2006

The Use of Downhole Presometers Implications for Modern Underground Mines

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THE USE OF DOWNHOLE PIEZOMETERS IMPLICATIONS FOR MODERN UNDERGROUND MINES

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ABSTRACT : An understanding of the hydrogeological environment of the strata over and about an operating mine provides some insight into the effectiveness of gas drainage, the identification of potential difficult drainage areas and the behaviour of overlying aquifers during mining.

Bore hole piezometers have been routinely installed in BHP Billiton's exploration holes for many years. The instruments were developed as one of the outcome of NERDCC research grants completed in 1983 and 1986. Piezometers and geophones packaged to survive the difficult environments of the Southern Coalfield remain operational and are routinely read today, twenty years after their installation.

The data acquired over the years present a view of the piezometric state of the selected target seams prior to, and during mining, that would be difficult to achieve by other means.

The installation of piezometers is now a routine part of the borehole abandonment procedure. Piezometers are precisely placed against the target coal seam at depths in excess of 700 m with minimal tools and non specialist field technicians.

The intention of this paper is to present procedures for installation of the instruments and some examples of the results as a means to encourage the greater use of borehole piezometers in the mining industry.

HISTORY

While the precise location and timing of the first vibrating wire piezometer installed by BHP in an exploration borehole in the Southern Coalfield is now lost in time, the period 1980 to 1982 is the most likely date. During and preceding this period, BHP in concert with other South Coast coal producers were involved in the enquiries relating to mining beneath stored waters which ultimately led to the creation of the Dams Safety Committee. These activities initiated an increased interest and competence in the monitoring of ground water behaviour during and after mining within the mining community.

In this same period, BHP was undertaking NERDCC funded research into the development and application of in-seam seismic for exploration. Part of this research was directed towards the bore hole to workings in seam seismic transmission technique. One of the outcomes was the manufacture of a bore hole geophone that could be economically placed in each exploration borehole during abandonment "in case" the need for an in seam seismicISS survey arose in the future. At some point in this early period the incorporation of a piezometer was made to the instrument bundle. BHP and now BHP Billiton have continued the practice of routinely installing geophone/piezometer modules in the coal seam of economic interest. Although not a topic of this paper the BHPB also regularly permanently install complex geophone arrays to assist in seismic control and multiple piezometer installations to meet the requirements of the Dams Safety Committee.

THE PIEZOMETER

The vibrating wire piezometer has proven to be a reliable instrument in the Southern Coalfield. Installations made in 1982 are still functional and are routinely monitored. Piezometers have been installed to depths in excess of 800 m in HQ (96 mm) holes. Piezometers are planned in boreholes exceeding 900 m in the immediate future. Some early piezometers were constructed using a wheatstone bridge type sensor but while excellent in operation they were discontinued due a break in local supply.

A vibrating wire piezometer operates by sensing pressure on a metal diaphragm which has a taut wire stretched between the diaphragm and a stable anchor point within the instrument. To read the instrument the wire is

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"plucked" by powering an electromagnetic coil with a sweep frequency pulse. The taut wire will resonate at a set frequency related to its tension which in turn is related to the small deflection of the pressure diaphragm. This frequency signal is induced into the electromagnetic coil and then to the surface logger. The output signal is very tolerant to the effects of cable length, resistance, cross talk and electrical leakage, thus reducing to a minimum the probability of failure of installed instruments.

BHPB re-engineer commercial vibrating wire sensors into a purpose built pressure rated sonde. This sonde may also contain a number of geophone elements and possibly a digital compass. Experience has shown that commercial instruments were unreliable at depths greater than 100 m and invariably failed at depths greater than 300 m after a period of time that varied from minutes to months.

Failure appears to be due to intrusion of ground water into the instrument cable and thence to the instrument. The problem was ultimately resolved by the development of a water seal at the cable end of the sonde that prevents the movement of water along the individual conductors inside the insulation. Cables are now sheathed in polyethylene rather than PVC which markedly reduces entry of ground water into the cable. In extreme situations where high strata gas or seam gas are present then grease block cable and/or additional water seals along the cable have been utilised.

Other than small modifications as more modern materials or machining processes become available, the BHPB piezometer instrument has remained the same since the mid 1980's

INSTALLATION METHODS

A number of methods have been developed to install piezometers or instrument bundles into HQ size (96 mm) exploration holes to depths of 900 m. The installation method must also ensure that the hole is totally filled with a grout that can guarantee the integrity of the future mine roof with regard to water ingress.

All of the piezometers installed prior to 2004 were installed in a sand pack with a cement grout seal above and below the installation horizon. This procedure was time expensive, generally involving two days of rig time. In 2004 a situation arose where an array of piezometers were to be installed in a shallow (160 m) NQ size (76 mm) hole. Full grouting without the use of sand packs was specified by the hydrologist.

