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Investigation of overburden behaviour for grout injection to control mine subsidence

Shen Baotang *, Poulsen Brett

CSIRO Earth Science and Resource Engineering, Brisbane, QLD 4069, Australia

A R T I C L E I N F O

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A B S T R A C T

This paper describes a field and numerical investigation of the overburden strata response to underground longwall mining, focusing on overburden strata movements and stress concentrations. Subsidence related high stress concentrations are believed to have caused damage to river beds in the Illawarra region, Australia. In the field study, extensometers, stressmeters and piezometers were installed in the overburden strata of a longwall panel at West Cliff Colliery. During longwall mining, a total of 1000 mm tensile deformation was recorded in the overburden strata and as a result bed separation and gaps were formed. Bed separation was observed to start in the roof of the mining seam and gradually propagate toward the surface as the longwall face advanced. A substantial increase in the near-surface horizontal stresses was recorded before the longwall face reached the monitored locations. The stresses continued to increase as mining advanced and they reached a peak at about 200 m behind the longwall face. A numerical modelling study identified that the angle of breakage (i.e., the angle of the boundary of caved zone) behind the longwall face and over the goaf was 22–25° from vertical direction. This is consistent with the monitoring results showing the high gradient of stresses and strains on the surface 150–320 m behind the mining face.

1. Introduction

Mining induced ground damage can significantly increase mining costs where major surface structures, facilities and natural environments need to be protected from ground movements. Longwall mining under river systems, gorges, cliffs, power lines, pipelines, communication cables, major roads, railways, bridges, and other significant surface facilities has occurred at a number of underground mines in Australia. Increasingly, mine subsidence and ground damage are becoming a major issue of community concern. To date, subsidence under sensitive surface features is often controlled by leaving large blocks of unmined coal behind. This method not only sterilizes the coal resource, but also increases mining costs as a result of production loss and longwall relocation. Remedial and mitigation measures to manage damage caused by subsidence can be very costly.

Technologies used for mine subsidence control today include the mine backfill, narrow panel mining, and protection pillar methods. Significant amount of researches have been carried out in the past to predict the surface subsidence and its environmental impact, to understand the overburden strata behaviour, and to improve the backfill technologies [1–10]. All these have helped to advance our understanding and technologies to reduce mine induced surface subsidence. This study deals with the feasibility of applying a subsidence control technology at a specific mine in Australia, West Cliff Colliery. West Cliff Colliery is mining coal at a depth of 500–600 m using the longwall method. A regional Georges River traverses much of the mine lease, and is sensitive to damage from mining activities. Mine induced subsidence and stress concentrations are believed to be the key factors in the observed river bed fractures and valley closures that have occurred in the past. Overburden grouting injection is considered as a potential technology to minimize the impact of underground mining on the river system [11,12]. However, successful application of this technology relies on a good understanding of the overburden strata movement and the near-surface stress change during mining. A research project sponsored by Australian Coal Association Research Program (ACARP) and BHP Billiton Illawarra Coal has been carried out with the specific focus of understanding:

(1) Strata movement and bed separation mechanism occurring in the overburden strata above the coal seam during longwall retreat.

* Corresponding author. Tel.: +61 7 33274560.
E-mail address: baotang.shen@csiro.au (B. Shen).

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(2) Local deformation and stress concentration in the strata zones near the ground surface.

Several previous field investigations were conducted to attempt to monitor the response of overburden strata during mining at West Cliff Colliery. In 2004, a deephole surface extensometer was installed above Longwall 29 [13]. As part of a BHP Billiton Illawarra Coal sponsored investigation project, a second deephole extensometer was installed to monitor the Longwall 31 subsidence profile in 2005 [14]. The extensometer anchors were installed within the Bulgo Sandstone unit, identified as the targeted injection region.

In a separate study, Mills et al. conducted a monitoring study of a rockbar at the Georges River above Longwall No. 5A4 [15]. The stress monitoring indicated a major increase in horizontal stress magnitude as the longwall face retreated and passed the monitoring point.

In the current study, a systematic geotechnical monitoring program at Longwall 32 was designed and conducted [16]. It was aimed to obtain the following data and information:

(1) mining induced bed separation at a depth range of 0–420 m, which includes the Hawkesbury Sandstone, Bulgo Sandstone, and their immediate roof and floor;
(2) stress changes in the near surface strata before, during and after mining.

Following the field investigation, a numerical study was conducted to understand the mechanism of overburden strata movement and the near-surface stress change.

