International Journal of Applied Research 2016; 2(9): 397-402

International Journal of Applied Research

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2016; 2(9): 397-402
www.allresearchjournal.com
Received: 17-07-2016
Accepted: 18-08-2016

Ng' ambi Immanuel
University of Zambia, School of Mines, Department of Mining Engineering, Lusaka, Zambia

Victor Mutambo
University of Zambia, School of Mines, Department of Mining Engineering, Lusaka, Zambia

Correspondence
Ng' ambi Immanuel
University of Zambia, School of Mines, Department of Mining Engineering, Lusaka, Zambia

Optimization of stope recovery and dilution at Mufulira mine through application of appropriate designs and practices

Ng' ambi Immanuel and Victor Mutambo

Abstract
The effectiveness of modern mining depends on proper mine designs and implementation of mining standards. Proper mine designs and implementation of mining standards help in maximizing ore recovery and reducing dilution. Reconciliation statistical studies of 2014 and 2015 indicate that there has been ineffective stope designs and improper implementation of stoping standards which has led to reduced stope recovery and increased dilution at Mufulira mine. Therefore, this study was aimed at determining the causes of low stop recovery and dilution. The actual average monthly stop recoveries where reviewed and compared with the targets of 80% and 84 % Mechanised Continous Retreat one (MCR1) and Mechanised Continous Retreat two (MCR1). The Actual Monthly dilutions were reviewed and compared with the theoretical values of 31% and 30 % for MCR 1 and MCR 2 respectively.
The study carried out has established some of the causes of low stop recovery and increased dilution are attributed to lack of proper implementation of preset mining standards. Hence based on these finding appropriate mine designs and practices have been recommended.

Keywords: Stope recovery; dilution; stope design; mining method

Introduction
A stope is an underground excavation from which ore has been sequentially removed. It is limited along its strike usually by the ore remnants and along the section by the country rock. Therefore, the stability of the rock at the boundary of the stope is closely linked to the stope design and vise-versa. The design is a function of rock mass quality and must be optimized in a bid to maximize ore recovery. A research study carried out at Mufulira mine has established that poor designing of stopes has significantly contributed to qualitative ore losses. Furthermore, the study also established that ineffective stoping procedures and practices such as poor stope drilling, charging and blasting have negatively affected stope recovery through formation of buildups and hang-ups in the stopes.

Materials and methods
The method of obtaining information for the research was carried out in three stages:

Literature review
The study of mine plans and literature reviews on stope designs and operations was conducted. Daily and monthly mining reports were reviewed and also some relevant information pertaining to the project was collected from previously published mining journals.

Field work
Various work sites underground were visited for collection of information on stope design and development, stope drilling and charging, stope blasting and drawing.

Stope designs and development

Information on stope designs underground was obtained through actual site reconnaissance during which stopes at a given sublevel were sampled. Their height was estimated using a distometer. The length of the stope was approximated by summing the number of panels along the length of each stope (each panel was 10m in length).

Information on underground stope development was also obtained through actual site reconnaissance during which all the developments required to access the stopes were reviewed.

Stope drilling and charging

Actual site reconnaissance was used to obtain information on stope drilling and charging operations underground. Sublevels were sampled and the drilling and charging operations at each sublevel were observed from the start of a shift until the end of the shift.

Stope blasting and drawing

Information on stope blasting and drawing was obtained through actual site reconnaissance. During stope blasting, the Delay given to each longhole in a ring was recorded. The expected advance and the number of rings being blasted were also noted.

During stope drawing, the actual tonnes drawn from a given stope were recorded with the help of grade control personnel. The total tonnes of ore drawn from a stope at the end of the shift were determined as being the product of the loader capacity and the total number of scoops (filled loader buckets) drawn from a given stope. The grade of the ore drawn from the stopes was obtained by hand picking eighteen (18) pieces of ore rock from every 10th scoop drawn from a given stope. The pieces of ore rock were then sent to the analytical department where they were examined and their grade determine.

Interviews and consultations

Interviews were conducted with some miners in charge of production and mine section supervisors while consultations were undertaken with mine technical department personnel for clarification of obtained information.

