Caterpillar Hard Rock Mining Innovations: Developments for Continuous High-Performance Block Cave Mining

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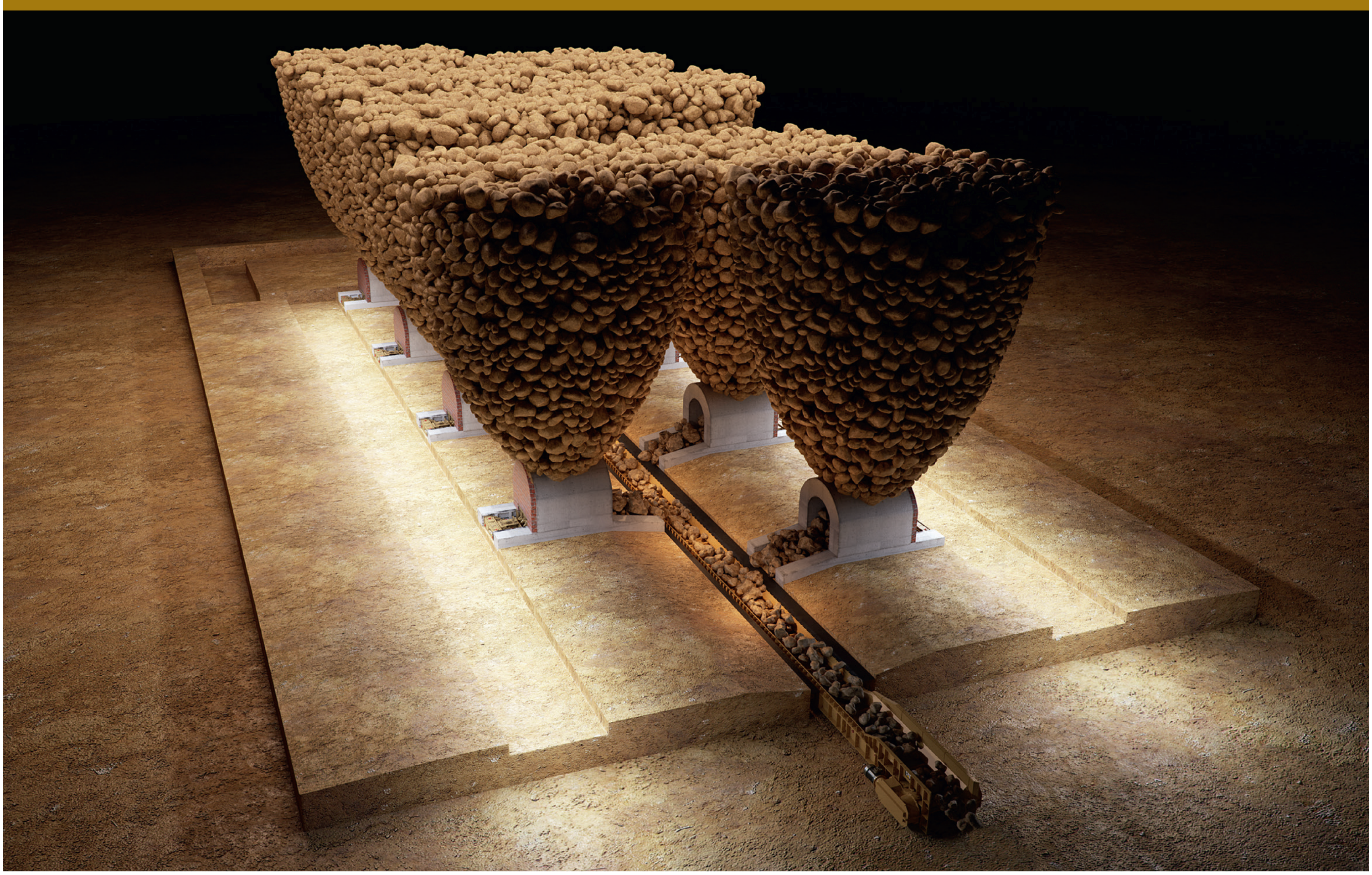


Table of Contents

Abstract

As global demand for raw materials continues to increase, mining companies are looking for ways to increase production capacity. As visible in actual Greenfield projects around the world, the trend in block caving has reached production rates of up to 160,000 tonnes per day. Keeping in mind this development in mine design — correlated with the capacity change of mine output figures and the actual market situation — this paper analyzes the limits of current block cave mines and points out an approach for maximized production capacities in future block caving mines. Primarily, this paper discusses the paradigm shift from discontinuous common hard rock mining to continuous operating, high-performance block caving operations.

