Comment on the paper: Design of Merensky Reef crush pillar

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in the *Journal* of SAIMM, vol. 110, no. 10, pp. 581–591
by B.P. Watson, J.S. Kuijpers, and T.R. Stacey

The author would like to refer to his contribution to the paper 'Design of pillar systems in South Africa' by Ozbay *et al.*[1].

The authors agreed 'wholeheartedly that further research, together with carefully planned field trials, in pursuit of this potentially highly rewarding concept' of the small span small pillar method is warranted.

On 30 September 2010 the author went underground at the Kroondal Chrome Mine to observe how the concept of smaller spans was being applied. He was pleasantly surprised to find that the typical coal mine bord and pillar sytem was being used very successfully. Although the deepest mining was taking place at a depth of only 450 metres, Kroondal would be an ideal mine to do further research together with carefully planned field trials. At Crown Mines Gold Mine, where the author worked, he was informed that the first recorded rockburst took place at a depth of 635 metres below surface. The depth of the platinum and chrome mines is increasing, with the risk of an escalation in injuries and fatalities due to'backbreaks' and siesmic activity. The rock engineer at Kroondal was not aware of backbreaks occuring on the mine. It is important that the rock engineers of the base mineral and gold mines get together and give more serious attention to the host rock environment in which the pillars are situated.

Studying the spreadsheet of the pillar design at Kroondal it seems that the factor of safety (FOS) of 2.4 is acceptible to a depth of 800 metres below surface. The percentage extraction will, however, be diminished from 71.4 to 44.7.

After his visit to the Koondal Mine, the author studied the papers 'Merensky pillar strength formulae based on back-analysis of pillar failures at Impala Platinum' by Watson *et al.*[2], 'Design of Merensky Reef crush pillars' by Watson *et al.*[3], and 'Pillar design in coal mines' by Wagner[4].

The author would like to share his thoughts on his findings with readers:

Watson *et al.*[2] state, and I quote 'If a sufficiently large mining span is achieved, or the stope abuts a geological feature, a large volume of hangingwall rock can become unstable, resulting in a stope collapse, or colloquially a "backbreak". In order to prevent these backbreaks a high resistance support system is required.'

The author fails to see how the residual strength of crush pillars can provide the required support resistance to prevent backbreaks and keep the stope hangingwall stable.

The crush pillar

A crushed pillar will have the following characteristics:

- Fragmented material with limited resistance to closure
- Negligible vertical or lateral cohesion in the pillar as well as its surrounding region
- No shock absorbtion ability to transfer shockwaves vertically or laterally
- Increased vertical and lateral stresses in the hangingwall and footwall
- Diminished ability to form stable beams between crushed pillars
- Failure to assist in maintaining equilibrium by the inability to distribute strains and stresses, especially tensile stresses, equally amongst the pillars and their host rock
- Weak clamping effect between pillars, especially where geological disturbances are present in the pillars as well as the bords.

The squat pillar

The squat pillar will support the following conditions:

- Solid pillar material will connect hangingwall and footwall beams vertically as well as horizontally
- The arching effect from pillar to pillar allows better absorption and distribution of shock waves caused by seismic events
- Squat pillars allow the closure of the stoped area to be managed and minimized
- Minimizing closure diminishes vertical and lateral strains and improves the ability to form stable beams in the pillar, hangingwall, and footwall. This assists the maintenance of the equilibrium in the regional host rock.

The support and cohesion in areas where geological disturbances are prevalent is also improved. Horizontal confinement of beams between pillars is improved.

A squat pillar should never fail! This is achieved in the following manner:

1 Assess the weakest material in the pillar as well as the host rock immediately in the hangingwall and footwall so as to be able to estimate/calculate the possibility of punching
2 Using the above information and considering the vertical and lateral stresses, calculate the maximum span that the material can carry as a beam without failing
3 Taking the stoping width and width to height ratio, together with the depth below surface of the squat pillar into consideration, calculate the minimum measurement of the length and width of the pillar.
4 The span stability, and not the pillar stabiliy must determine the span.

The pillar should never be subjected to stresses in excess of its critical excess shear stress characteristics.

The author agrees that pillars could have burst as a result of local siesmicity (p. 454).

The following statements by Watson *et al.*[2] underline the author's above reasoning:

The punching phenomenon becomes an important aspect of the failure mechanism of the pillar system, and effectivel controls the pillar at larger width-to- height ratios.

The failure of realistic pillar systems, with the probable exception of very slender pillars in hard rock, is to a large extent controlled by fracture and failure processes in the foundation. The author would like to add failure in the hangingwall.

Results of numerical models clearly show that pillars need to be viewed as a system that incorporates the immediate hangingwall and footwall as well as the pillar itself.

Increasing pillar strength and pillar load results in increasing damage and failure in the hanging and or footwall. The author is of the opinion this can be alleviated by smaller pillars carrying smaller loads as a result of smaller spans. Stable pillar design and behaviour cannot be considered in isolation.

In their paper 'Design of Merensky Reef Crush pillars' Watson *et al.*[3] state that pillar size should be designed with residual strength in mind, and also the need to consider peak strength and loading environment. It is the author's considered opinion that no crush pillar design will achieve this.

Watson *et al.*[3] again concentrate on assessing pillar strength but come to the conclusion that, and the author quotes: 'The calculations should include panel spans between pillars rather than a pure extraction ratio.' It is the author's opinion that this should not allow any probability of failure by loading pillars in excess of their peak pillar strength.

Wagner[4] in his paper 'Pillar design in coal mines' conduct a critical examination of the principles underlying the design of coal pillars, and states that pillar strength must take into account the properties of the pillar material and the surrounding rock strata as well the nature of the contact surfaces.

Wagner[4] states that the most important parameters that control the magnitude of induced stresses, decrease with increasing pillar size and decreasing bord width.

Using his equation for the maximum normal stress at the end of the beam, Wagner[4] finds that a change of bord dimensions from 6 metres to 5 metres results in a 31 per cent reduction in maximum tensile stress in the immediate hangingwall beam. He also states that not enough use is being made of this effective method of improving roof quality. He also emphasises the effect of strata and pillar stiffness and of panel dimensions on pillar loads.

According to Wagner[4], the most imortant parameters that control the magnitude of the induced stresses are the size of the pillars and the bord width. The author is of the opinion that of late too much emphasis is being placed on the size and strength of the pillars, while the effect of the bord widths are being neglected when analysing critical stress levels.

Suggestions

The author suggests the following research procedure using the appropriate analytical solution and numerical models techniques.

Assume a fixed extraction ratio of 75 per cent.

Vary the size of square pillars and square boards of equal length and width dimensions to find the most favourable tensile stress condition for the applicable variables of the strength of host rocks, strength of pillar material, and width-to-height ratio.

Acknowledgements

The author wishes to acknowledge Wouter van Aarde, Rock Engineering Manager of Xstrata Alloys-Western Mines, for his support and for arranging the underground visit to Kroondal Chrome Mine.

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