International Journal of Rock Mechanics & Mining Sciences 78 (2015) 144–154

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Technical Note

Drill monitoring results reveal geological conditions in blasthole drilling

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A R T I C L E I N F O

Article history:
Received 22 October 2014
Received in revised form
14 May 2015
Accepted 19 May 2015
Available online 25 June 2015

Keywords:
Monitor-while-drilling (MWD)
Rock mass characterisation
Geophysical logging
Open pit mining
Blasting

1. Introduction

In open pit mining, monitor-while-drilling (MWD) systems which monitor performance factors such as rate of penetration (RoP), torque (τ), weight on bit (WoB) and rotary speed (ω) are becoming standard features on the blasthole drill rigs supplied by equipment manufacturers. MWD measurements enable drill automation[1] and can be used to monitor the health of these major items of equipment. While it has also long been recognised that through MWD data, geological conditions can be revealed,[2–4] MWD data is rarely used for geological characterisation in activities such as blast design.

Part of the reason for this lies with the difficulty in keeping MWD systems operational in the hostile mining environment. Unless they are integral to specific mining tasks (e.g. automation), MWD systems are frequently turned off or not fully operational. However, were there a better appreciation of how well MWD data reflect changes in the geology, mining companies might begin to make use of MWD data for geological and geotechnical purposes.

In making comparisons between MWD and geological data, difficulties arise in obtaining geological information for comparison with the MWD data. Blastholes have relatively large diameters (>200 mm) and are drilled using rotary and percussion methods. Drill chips do not provide adequate information and if geological and geotechnical models developed from broadly spaced (100 m plus) exploration drilling are used, these are not sufficiently precise for comparison with blastholes which are typically drilled at centres of about 10 m. Even when cores from nearby cored holes are available, these are not adequate because the cores are not from the actual blastholes and in any case, once cores are removed from the ground, they are no-longer under in-situ conditions and it is not possible to capture the influence of in-situ stresses and fractures. Given the difficulties with all of these approaches, geophysical logging conducted within the blastholes probably provides the best opportunity for obtaining precise geological information from within the blastholes drilled with rigs equipped with MWD capabilities.

In this technical note we provide results for a study undertaken at an open cut coal mine in the Hunter Valley of NSW, Australia. The MWD data were obtained using Caterpillar's Aquila® drill monitoring system. RoP measurements are assessed as well as the specific energy of drilling (SED).[5] Geophysical logging was then conducted in the same blastholes and the results analysed to establish the down-hole lithology and rock quality.

At the mine where this work was undertaken, the main incentive for the study was to investigate whether MWD data could identify the top of coal seams and allow drilling to be halted, thus preventing unintended blasting of coal and associated problems with coal fragmentation and dilution. A description of these results and a new MWD measure called Modulated Specific Energy (SEM) is introduced in Ref. 6. This approach is well suited for picking the changes in MWD performance when coal seams are encountered.

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http://dx.doi.org/10.1016/j.ijrmms.2015.05.006

The more general blast design problem and the potential for MWD to reveal changes in overburden rock quality are now considered. Of particular interest is the association between MWD parameters and sonic velocity. Velocity has been used as a proxy for rock strength by many authors.[7–12] A direct correlation between MWD data and sonic velocity can therefore be expected. Also of interest was any association between the MWD data and the rock lithology revealed by natural gamma logs (sandstones versus siltstones and claystones) and density logs (clastic rocks versus coal and carbonaceous layers containing mixtures of coal and clastic sediments).

Previous blasthole studies employing geophysical logs are described in Ref. 13 where geophysical logs were used to indicate the locations of coal seams and Ref. 14 where density logs were used to assist with the application of pattern recognition techniques for rock characterisation using MWD data in an open pit coal mine.

