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A Study of Technical Measures for Increasing the Roof-Contacted Ratio in Stope and Cavity Filling

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Abstract

Due to the increasing depth of mines, fill mining is increasingly widely used in metal mines. As a result, supporting pit roofs has become an important issue to which an increasing number of people are devoting attention. This paper analyses the factors affecting the rate of supporting pit roofs under stope filling conditions, including filling slurry properties and the filling process. Building on this, the paper examines a number of potential measures for improving the rate of supporting pit roofs, including creating good conditions for filling, optimizing filling slurry properties, eliminating the problems caused by water and improving filling technology. Mining companies must select from these measures according to the particular conditions in which their mines operate, but given the right conditions all of the measures examined have the potential to increase the rate at which pit roofs are supported.

Keywords: filling mining, rate of supporting pit roofs, stope filling conditions, filling process, filling slurry properties

1. Introduction

The increasing depth of mining in recent years and instability in roadway and fields of rock has precipitated a rise in the potential for geological disasters such as rockburst or seismic rockburst (Fall, Célestin, Pokharel, & Touré, 2010). This in turn, in combination with broader public awareness of issues relating to the environment has increased the application of stoping in metal mines and more widely. Cemented filling, layered filling and fill mining are the most commonly used methods (Zhou, Chen, Zhang, & He, 2012). Fill mining is not only applicable when the ore body creates complex mining conditions, but also as a method of minimizing mining dilution, improving ore recovery, controlling press activities, increasing efficiency of production, ensuring mine safety and reducing the environmental and ecological damage. (Zhang, Yan, & Liu, 2012; Gürtunca, Leach, York, & Treloar, n.d.; Zhou, 2010). But we found that there are still issues relating to poor filling stoping, low mining intensity, labor-intensiveness and other practical matters in the mining process, which filled most obvious pick top rate (Trist, Higgin, Murray, & Pollock, 2013).

The 'filling top rate' is a general indicator of how much filling has occurred, and should be strictly defined in relation to the filling paste and the area of the roof ceiling. Under realistic conditions it is difficult to calculate the total area of roof space more accurately than the top rate value. In order to facilitate the calculation of this indicator, Zhang Yongliang proposed the following three methods to calculate the rate of the top pick:

(1) The ratio of the average height of representation

Before filling begins, measure the height of an empty field in different locations and record the average height (H). After a complete end is filled out, measure the average H of the filling body, or alternatively install a viewing window in the wall looking into the space which is to be filled before filling it. Select a stope roof similar in height to the average H of the measuring point for the mark after filling has been completed, and then measure the H of the upper surface markers and filling body. We can then use the following formula to calculate the results to approximate the rate of filling body top pick, ε:

$$\varepsilon = (h / H) \times 100\%, \text{ or } \varepsilon = [(Hh') / H] \times 100\%.$$

H: vertical height of the area before filling, h: vertical ascent of the area after filling

(2) Cross-sectional area ratio method;

The total area with top pick rate ε is expressed as backfill of the area s of top pick, before filling the empty field with the roof of the S ratio ($\varepsilon = s / S$).

(3) Volume ratio of representation. The aim of filling slurry is to form stope backfill volume, and for the volume of the ore mined ratio to represent the rate of filling on the top pick.

This theory does not take into account the strength of the filling materials. In order to achieve the effect of a higher filling body to support the roof rock, and then filling the top rate as high as possible (Ford, Price, Cooper, & Waters, 2014)—especially in mining, workplaces such as roof pillars and under other unusual conditions—effectively supporting the control stope roof is pressed to make the filling body. In addition to filling body strength and the required standards of technical performance, it also meets the requirements of backfill compaction top. When the top is defunct then filling the empty roof top area of the supporting roof meets or exceeds the effective maximum allowable storm drain area. Once this has been filled with ore body or caving, security staff will pose a greater threat (Wang & Park, 2001). After mining, part of the survey showed that the use of filling method and filling the top rate is not as high as is commonly a problem in mines, and the higher rates of some mines are empty on top. Although according an alternative mining method dictates the reduction of the width of the road into the concrete after filling remedies, this only increases the cost of filling mining and reduces botg production efficiency and the strength of the filling body.

2. The Top Pick Effect—Stope Effect Factor

A number of factors influence the effect of top pick filling; including specific, random, unpredictable, multifaceted and other kinds of factors. Making reference to the relevant literature, we summarize the following aspects of first the lead mining field, then empty area filling, in the top rate factors:

2.1 Stope Conditions

(1) The roof is not flat. Due to uneven roof space area, it is difficult during the filling process to ensure the slurry and depression top pick in the filling material do not block spout. In addition, there are likely to be some blind spots which remain unfilled, resulting in a partially empty top.

(2) It is difficult to set the discharge port plate in the highest possible position. If stope is constrained by existing conditions and cutting points are arranged at the highest point of the roof space area, the higher stope roof is difficult to pick at the top.