Introduction

This paper will analyze the bottlenecks in different processes for block caving mines rated at 160,000 tonnes per day—and discuss a new technical concept aimed at overcoming these bottlenecks.

The first step of this investigation was to define a mine design with adequate rock properties and set a proper production rate for the case study. Next, bottlenecks—generated by the evaluated case study parameters—had to be identified and eliminated for the mining operation.

Case Study

MINE DESIGN

For this study, the mine design was set for a panel caving operation with a typical draw point spacing of 15 x 15 m and a characteristic average block height of 560 m. The ore density is set to ρ=2.7 t/m^3.

One obstacle to increasing the extraction rate is balancing the different phases of the mining sequence (reaping, spreading and development of new areas) in order to achieve a constant output of production and avoid standstill waiting times.

The extraction rate of the initial phase (spreading) of the caving process is restricted to low values in order to prevent undesired events such as high seismic activities or sudden air blasts. Therefore, the mean extraction rate can only be raised by increasing the production rate in the regular phase (reaping). Formula 1 describes this relationship:

$$\tau m = (n * \tau s + \tau r) / (n + 1) \qquad (1)$$

τm = mean extraction rate

τs = extraction rate spreading phase

τr = extraction rate of regular caving

n = number of blocks in initial phase

τm is calculated under consideration of the extraction rate during the initial caving process phase and the extraction rate of regular caving as a function of the number of blocks in the initial phase.

For this case study it was assumed that the spreading rate is limited to 0.45 tpd/m^2 (tonnes per day per square meter) when applying pre-conditioning methods. According to the paper "Mechanized Continuous Drawing System: A Technical Answer to Increase Production Capacity for Large Block Caving Mines," presented by V. Encina, et al., at the MassMin 2008, the optimal ratio of of reaping blocks to spreading blocks is 1:3.

Case Study

As figure 1 shows, the mean production rate can only be increased marginally when more than 3 blocks in spreading are applied per block in reaping. Accordingly, the ratio 1:3 is used in this case study as an economical optimum.

The correlations described above indicate that with the given maximum spreading rate, the reaping rate can be raised to a maximum of 4.05 tpd/m^2 and that the mean production rate will be 1.35 tpd/m^2. In order to achieve a daily production rate of 160,000 tonnes per day at this mean extraction rate, the mine will need a footprint of 29,630 m^2 per one of four blocks. With the assumed draw point spacing of 15 m by 15 m, which leads to a draw point of 225 m^2, 132 draw points are required per block. At a block height of 500 m and a rock density of ρ= 2.7 t/m^{3,} each draw point has a tonnage of 300 * 103 t.

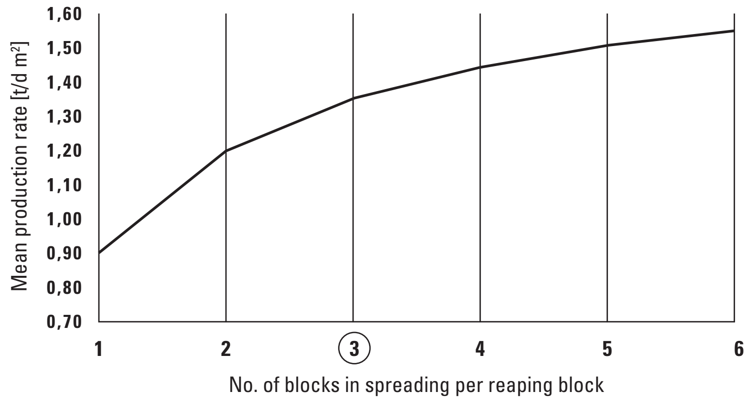


FIGURE 1: ***Interdependence of mean production rate to spreading blocks per reaping block***

The main question arising from this case is:

> How can the performance of the haulage system be increased to the level of 4.05 tpd/m^2 for the reaping block?

PRODUCTION

The intention of this case study is to discuss methods for raising the production rate of future block caving mines to 160,000 tonnes per day. Compared to current block cave mines, this output rate requires an enormous increase of the reaping rate. It would also require an extremely large footprint using conventional mining methods.

The main bottleneck preventing a significant increase of production is the capacity of the haulage system. If draw point extraction is done using LHDs, the maximum extraction rate is 0.4 – 0.5 tpd/m^2.