Data collection and results

Mining methods at Mufulira mine

The current mining methods used at Mufulira mine are variants of Mechanized continuous retreat (2015). These mining methods (figures 2.1and 2.2) are essentially variants of sublevel open stoping method with delayed hanging wall cave referred to as Mechanized continuous retreat 1 (MCR1) and Mechanized continuous retreat 2 (MCR2) respectively. The methods involve establishing longitudinal stope blocks along the strike of the orebody. The design incorporates 3.0m chain pillar at the top of the stope. This pillar retains the broken or collapsed hanging wall material from upper levels and thus prevents the waste ground from diluting the freshly blasted ore. The pillars collapse under rotational moment about 50m behind the advancing stope front(Kapembwa, 2010).

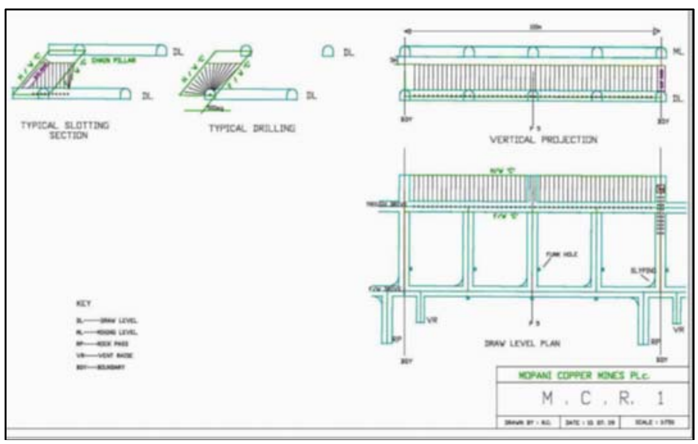

Fig 1: MCR1 layout

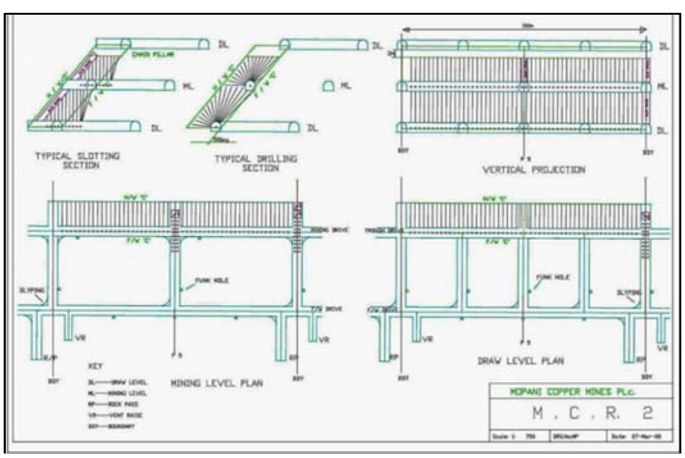

Fig 2: MCR2 layout

Stope design and development

Table 1 shows stope designs and development parameters observed underground

Table 1: Stope design and development parameters

Parameter	Measurement/location
Stope length Stope height, m Stope width = dependent on orebody True thickness, chain pillar thickness, m	50 17 3
Average lag between stope face positions in adjacent sublevels, m	50
Position of stopes	Stopes are developed in the mining drive which is positioned at the geological footwall contact of the orebody
Abandoned dewatering sites	Along the mining drive

Stope drilling and charging

Table 2 shows the stope drilling and charging parameters observed.

Table 2: Stope drilling and charging observations

Parameter	Comment
Longhole drilling operation done using drill rigs	Operation done using drill rigs
Longhole toe burdens	Sometimes not measured
Longhole ring burdens	Greater than 1.8m
Longhole ring	Angle is rarely measured
Longhole drilling pattern	Not usually followed
Longhole length re-measuring	Usually not done
Longholes are charged using bulk emulsion explosives	-
Emulsion cup mass weighing	Not usually done
Collar Length of Longholes	Holes have constant collar length of 1m

Stope blasting and drawing

Table 3 shows the stope blasting and drawing parameters observed underground

Table 3: Stope blasting and drawing observations

Operation	comment
Timing of holes	Longholes rings are not timed during blasting (longholes have the same delay)
Ring blasting	Inconsistent number of rings blasted at once
Post blast	Post blast profile of the stope is not checked
Stope sampling method	Usually not routine
Stope support system	No stope support system is installed during blasting