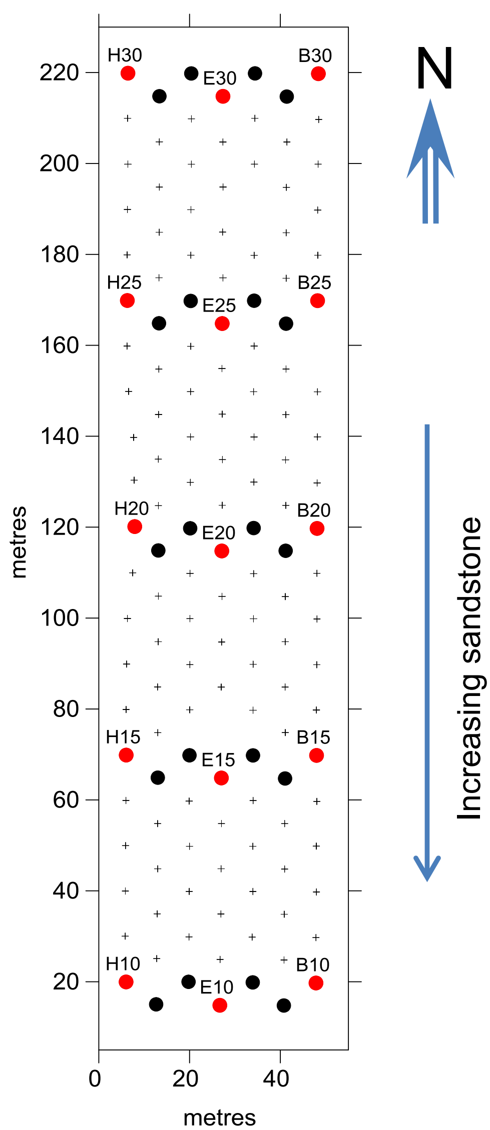

Fig. 1. Blasthole pattern for the bench at the trial site. Holes are in seven rows (B to H). The holes shown by black in-filled circles were drilled through to the base of the coal seam. These were geophysically logged with natural gamma, caliper and density tools. In addition, sonic logs were run in the holes which are labelled and shown by red in-filled circles. For the sonic logs to be run, it was necessary to fill these holes with water. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Neither of these studies extensively explored the correlation between MWD parameters and geological conditions revealed by the geophysical logs.

In the case of the MWD techniques and geophysical logging employed by the petroleum industry, that work is not directly relevant to the rock characterisation problems in open pit mines. In petroleum, holes are hugely expensive, drilled to depths of many thousands of metres and are widely spaced. In these very deep holes, the use of drilling fluids, the interaction between the bit and the rock, bit wear and the abrasivity of the strata are major considerations. In open pit mining, blastholes are cheap, drilled with air and drilled to depths of no more than a few tens of metres in a matter of minutes. As already noted, they are also closely spaced. In mining, bit–rock interactions and variations in bit wear down-hole and from hole-to-hole are not major concerns when characterising rocks.

2. Site description

The site for the trial is an open pit coal mine operating within the Jerrys Plains Subgroup of the Whittingham Coal Measures and part of the Permian sequence of the Sydney Basin.[15] It was formed in an upper to lower delta plain terrestrial environment and the interburden rocks between the coal seams consist mainly of lithic sandstone, siltstone and conglomerate. The thirteen named coal seams frequently split and provide numerous mining opportunities. Carbonaceous siltstones and tuffs also occur throughout the Subgroup.

Fig. 1 shows a map of the bench at the trial site. Here, an interburden approximately 24 m thick overlies a 2–3 m thick coal seam, depending on the thickness of a mid-seam split. The interburden is mainly sandstone and siltstone and as shown by the photographs in Fig. 2, siltstones in the north grade into sandstones in the south. At this location, a layer of carbonaceous siltstone which can also contain a minor split of the coal overlies the main coal seam.

One-hundred forty-four blastholes were drilled by experienced operators using CAT Reedrill SKS rotary drill rigs in preparation for a normal production blast. There were seven north–south rows of blastholes 7.5 m apart, with the blastholes within each row at 10 m centres. Most holes were drilled to the top of the seam with the driller ceasing drilling at the expected coal seam depth and also according to any observed changes in the RoP and the colour of drill chips. As an exception to this normal practice, blastholes were deliberately drilled through to the base of the seam in five east–west rows. This provided the opportunity to properly establish the seam depth and to obtain geophysical and MWD data through the coal.

The diameter of the blastholes was approximately 26 cm. For the 35 blastholes drilled through the coal, geophysical logs were obtained by a geophysical contractor using conventional slimline tools normally used in exploration boreholes. Geophysical measurements were taken with a combined density, natural gamma and caliper tool (7 cm diameter tool pushed against the wall of the hole). Full waveform sonic (FWS) logs (5 cm diameter tool centralized within the blasthole) were also obtained in three holes in each of the five rows, see Fig. 1. To obtain the sonic logs, these holes needed to be first filled with water because sonic logs require fluid coupling to transfer signals between the tool and the blasthole walls.

As discussed below, there are differences in the hole depths reported in the MWD and geophysical data. This is due to the practice of the drill operator to set the zero depth at the point when the drill was set into drilling mode point, approximately 0.3 m above the surface of the bench. In the case of the geophysical