With this performance and a limitation of the LHD fleet by traffic stream and the deposit footprint, this discontinuous haulage system is inadequate for upcoming mega mines. To solve this problem, new concepts for block caving operations were developed between Codelco and Caterpillar and will be presented in the following chapters.

Moreover, high production leads to increased efforts for development and preparatory works at production level and in the undercut level, as well. These required rapid development rates demand new concepts and suitable techniques. In this paper, these challenges facing future high-performance mines will be discussed in detail.

Haulage System

In conventional LHD block caving operations, less than 10 percent of the active mining area is used for production due to the fact that the LHD can only extract the ore from one draw point per production drift at a time.

Therefore, the maximum achievable mean extraction rate for a discontinuous LHD haulage system is considered to be in the range of 0.45 to 0.5 tpd/m^2 for block caving operations.

To achieve a significant increase in production, either the active area of the panel must be extended or the extraction rate has to be multiplied.

CONCEPT

The draw rate can be increased significantly by converting the haulage system from batch-type operation to continuous haulage (Continuous Mining Concept of Codelco). The continuous mining system consists of mobile feeders, referred to as dozer feeders, which are installed in each draw point (see figure 2). The dozer feeder is pushed into the draw point—filled with caved ore—by means of a hydraulic pushing device. The dozer pushes the caved material by a dozer plate onto a chain conveyor, installed in the production drift. The chain conveyor transports the material to a primary crusher, followed by a regular belt conveyor (figure 3).

For this system, the production level design was modified. Service drifts provide access for the installation and supply of the dozer feeder units from one side of the draw point, whereas the production drift with the chain conveyor is located on the opposite side. Both the service and production drifts are used for draw points to either side. A schematic overview of the installed system is given in figure 3.

