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Toper, Ali Zafer

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UNIVERSITY OF THE WITWATERSRAND

Ph.D. Thesis

THE EFFECT OF BLASTING ON THE ROCKMASS FOR DESIGNING THE MOST EFFECTIVE PRECONDITIONING BLASTS IN DEEP-LEVEL GOLD MINES

Ali Zafer Toper

A thesis submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

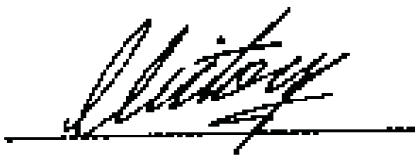
Johannesburg, June 2003

DECLARATION

I declare that this thesis is produced mainly from the results obtained from a research project funded by Safety in Mines Research Advisory Committee (SIMRAC) and that some parts of it (e.g. measurements, analysis, interpretations, etc.) were provided by other members of the research team of CSIR Division of Mining Technology (see Acknowledgements section).

It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg.

This thesis has not been submitted before for any degree or examination in any other University but some parts of it were published in some local and international journals and presented at various seminars and conferences.



Ali Zafer Toper

23rd. day of JUNE (year) 2003

ABSTRACT

According to the accident database compiled by CSIR Division of Mining Technology (Miningtek), a significant percentage of fatalities have resulted from faceburst incidents throughout the South African gold mining industry. In order to address this problem, an extensive research programme has been undertaken.

Two different preconditioning techniques have been developed; namely, face-perpendicular preconditioning and face-parallel preconditioning. Both have prevented face bursting in the areas to which they have been applied, even though several large seismic events have occurred close to the faces in some areas. In addition, minimal overall damage was observed in the preconditioned panels following these events, compared to similarly exposed unpreconditioned panels. Preconditioning has also provided some protection from distant events to the face area, through the capacity of the preconditioned ground to absorb energy.

Although the main purpose of preconditioning was to prevent facebursts, an improvement in hangingwall stability and a significant increase in the face advance rate, consistent with improved fragmentation, have been noted in preconditioned areas. During preconditioning, the average face advance rate increased significantly compared with unpreconditioned periods. Owing to this increase in face advance rate, the mining cost per area mined decreased in preconditioned panels. The effect of preconditioning on improving the drilling rate of production holes was also significant. The preconditioning experiments also indicated that it was possible to implement this method in a deep-level longwall mining environment without significant disruption to the mining cycle. Guidelines for both preconditioning techniques have been compiled.

In order to determine the optimum blast parameters for achieving the most effective preconditioning, an extensive optimisation study was carried out for the face-perpendicular preconditioning technique. While optimum values for parameters such as hole length, diameter and spacing were determined, it was ultimately concluded that the differences in results obtained by varying the

preconditioning parameters were less significant than the clear positive differences observed when comparing preconditioned areas with non-preconditioned areas.

In order to assure successful implementation of the techniques in the mining environment, a structured implementation procedure has been developed from experience gained at research sites. This procedure consists of education and training of all levels of the production personnel as well as the personnel of the training and safety departments of the mine.

In memory of all mine workers

who lost their life

as a result of

rockburst accidents

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1 INTRODUCTION

South Africa is one of the largest gold producers in the world. The South African gold ore is found in a geological setting called "The Witwatersrand Basin" and consists of extensive, narrow, tabular deposits generally called reefs. Extensive mining has occurred at shallower depths over the last 100 years and today much of the mining occurs at great depth. The mining of reefs at depths in excess of 2000 m induces extremely high stresses on the rockmass in the vicinity of any excavation. In stopes, in particular, such high stresses induced by mining increase the strain energy stored in the rockmass and result in a state of unstable equilibrium. The release of excessive energy in the rockmass can be in the form of the extending of the fracture zone ahead of the stope face and / or the displacement of pre-existing discontinuities either violently or non-violently. The violent release of accumulated strain energy can be described as a seismic event that may result in a rockburst, depending on the magnitude, the distance between the source and the excavation and existing ground conditions around that excavation. If a seismic event results in a rockburst, it can cause extensive damage to underground workings, and varying degrees of injuries and even fatalities.

Although a number of solutions have been suggested by various investigators in the past and some of them have been successfully implemented, the rockburst problem still poses a serious and ongoing hazard to the gold mining industry in South Africa.

1.1 Research problem

The violent release of accumulated strain energy can be in the form of ejection of mining faces into the mine openings at a very high velocity and this phenomenon is called a faceburst.

Data from a rock-related fatal accident database that was compiled by CSIR / Miningtek shows that a total of 216 rock-related fatalities resulted from 134

faceburst incidents throughout the South African gold mining industry during the period 1990 - 1997 (see Table 1.2.1). This figure represents more than 27 percent of the total of 793 rockburst fatalities recorded during this period. The rockburst fatalities are 44 percent of a total of 1808 rock-related fatalities over the same period. The author believes that facebursts comprise a much greater percentage of total rockbursts than this data would lead us to believe because many of the faceburst fatalities were more generally classified as rockburst fatalities. Thus, facebursting is a major concern for the South African gold mining industry. The most problematic reefs are the Ventersdorp Contact Reef (VCR), Carbon Leader (CL) and Composite reefs in which more than two-thirds of all faceburst fatalities occurred.