Published papers (McKenna, 1994, Mikkelsen, 2003) promoting the grouting of vibrating wire piezometers completely within cement have been promoted by piezometer manufacturers. McKenna (1994) states "the key to the success of the grouted in installation method is that modern diaphragm-type piezometer tips require only a very small fluid volume change for pressure equalisation, and the grout can transmit this volume over the short distance from formation to the tip very quickly" Slope Indicator (2006) cite a maximum lag time of 3.5 minutes to respond to a 70 kPa pressure change through 200 mm of grout.

Following the success of the shallow hole trial the decision was made to apply this grouting method to deep exploration holes.

The success of the grout in method demands that the diaphragm of the piezometer be immersed completely in the grout without the presence of any air bubbles. The grout in method operates on the premise that minimal fluid movement is required to make the small dilation of the piezometer diaphragm. The presence of any air adjacent to the diaphragm will markedly affect the reaction time of the piezometer. The usual field solution to this problem is to remove the sintered screen from the piezometer and then to install in the inverted position ie the diaphragm facing upwards thus ensuring any air bubbles escape. The cable glanding of the BHPB unit prevents inverting the piezometer diaphragm. The coupling of the piezometer with the grout was achieved by filling the volume in front of the diaphragm with flexible epoxy filler, eliminating potential air entrapment spaces.

The elimination of the previous multistage grout/installation process with a single pass grout installation has meant that a drill rig can be released prior to geophysical logging. This equates to a saving of four to five days of rig time previously spent on stand by or grouting operations.

Piezometer installation is achieved using three people and minimal hardware.

Sufficient 25 mm poly pipe is laid out on the ground to reach the bottom of the hole.

The geophone is measured out and marks taped on the cable identifying the install depth and usually the position of the top and bottom of the seam.

A PVC ballast pipe containing nominally 20 kg of clean coarse gravel is attached to the poly pipe as a leader. The opening of the poly pipe must remain unobstructed.

All lengths are reconciled and marks made on the poly pipe at the install level of the piezometer and the collar of the hole.

The poly pipe is introduced into the hole over a large diameter wheel. It will be found that the pipe will sink in a controlled manner once the poly enters water.

When the first mark on the poly reaches the collar which indicates that the piezometer is at the correct installation depth.

MONITORING

Monitoring using automated loggers have captured most of the initial data from each new piezometer from the time of installation and for a period of a few days after grouting. Many of the earlier bores were not monitored after that time, particularly if they were remote from active mining. More recently a concerted effort has been made to instrument every new piezometer site and to manually read initially and ultimately to instrument every piezometer.

A logger has been selected that can be enclosed within the collar casing of the bore hole. The collar casing is extended to a height of 1.5 m above the ground and a thick walled PVC enclosure of the same diameter as the casing is attached to the top. A small solar cell (1 watt) provides long term power. The selected logger has a low power wireless data link which can be addressed within 500 m range. Experience has shown that range can vary from 50 m to 1200 m depending on site conditions. The radio link minimises the need to enter private properties and unduly impose on the residents.

TYPICAL OUTCOMES

Mine 1

A series of piezometers covering the proposed mine area of Westcliff Mine are showing draw down effects due to the proximity of the mine and the effect of in seam gas drainage. A zone of higher piezometric head adjacent to the north western extremity of the present longwall development is coincident with an area of high CO_2 seam gas and related poor drainage. The zone of higher piezometric head interpolated from bore hole piezometers remote from the immediate vicinity of the roadways supports the geological model and the predicted continued difficult gas drainage difficulties in that area.

Mine 2 dyke zone/ gas

The proposed Dendrobium longwall development is cut by a major structural zone characterised by jointing and multiple, intermittent igneous dykes. The piezometric data derived from wide spread exploration bores support the premise that the areas on either side of the dyke zone are most probably discrete features with regard to their gas properties. The north eastern region is characterised by a higher piezometric head, not all of which is attributable to gas pressure. However the piezometric pressures measured are sufficient to permit the storage of a higher volume of seam gas. Conversely the south western area is typically very low in piezometric head which also indicates that the gas saturation of the seam is also low.

These data, along with other considerations, has altered the proposed mine plan to maximise the extraction of coal to those areas initially least affected by excessive volumes of seam gas.

CONCLUSIONS

A method for the installation of piezometers and other instrumentation into deep exploration bore holes has been developed and successfully applied for over fifteen years. Piezometric data are routinely gathered and form part of the suite of geological information assessed in the evaluation of a mine area.

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