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Measurement of shear movements in the overburden strata ahead of longwall mining

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ABSTRACT

An underground coal mine located in New South Wales has a target coal seam located 160–180 m deep directly below a 16–20 m thick conglomerate unit that has been associated with significant periodic weighting events on the longwall face. As part of the investigations to better understand the causes of periodic weighting at the mine, inclinometers capable of measuring horizontal shear movements through the full section of the overburden strata were installed ahead of mining at two locations approximately 1 km apart above the centre of two longwall panels. These inclinometers were monitored as the longwall approached each site. This paper presents the details of the installation, the results of the inclinometer monitoring at both sites, and the insights that these measurements provide for overburden behaviour about longwall panels. Horizontal shear movements were observed to develop on shear horizons that correlate closely across the two sites suggesting a mechanism that is consistent across a large area of the mine. Shear movements were observed to develop on a single horizon near the top of the conglomerate strata that was mobilised almost immediately after initial formation of the longwall goaf at a distance of 425 m ahead of the longwall face.

1. Introduction

Longwall mining is recognised from subsidence monitoring, surface extensometer measurements and various other observations to cause significant disturbance to the overburden strata directly above the extracted goaf of each longwall panel. Disturbance to the overburden strata beyond the limits of each longwall panel is not so well understood. Subsidence monitoring indicates that horizontal movements beyond the edges of the extracted longwall panel are generally greater in magnitude than vertical subsidence and horizontal movements may extend up to several kilometres from the edge of the panel in some circumstances [1–5]. The mechanics of how these movements are accommodated within the overburden strata is only poorly understood and there are few direct measurements.

Inclinometers were installed from the surface to investigate how the overburden deforms ahead of mining and whether periodic face weighting events were associated with significant shear events within the overburden strata. The opportunity to measure the shear movements within the overburden strata at this mine has provided significant insights into the extent and characteristics of shear movements within the overburden strata ahead of mining. The gradual nature of the movements observed at both inclinometer sites is consistent with the absence of significant periodic weighting events on the longwall face during the period of monitoring. The absence of periodic weighting events meant that a correlation between periodic weighting events and significant shear movements was not able to be confirmed directly.

This paper presents detail of the inclinometer monitoring, the nature and characteristics of the shear movements observed, and a discussion of the results in the context of both the site locally and overburden behaviour about longwall panels more generally.

2. Site description

The subject coal mine is longwall mining a 4 m thick section of a 4–8 m thick coal seam at a depth below surface of 160–180 m. The longwall panels form a void that is nominally 306 m wide separated by chain pillars that are 30 m wide measured rib to rib.

Fig. 1 shows a plan of the first three longwall panels and the location of the two inclinometer sites. The first is located in borehole NC533, 20 m offset from the centreline of longwall 102 and approximately 1 km from the start of the panel. The second installation is located in boreholes E103A above the centre of longwall 103 approximately 450 m from the start of the panel.

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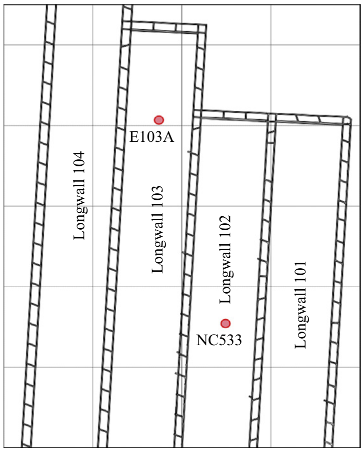

Fig. 1. Site Plan shown location of inclinometer boreholes relative to longwall panels.

Overburden stratigraphy across the site is relatively uniform with the coal seam dipping gently to the west. The Hoskissons Seam is located directly below the 16–20 m thick Digby Conglomerate. The conglomerate is overlain by approximately 100 m of siltstones and sandstones of the Napperby Formation, the lower part of which comprises a siltstone unit that is 35–45 m thick. There are several low strength bands within the Napperby Formation that are prone to breakout and swelling, including one just above the contact with the conglomerate. A dolerite sill is intruded into the Napperby Formation in some areas about 30 m above the conglomerate. The Garrawilla Volcanics comprising weathered basalt and the Purlewaugh Formation lie on top of the Napperby Formation. These units are overlain by surface alluvium. The stratigraphic sequence in each of the two inclinometer boreholes is shown together with the results of the inclinometer monitoring.

3. Inclinometer installations

Inclinometer casing was installed in two boreholes, NC533 and E103A, at the locations shown in Fig. 1.

The boreholes were drilled to the base of the Napperby Formation and a short distance into the Digby Conglomerate. The holes were fully cased with 200 mm steel casing. Inclinometer casing was installed to allow measurements to 148.5 m in NC533, and 176.0 m in E103A. The space between the steel casing and the inclinometer casing was backfilled with 2 mm diameter pea gravel. This annulus of pea gravel was designed to increase the shear capacity of the inclinometer monitoring system.

Fig. 2 shows a photograph of the inclinometer casing that was installed into each borehole and a photograph of the inclinometer itself. An RST instruments digital inclinometer probe was used for the surveys. The probe houses two micro electro mechanic systems accelerometers that measure tilt on two orthogonal axes. Spring loaded wheels attached to the inclinometer probe allow the instrument to track in grooves in the casing so the instrument remains consistently orientated between sets of readings.

The inclinometer is lowered to the bottom of the hole and withdrawn in 0.5 m increments with the inclination of the instrument recorded at the surface at each increment. By accumulating the inclination of the instrument up the borehole, the magnitude of shear offsets can be measured in the plane of the instrument and changes observed through repeat measurements. Although the instrument measures the inclination in both planes, the measurement in the plane of the wheels is more accurate. By conducting a second survey with the instrument aligned in the second set of grooves, a more accurate measure of direction and magnitude of shear offsets can be determined on a plane perpendicular to the first set of readings. By repeating both surveys again with the instrument directions reversed, systematic errors associated with any zero offset can be eliminated. In general, four surveys were undertaken at each set of readings to give the highest resolution measurements possible.

At the surface, the primary axis, referred to as the A+axis, was aligned to along the panel axis (about 3 GN). Positive values in the A+plane represent relative shear movement of the ground above the shear plane to the north. The secondary axis, referred to as the B+axis, is aligned to measure displacement perpendicular to the approaching longwall face. Positive values in the B+axis represent shear movement of the ground above a shear plane to the east.

Although the orientation of the grooves is known at the surface, any twist in the casing can affect the interpretation of the direction shear movement. A twist meter tool was used to measure the orientation of the grooves down the length of the borehole. This tool showed a relatively uniform twist clockwise looking down the hole in both holes. In NC533, the twist between the top and bottom of the hole was 50° and in E103A 78°; both very significant amounts of twist. These measurements confirm the importance of undertaking a twist meter survey and then taking account of the twist in the analysis to determine components of horizontal shear movement in deep holes.

Absolute shear movements can be determined if the location of the collar of the base of the hole or the surface is known. Normally in slope stability monitoring, the base of the hole can be assumed to be the stable reference. However, given the potential for the ground to be moving at seam level as well as at the surface, absolute shear magnitudes were calculated relative to the location of the collar. This location was interpolated for the time of the survey from daily subsidence monitoring on the centreline of longwall 102 for NC533, and the less frequent, but nevertheless sufficient,

Fig. 2. Photograph of inclinometer casing and inclinometer probe.