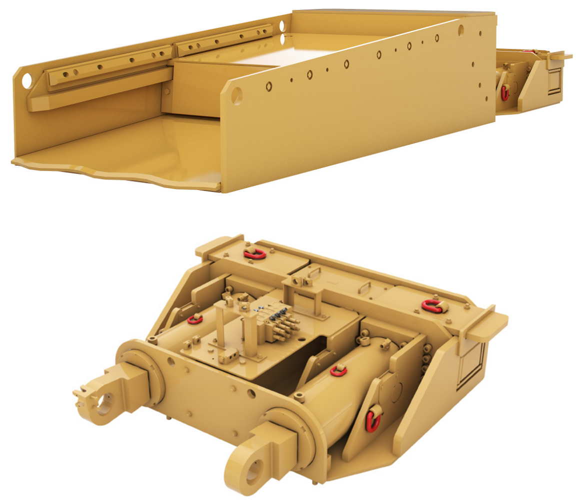


FIGURE 2: ***Mobile Feeder***

FIGURE 3: ***Continuous haulage system at production level***

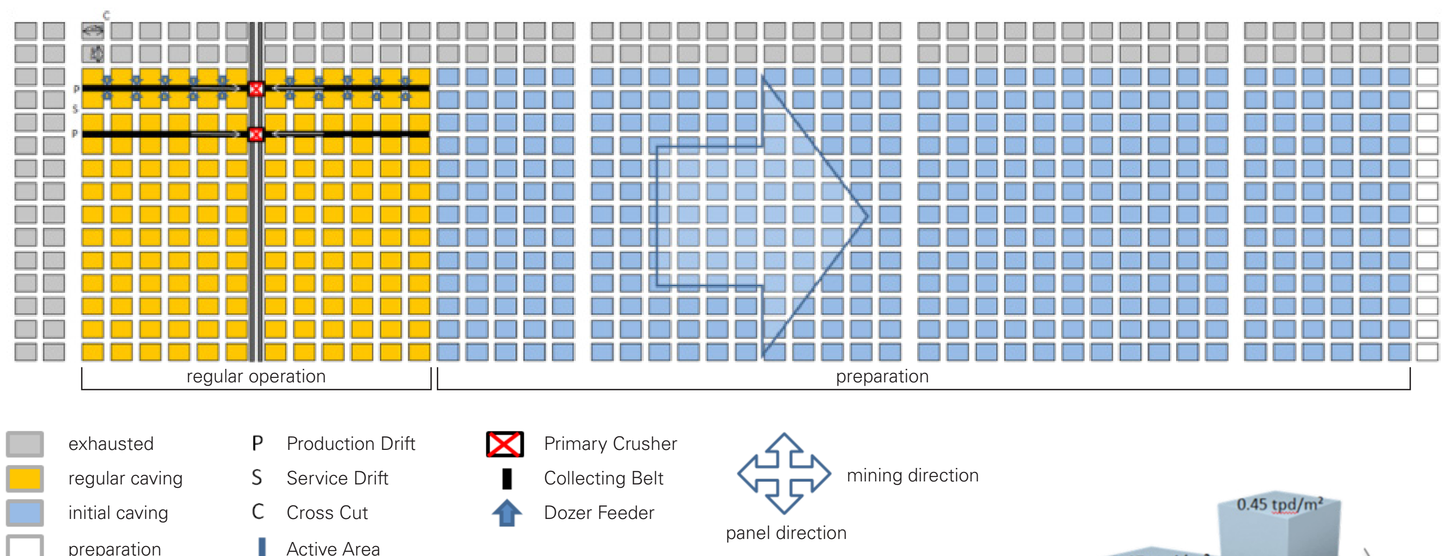
Haulage System

The continuous haulage system was set up for the following configuration:

Each production conveyor is rated with a mean load capacity of 700 tph, fed by 10 Dozer Feeder units with an average extraction rate of 260 tph. The system utilization rate is calculated to approximately 42%. Even if feeding units have downtimes for maintenance reasons or caused by hang-ups, the daily production rate is covered by this utilization rate. To meet the daily production target, this configuration is installed 14 times within the panel. So all 140 draw points within a regular operation phase are mined out with the continuous haulage system.

The additional draw points in the preparation field are calculated to 420 using n=3. These extraction points will be extracted conventionally, as the LHD extraction rate nearly matches the needed extraction rate, so the new high-performance system doesn't necessarily need to be installed at that time.

With these mining sequences, the block life span can be calculated to 900 working days, with 675 days of initial caving phase and 225 of regular extraction. The panel design and schematic panel pattern results in figure 4.



Schematic panel pattern

225	225	225	225	225	225	225	....
225	225	225	225	225	225	....	
225	225	225	225	225	....		
225	225	225	225	....			

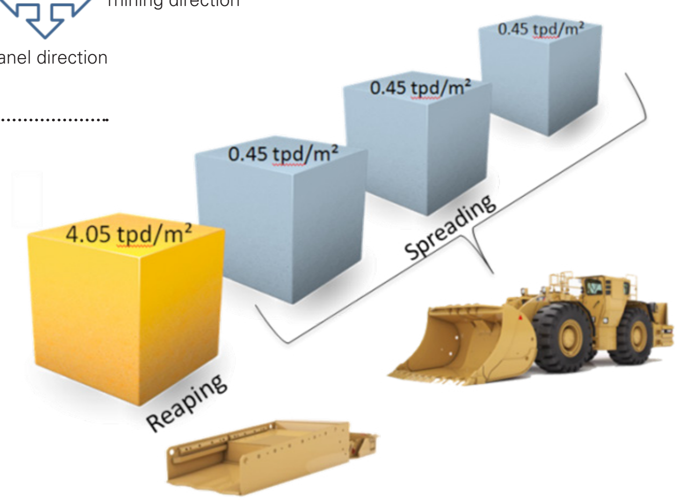


FIGURE 4: ***Panel layout plan & panel pattern***

Haulage System

CURRENT DEVELOPMENTS AND INNOVATIONS

To date, removable feeder units consist of two main units: The corpus — with hydraulic dozer plate — and the pushing device unit (see figure 2). For installation of dozer feeders into draw points, the units are temporarily assembled on the surface and pushed into the draw points as a whole. For mobility purposes and the possibility of tightly arranged units, an alternative to the autonomous pushing device is under development to increase the flexibility of the dozer feeder.

The main idea behind this new development is to install the pushing device permanently in front of a modified LHD, crawler track chassis with rotation tables, redesigned shield trailer or any equivalent underground vehicle.

CONCLUSION

On top of the fact that a continuous system leads to a high-performance block caving operation, there are a number of secondary benefits to be obtained.

Generating a continuous haulage stream from the draw points can result in significant cost reductions due to a high grade of automation within the mining process and as a result of a manless production process. This also results in increases in work safety. In addition, the absence of LHD diesel fumes and heat has a positive environmental effect — as well as reducing ventilation costs.

OUTLOOK

In a concept test with 4 dozer feeder units at Codelco's "Inca" underground mine conducted from April 2007 to December 2008, the mine achieved peak extraction rates of 1.8 tpd/m^2 — six times the average achieved using conventional LHD haulage.

After a reengineering and modification phase, the system will go to its first industrial application with 32 dozer feeder units in four production drifts at Codelco's "Andina" underground mine.

Source

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