Stoping statistics

Table 4 shows a typical example of the total collected stoping statistics for the months of May, June and July in the year 2015

Table 4: Total stoping statistics for May, June and July 2015

	May 2015	June 2015	July 2015	Totals
Tonnes blasted	51438	50429	72332	174199
Tonnes trammed/delivered	46765	67907	61912	176584
Copper Blasted	1238	1108	1620	3966
Copper trammed/delivered	743	957	952	2652
Stoping Recovery	60	86	59	205
Planned Extraction	100	101	87	288
Stoping Extraction	91	135	86	311
Planned Dilution	28	28	31	87
Stoping Dilution	51	56	46	153

Source: Mufulira mine

Data analysis and discussion

Stope design and development factors

Use of orebody limits as stope boundary extents

The stability of the rock mas at the boundary of the stope is closely linked to the stope design. The design of each stope must be optimized as a function of local rock mass quality.

For Mufulira mine rocks, the Rock Mass Rating (RMR) and the Rock Mass Strength (RMS) were determined using Laubschers Geomechanical Classification as shown in table 5.1

Table 5: RMR and RMS for Mufulira rocks(Owusu-Sarpong, 2014).

Rock type	RMR	RMS (MPA)	Class
Footwall quartzite	61	112	Good
C quartzite (orebody)	81	164	G/V.good
Inter B-C	64	94	Good
B quartzite (ore-body)	81	164	G/VGood
Lower dolomite	49	15	Fair
Inter A-B	68	126	Good
A quartzite (ore-body)	81	164	G/V.Good

From the table above, it can be seen that the ore-bodies are generally more competent than the immediate footwall and hanging wall rocks.
However, in Mechanized Continuous Retreat mining method used at Mufulira, the use of orebody limits as stope boundary extents contributes to qualitative ore losses because during stope blasting, the energy required to blast the ore (which is much more competent than the surrounding rock masses) tends to also fragment the rocks at the boundary of the stope i.e. the footwall and hanging wall. These fragmented rocks which are basically waste material slough into the stope and mix with the valuable ore hence causing increased dilution.

Positioning of mining drive not optimized.

Poor positioning of mining drive results in the limitation of the angle of draw of blasted ore. Currently mining is being done on contact (meaning the mining drive is always positioned at the geological footwall contact of the ore body). This is due to lack of enough geological information about the orebody such as the orebody dip angle, true thickness etc.

Lack and poor mining of slot raises for some stopes

A design standard for Mechanized Continuous Retreat mining method used at Mufulira is that each stope (especially stopes in MCR1) must have a 2m diameter slot raise mined at one of its ends. The slot raises are supposed to be mined 1m from the geological hanging wall contact of the orebody and at an angle equal to the orebody dip angle. This is because the slot raise is used to raise the stope profile up to the chain pillar. However, in some areas of the mine where MCR1 is being used, slot raises are not mined for some stopes due to difficulties faced with the conventional methods being used to mine the slots. Lack of slot raises results in a drop in the profile of these stopes. This implies that for most of these stopes the thickness of the chain pillar is greater than the planned 3m. Poor mining of slot raises results in breaching of the hanging wall and hence causes qualitative ore loss.

Presence of remnant pillars and abandoned dewatering sites

Mechanized Continuous Retreat mining method used at Mufulira requires that all remnant pillars and abandoned dewatering sites along the mining drive be demolished as quickly as possible. This is because they tend to transmit stresses to mining levels below. These stresses cause shearing of longholes and in some instances, they may cause stopes in mining levels below to collapse (for example the situation at 1390mL). The collapsing of stopes leads to increased dilution and ore losses.

Non adherence to Standard mining echelon

Mechanized Continuous Retreat mining method requires that for two adjacent sublevels, the stope face position in the upper level must lead that in the lower sublevel by 5.4m. This helps reduce on stresses produced due to the stoping operations. Currently most stope face positions in adjacent sublevels have a lag greater than 5.4m (50m in some sections). This increases the stresses that are transmitted to the lower level hence causing low extraction and dilution through hang-ups and peeling off of the hanging wall. In areas where MCR2 is being used, such huge lags between the mining level and the draw level increases qualitative ore losses as the hanging wall on the mining level begins to peel off onto the blasted ore awaiting to report the draw level. The chain pillar may also collapse onto the blasted ore.

