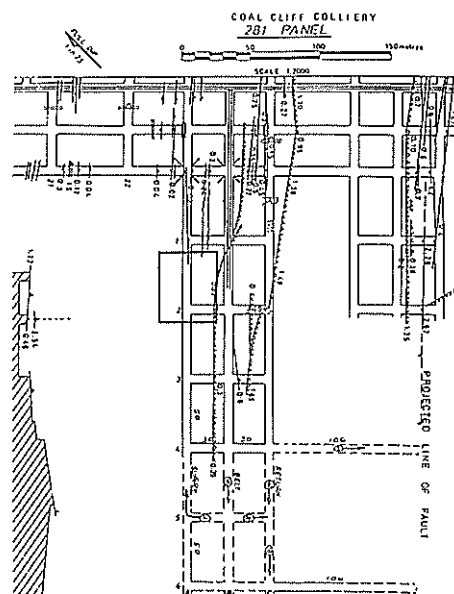


Figure 1 Part plan of the Coal Cliff Colliery showing the site of peripheral fractured zones in roadways.

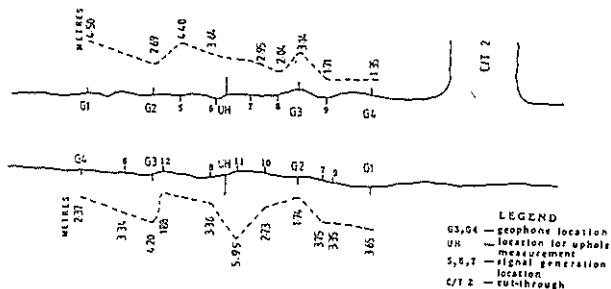


Figure 2 Positions of geophones and seismic impulses and computed mean depths of the peripheral fractured zones in the pillar and continuous rib opposite

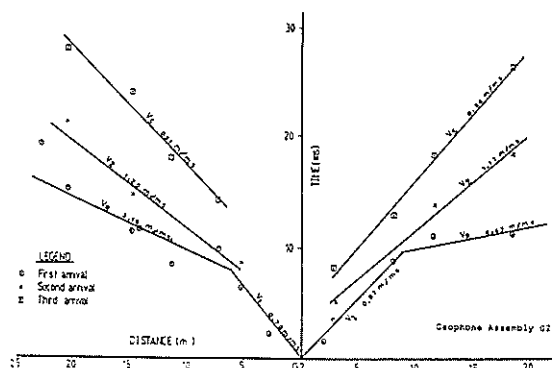


Figure 3 Time-distance plots of the arrivals of signals at geophone G2 in the continuous rib

- ii) velocity V_2 related to the arrival of P-waves refracted along the interface between the fractured and the intact zones (and detected by the geophone oriented along the axis of the assembly);
- iii) velocity V_R related to the arrival of P-waves refracted along the interface between the coal seam and the roof-floor;
- iv) velocity V_S related to the travel of SH waves (which also originated from the hammer blows) refracted along the interface between the coal seam and the roof-floor.

The arithmetic means of the values of V_1 and the 'harmonic means' (Redpath, 1973) of the values of V_2 determined from the travels of the signals to the different geophones were used in the subsequent determinations of the depths of the fractured zones.

2.4.1.2 Determinations of the depths of fracture zones

The depth of the interface between the fractured and intact zones at a geophone position was determined by the 'intercept time' method (Redpath, 1973). The depth of the interface at a signal location was determined from the recordings of a signal by a pair of bracketing (i.e. enclosing) geophones using the 'delay time' method (Redpath, 1973).

The determined mean depths of the peripheral fractured zones in the pillar and the continuous ribside opposite are shown by the broken lines in Figure 2, and Table I.

2.4.2 Application of the modified uphole method

10m long horizontal boreholes denoted as UH in Figure 2, were drilled at the mid-seam height for the application of the uphole method. A geophone assembly was installed at successively decreasing depths within the borehole. At each depth, the seismic signal generated at a fixed position near the collar of the borehole was recorded by the geophone assembly with the stacking of eight repetitions. Seismograms of the recording was then obtained as described in section 2.4.1.

2.4.2.1 Time-distance plots of the arrivals of seismic waves and determination of their velocities

In this instance, the direct travel of the P-waves as detected by the geophone oriented along the axis of the assembly were of interest. The time-distance plots of such arrivals and the calculated velocities along the geometrically direct paths are shown in Figures 3 and 4.

2.4.2.2 Determination of the depths of fractured zones

The depths of the fractures zones along the employed particular boreholes were estimated by inspection of the determined velocities and are indicated by the dotted lines in Figures 4 and 5.

The likely sources of error in the method were: the assumption of homogeneous fractured and intact layers with constant seismic wave velocities and inadequate time resolution between close successive positions of the geophone assembly in a borehole.

TABLE I

DETERMINED DEPTHS OF PERIPHERAL FRACTURED ZONES IN ROADWAYS

Site of investigation				Seismic method used	Determined width of peripheral fractured zone (m)		Mean value of in situ velocity of P waves m/ms		Ratio V_2/V_1	Mean value of P wave velocity determined in the laboratory m/ms
Colliery	Seam	Height of mining (m)	Depth of cover (m)		continuous ribside	Pillars	Fractured zone V_1	Intact zone V_2		
West Cliff	Bulli	2.5	450 to 480	Refraction method	4.15 ± 1.03	3.62 ± 1.01	0.86 ± 0.30	2.45 ± 0.85	2.85	1.29 ± 0.40
					3.30 ± 1.17	2.94 ± 1.12	0.85 ± 0.20	1.79 ± 0.42		
Coal Cliff	Bulli	2.5	350 to 400	Uphole method	6.00	4.75	1.43 ± 0.17			

2.4.1.3 Determination of the degree of fracturing

The degree of fracturing estimated by the ratios of V_2 and V_1 are shown in Table I. The likely sources of error in the method were: the assumption of homogeneous fractured and intact layers with constant seismic wave velocities, unevenness of the interface, inaccuracies in determining the plan geometry of the roadway and the proximity of the roof and floor strata of higher seismic velocities.

3. CONCLUSIONS

The results of the seismic study of the fractured zones in a pillar and the continuous ribside on the opposite sides of a roadway at the West Cliff and Coal Cliff Collieries are summarised in Tables I and II. As may be observed, the depths of the fractured zones determined by the refraction method were lower than those by the modified uphole method. The reason may partly be that the latter were just estimates as indicated in Figures 4 and 5. This aspect should be investigated further.

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The depths of the fractured zones determined by the refraction method seem to indicate a relationship with the depth of the seam below the surface. This agrees with the suggestion of Wilson (1972), although the determined depths of fractured zones are lower than his as well as Barron's (1978) findings.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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TABLE II

COMPARISON OF THE WIDTHS OF PERIPHERAL FRACTURED ZONES IN ROADWAYS DETERMINED BY SEISMIC METHODS WITH THOSE OF WILSON(1972) AND BARRON (1978)

Mine				Width of fracture zone (m)			
Name	Depth of cover (m)	Pillar width (m)	Pillar height (m)	Seismic Refraction Technique	Uphole method	According to Wilson (y=.0049 mh)	Barron's results (mean)
West Cliff Colliery	450-480	28	2.5	3.94± 1.03	-	5.51to 5.88	6.58±
Coal Cliff Colliery	350-400	25	2.5	3.14± 1.14	4.75to 6.00	4.29to 4.90	2.63