1.2 Rockburst control research programme

Since 1987, an extensive research project has been carried out by a group of researchers within the Chamber of Mines Research Organisation (COMRO) which, in 1993, became the Division of Mining Technology (known as Miningtek) of the Council for Scientific and Industrial Research (CSIR). The philosophy adopted by researchers working on this project accepts that rockbursts can neither be predicted nor prevented with current knowledge and technology, but may be controlled. Thus, the main objective of the research programme was to develop rockburst control methods to enable mines to operate in areas which are at most risk from seismicity and the resulting rockbursts. In other words, the intention was to control the time and size of seismic events that could result in rockbursts, as well as to minimise the potential damage resulting from such events.

Preconditioning, also called "destress blasting", is a rockburst control technique that involves setting off designed blasting ahead of the stope face. In this way, preconditioning is intended to transfer the stresses further away from the stope face through remobilising the existing fractures in the rockmass.

Table 1.2.1 Statistics of rock-related accidents and resulting fatalities in South African gold mines from 1990 to 1997 (both incl.)

Accident Type	Reef Type	Incidence		Fatality	
		Number	per 10^8 m^2	Number	per 10^8 m^2
Rock-related	Basal	193	7.26	214	8.05
	Carbon Leader	159	20.24	245	31.19
	Composite	15	8.09	20	10.78
	Main	56	10.30	66	12.14
	Vaal Reef	192	8.63	225	10.11
	VCR	297	15.58	374	19.62
	Other reefs*	152	3.88	328	8.37
	Off-reef**	160	-	336	-
	Total / Avg.**	1224	8.70	1808	12.04
Rockburst	Basal	25	0.94	48	1.81
	Carbon Leader	109	13.88	202	25.72
	Composite	12	6.47	17	9.17
	Main	16	2.94	19	3.49
	Vaal Reef	45	2.02	85	3.82
	VCR	157	8.24	242	12.70
	Other reefs*	42	1.07	64	1.63
	Off-reef**	56	-	116	-
	Total / Avg.**	462	3.32	793	5.54
Faceburst	Basal	4	0.15	10	0.38
	Carbon Leader	27	3.44	52	6.62
	Composite	7	3.77	11	5.93
	Main	4	0.74	4	0.74
	Vaal Reef	13	0.58	18	0.81
	VCR	53	2.78	82	4.30
	Other reefs	12	0.31	21	0.54
	Off-reef**	14	-	18	-
	Total / Avg.**	134	0.98	216	1.62

* Other reefs category also contains unspecified reefs.

** Off-reef values are included in total but excluded in average calculations.

Preconditioning techniques have been used in different mining environments around the world since the 1950s and, in many cases, have been found to be very effective in controlling and minimising the effects of rockbursts. The main idea behind these techniques is to detonate a preconditioning blast ahead of a mining face to re-distribute the stress peak further into the solid region ahead of the stope face by eliminating the strain energy "lock-ups" in the asperities of pre-existing or mining-induced fracturing.

In order to quantify the success of preconditioning in highly stressed rock, a better knowledge of the effects of a blast in confined rock is required. An understanding of the genesis and sequence of blast-induced fracturing and the effect of blasting on pre-existing fracturing is crucial for the design of effective preconditioning methods, and for the assessment of the success of preconditioning blasts.

The design of preconditioning blasts involves making a decision on the charge mass, type, hole spacing and diameter, and the position of the charge in the rockmass, as well as the initiation of the charged holes. The quantification of the actual effects of preconditioning on rockmass requires a knowledge of the effect of explosives on rock. Dynamic computer codes can provide insights into the effect of explosives on rock under confined conditions, but very few physical measurements have been made of the effects of explosives under such conditions.

1.3 Objectives of this study

The ultimate objective of this work was to develop and implement preconditioning techniques to control facebursts for the achievement of safer mining in seismically hazardous areas. In order to achieve this main objective, the following goals were also set:

- an investigation of the actual effect of the explosives in the confined and highly stressed rock;
- an understanding of the faceburst and preconditioning mechanisms;

- proving the concept by actual preconditioning experiments at different sites;
- a quantification of the effects of the preconditioning blast on the local rockmass;
- verification of the effects of preconditioning blasts by numerical simulations;
- an optimisation of the preconditioning blasts by varying charge mass, type, hole spacing and diameter, position of the charge in the rock and the initiation sequence of the charges;
- the transfer of the knowledge and experience gained of preconditioning to the mining industry for implementation;
- the development of guidelines for the implementation of preconditioning techniques and determining the requirements for the successful implementation of preconditioning in the industry.

1.4 Outline of the content of the thesis

This thesis consists of 9 chapters. Following this introductory chapter, a summary of an extensive literature review is given in Chapter 2.

The author's initial involvement in the Rockburst Control Research Programme was at the research site established at West Driefontein Gold Mine, where the effects of controlled test blasts were investigated. The findings from these activities are given in Chapter 3. However, this research work had to be stopped after one year, as no funding was made available for continuing the research activities at this site.

The majority of knowledge and experience gained on preconditioning was from the site investigations carried out at the research sites established at Blyvooruitzicht and Mponeng Gold Mines. The results obtained from an extensive monitoring of actual preconditioning blasts in these sites are given in Chapters 4 and 5. While the author had very limited involvement in the investigations on the face-parallel preconditioning discussed in Chapter 4, he headed the research activities involving face-perpendicular preconditioning at Mponeng Gold Mine.