Delayed development of footwall drives

Development standards of Mechanized Continuous Retreat mining method require that the footwall drive be developed earlier than the mining drive. This provides time for geologists to correctly map the orebody and hence provide enough information such as, type of orebody, its inclination, structure, true thickness etc. for the optimization of the position of mining drive. Currently in all mining sections, mining drive development is given more priority than footwall drive development. This makes it difficult for geologists to carry out proper orebody mapping and thus they only provide the mine planners with preliminary geological information about the orebody.

Stope drilling and charging factors

Stope drilling and stope charging are very important stoping operations whose standards need to be adhered to. Failure to follow some of the standards leads to ore loss through hang-ups and increased dilution due to chain pillar breaching and peeling off of the hanging wall (1989). The following stope drilling and charging factors cause low stope recovery and dilution at Mufulira mine;

Poor longhole ring marking

In some sections of the mine visited, the longhole rings are not properly marked. Figures 3 and 4 show a comparison between the standard way of marking rings and the actual marking found underground. The ring in figure 4 was poorly marked leading to poorly drilled longholes. Poor drilling of longholes leads to increased toe burdens. This increase in toe burden increases the volume of ore that will have to be blasted by each charged hole and hence creating hang-ups.

Longhole deviations

Longhole deviations are common due to the use of drill rigs without stingers. Currently most of the longhole drill rigs used in the mine have no stingers and for those with stingers, the operators do not use them due to lack of sensitization and motivation. Hole deviations tend to increase the longhole toe burdens which in turn causes buildups due to increased ore tonnes to be blasted by each charged hole.

Longholes not drilled to the planned lengths and in the planned plane

To prevent increased toe burdens, longholes in a ring are supposed to be drilled in the same plane (Fan angle) and to the planned lengths. Currently due to lack of proper measuring equipment and lack of sensitization, some longholes are not drilled to the required lengths especially in sections that are highly stressed and were longholes are believed to shear with time. This results in increased toe burdens and thus causes ore losses through hang-ups.

Fig 1: Properly marked rings

Fig 2: Poorly collared longholes

A design standard for Mechanized Continuous Retreat mining method used at Mufulira is that not less than 3 longholes in each ring from the draw level must hole into the adjacent mining level in areas where Mechanized Continuous Retreat two (MCR2) is in use. This helps to create an adequate opening for blasted ore from the mining level to report to the draw level. Currently in some areas were MCR2 is in use, due to poor drilling and improper alignment of the adjacent mining drives, only 2 longholes from the draw level hole into the mining level. This reduces the size of the opening created and hence results in a reduction in the amount of blasted ore reporting to the draw level and subsequently ore loss through buildups on the drilling level.

Measurement of longholes

Longholes are not re-measured and flashed before they are charged: The drilled longholes are measured by hole checkers several weeks before they are charged and so many things (such as hole shearing and blocking) happen during that period, it is therefore salient that the charging crew measures and flashes the holes before charging them. Currently, longhole measuring and flashing is not done by some charging crews due to, exhaustion and sometimes lack of measuring equipment. This increases the chances of ore loss through hang-ups as explosives may not be pumped up to the toe of some holes due to blockages.

Poor charging practices: Due to lack of motivation and exhaustion resulting from pushing the charging horse, the charging crews in some instances tend to leave longholes uncharged and in other instances, the horse is not pushed to the toe of the holes. This too increases the probability of ore loss through hang-ups as the burdens between charged longholes is increased.

Emulsion cup mass and density not weighed after it has gassed: Currently, the measurement of bulk emulsion density is not done due to absence of graduated cup and measuring scale. Emulsion pumped into the longholes may not have the required explosive energy due to imbalanced ratio of sensitizer and emulsion. This results in poor fragmentation due to poor distribution of blasting energy.