2. Field geotechnical monitoring

The targeted longwall panel was 305 m wide from rib to rib with chain pillars 37 m wide. Mining was undertaken at West Cliff Colliery in the Bulli Seam with a seam thickness from 2.5 to 2.75 m. Depth of overburden was approximately 520 m. A typical stratigraphic section for the middle part of Longwall 32 at the West Cliff Colliery is shown in Fig. 1.

Two massive sandstone units dominate the overburden geology. They are the Hawkesbury sandstone (thickness = 180 m) and the Bulgo sandstone (thickness = 170 m). The Bulgo sandstone and its surroundings are the targeted zone for grout injection.

Field monitoring was carried out at a location close to the bottom of a small valley along the panel centerline. It included one deephole extensometer and two piezometers that covered a depth range of 0–420 m, and two biaxial stressmeters installed at a depth of 22 and 36 m, respectively.

2.1. Monitoring design

2.1.1. Deephole surface extensometer

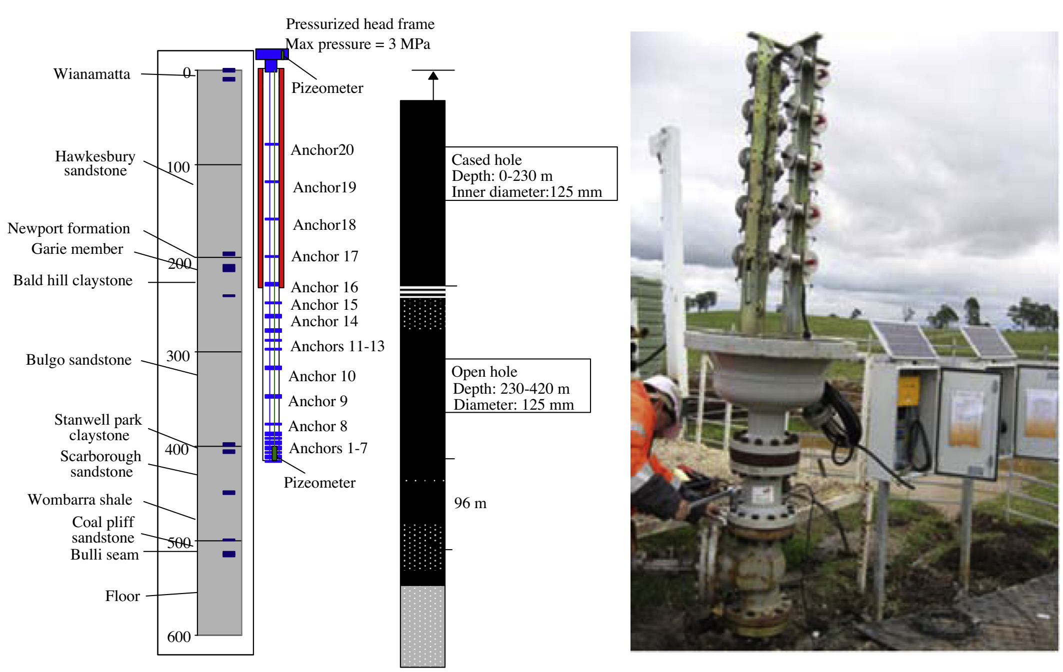
The extensometer borehole was drilled to a depth of 420 m at the panel centerline of Longwall 32. The top 230 m of the borehole was cased to prevent any water cross-contamination between the Hawkesbury and Bulgo sandstones. The section between 230 and 420 m was open hole, which included the Bulgo sandstone and Stanwell Park claystone. A total of 20 anchors were installed in this hole to measure the vertical movement of the overburden strata relative to ground surface. Survey lines at the borehole location were set up and monitored on a weekly basis to provide the reference movement of the ground surface.

2.1.2. Piezometers

Two piezometers were installed in the extensometer hole, one at the bottom of the hole, i.e., at a depth of 420 m; the other was in the pressure chamber on the ground surface. The borehole and surface instruments were tightly sealed to contain high pressure gas (up to 3 MPa) from the Bulgo sandstone. The deep piezometer was designed to measure the water level in the borehole during mining, and the surface piezometer was used to measure gas pressure in the borehole.

2.1.3. Stressmeters

Two biaxial stressmeters were installed in the Hawkesbury sandstone at a depth of 21.8 and 36.3 m respectively (Fig. 2a) at locations close to the extensometer. The aim of the stressmeters



(a) Overburden geology and extensometer anchor locations (b) Extensometer after installation

Fig. 1. Extensometer monitoring.