Pumping of wrong quantity of explosives into the longholes

Most of the mobile charging units currently in use in the mine have defective batching systems. This makes it difficult to determine whether the correct mass of explosives have been pumped into each longhole. In most cases the longholes will be charged with emulsion of mass less than the required. This results in ore losses due to poor fragmentation.

Stope blasting and drawing factors

Not timed longholes

Timing of longholes is key to uniform transmission of the shock wave through the rock and hence prevent hanging wall damage which may subsequently cause qualitative ore losses. Each hole in a specific ring must have a delay period especially the holes near the geological footwall contact. These holes must have the least delay meaning they should be blasted earlier than the other longholes. Currently, due to lack of sensitization, the blasting crews do not time the longhole rings and as such all the holes are given the same delay. This practice increases the probability of hanging wall damage and consequently qualitatively ore losses.

Blasting of more than one ring at once

The amount of explosives pumped into a single ring is quite large, this means even the vibration shock wave transmitted to the hanging wall during blasting of a single ring has a serious impact on its stability. Blasting of more than one ring has more serious impact and can be catastrophic to the hanging wall. It induces hanging wall failure and consequently increases ore dilution

Lack of equipment to measure the post blast profile of the stope

Mechanized Continuous Retreat mining method involves the creation of cavities (stopes) along the strike of the orebody. After blasting a few rings in the stope, equipment such as the Faro laser scanners and cavity monitoring systems must be used to pick out some offsets and create a block model of the stope. This block model must then be compared with the planned model so as to verify whether the stoping operation is going according to plan and to be able to detect any situations of wall rock overbreak. Currently, the mine lacks such equipment hence it is very difficult to determine cases of over breaks and sometimes under breaks. As a result of the above, ore is lost through drops in stope profiles that are not detected. Furthermore, dilution is also increased due to over breaks that are also not quantified.

Stope overdraw

In Mechanized Continuous Retreat mining method, blasted (fragmented) ore is extracted from stopes using LHD (Load Haul Dump) loaders which muck the stopes clean. Lack of proper equipment for developing the solid model of the post blasted stope, very slow development operations and improper sampling methods induces stope overdraw. Most stopes at Mufulira mine are overdrawn due to the above mentioned factors. Overdrawing of stopes increases qualitative ore losses.

Biased ore sampling: The current ore sampling method in place at the mine is quite biased and cannot provide an accurate approximation of the grade of ore being extracted. This contributes to qualitative ore losses because low grade material (waste) is also extracted without being noted and mixed with the valuable ore.

Conclusion

In Mechanized Continuous Retreat mining method used at Mufulira mine, stope recovery can be optimized by application of effective stope designs that do not incorporate the orebody geological hanging wall and footwall. To achieve this, the stopes should be developed in ore and stop design and geometry should be based on Rock Mass Rating (RMR). Footwall drive development must be given priority over the mining drive so as to allow detailed geological mapping of the orebody. Sensitization must be made on the demolition of remnant pillars and dewatering sites, proper mining of slot raises and adhering to the standard mining echelon. Proper stope drilling, charging, blasting and drawing practices must be utilized to prevent hanging wall damage and ore loss through hang-ups.

With the advancement in technology various stope monitoring equipment such as Faro laser scanners and cavity monitoring systems have been developed. These maybe employed to help in quantifying and detecting wall rock overbreaks and drops in profile in stopes.

Acknowledgements

The author offers heartfelt gratitude to Management of Mufulira mine for granting this author an opportunity to undertake this study.

References

1. Kapembwa M, Kampeni K. Description of Mining Methods at Mufulira Mine [Report]. - Mufulira: Mopani Copper Mines, 2010.
2. Tomson Sinkala. Hole deviations in percussion drilling and control measures. Doctoral Thesis, LuLea University of Technology Sweden. 1989.
3. Kangwa Sam. Economic Consequences of Hole Deviations In Mining Operations - Lusaka, Masters thesis. 2002.
4. Lewis* KI, Afewu GO. Sampling of run-of-mine mill feed—A practical approach, Randburg: The South African Institute of Mining and Metallurgy. 1998.
5. Owusu-Sarpong Seth. Ground control management plan. Report. - Mufulira: Mopani copper mines, Zambia. 2014.