(3) In the filling mining approach; the top rate is affected by the sectional shape of the stope (Nasir & fall, 2009). Route type stopping system, flat arch arc tops and influenced spandrel arches can still lead to slurry settling in part of the top pick. In gravity-delivered filling systems it is easier to pick the top. Where there is a flat-shaped roof with an empty top, the empty top area is significant and it becomes difficult to guarantee the safety of mining operations.

Pulp slurry leakage does not generally lead to the closure of the drilling project (Vaszita, 2014). Whether or not this is not closed after the construction of the project, there with still be unavoidable empty drilling rock fissures in which pulp slurry filling will have to be run. Plasma leakage phenomenon leads to the top of the filling area appearing empty.

2.2 Filling Slurry Characteristics

(1) A low concentration of filling slurry indicates or precipitates a high water content. When filling slurry concentration is too low, therefore, the filling material will segregate and stratify. If the material is mortar, if its coarse particle deposition is too concentrated, the natural slope angle increases and the water moves to occupy a specific area space. It then stops filling slurry filling this area.

(2) Natural sedimentation of filling slurry (Liu, Dang, & He, 2012; Zhang, Yan, & Liu, 2012). Once the area has been filled by slurry, dehydration and solidification sclerosis cause the volume of he filling material to decrease, leading to an empty top. The presence of water (capillary water in the rock or gravity-pooled water) is a major factor in causing slurry to appear as natural subsidence.

(3) The filling slurry gravity gradient (Zhang, Yan, & Liu, 2012): Gravity flow in filling is used when slurry flows due to the settlement of filling aggregate in the filling pipe discharge mouth-edge, and this position appears to stope the gravity gradient. Poor filling slurry fluidity means a greater gravity gradient, resulting in the filling tube becoming attached to the top of the discharge port; the slope under the influence of gravity cannot pick the top edge of the stope.

(4) Poor physical properties of filling material (Wenbing, 2004): Filling slurry particle size, grain size distribution, clay content and other factors such as fluidity, permeability, sedimentation rate and natural shrinkage greatly affect the natural slope angle. The natural slope angle has significant impact on the top of the flat geometry of the mined areas; large gob makes it hard to pick the top. Settlement and natural shrinkage inevitably occur between the backfill and the roof space.

2.3 Filling Process

(1) Since the filtration of water from filling slurry is a slow process, the excess water which slurry generally contains results in slurry taking a long time to fill. If water *is* completely filtered out, a large gap is left. During the filling process, the larger the body to be filled, the more difficult the process (Ford, Price, Cooper, & Waters, 2014; Wang & Park, 2001), and this difficulty has a serious impact on the top area in the resulting fill.

(2) Strawed direction of water to the filling area and then into the headspace area: in order to prevent clogging of the pipeline during filling, before and after each filling there is often an injection of water for 5-10 minutes into the filling tube. The resulting entry of water into the top pick area to be filled causes fine particles of cement and suspended fine mud to transfer, resulting in segregation and lower body mass filling. The excess water quickly becomes difficult to filter out, seriously affecting the filling top pick.

(3) Single-point cutting: this refers to forming a large natural slope angle (Ford, Price, Cooper, & Waters, 2014). In filling processes using a single point cutting, the cutting-point filling slurry forms a large natural slope angle. In large empty field areas, this phenomenon is more pronounced and results in an empty field which cannot support a pick at the top edge.

(4) Unreasonable filling cutting position: if you do not fill the pipeline located in the highest point of the roof or near the top pick at the spout empty area, and yet still higher than the top, it is difficult to take effective measures to improve the effect of top pick filling.

2.4 Human Factors

Inevitably, the level of experience of the mine operators, their understanding of filling time and their flexibility to use and adapt top technology will impact on top pick filling.

3. Analysis of Measures to Improve Top Rate Access

Gob factors in the pipeline filling of top pick present many challenges, and numerous measures have been developed to overcome these. But each of these measures only applies under certain circumstances and tackles particular factors: gob is a world filled with top pick technical problems (Liu, Dang, & He, 2012). Thus in the implementation of top pick filling operators must adopt a variety of measures to achieve the best results.

3.1 Creating Good Conditions for Stope Filling Top Pick

(1) The application of smooth blasting on neat roof space area (Smooth blasting on neat roof space area, Han, Kamber, & Pei, 2011): in order to meet roof space specifications, the method of horizontally stratified cemented fill mining is used in last tier recovery. Once the top pick has been inserted into the hole slightly inclined blast holes are arranged in a row, according to the requirements of the particular blast. Coupled charge pressure-mining should *not* be used, as it will empty the flat roof area.

(2) Improved outstanding shape headspace region (Santamouris, 2014): this method has long been applied where the ore body is particularly thick. A tilt approach is recovered from a hierarchical approach roadway to the bottom end, approaching at 3 to 8 degrees. The angle stope filling roadway ends in slim contact with the filling material. Easy-filling slurry is used in order to better fill up to the top of the field.

3.2 Preparation of Filling Slurry

(1) Select the appropriate slurry concentration and packing materials. After filling the slurry into the stope there will be natural subsidence due to slurry dewatering which will lead to some shrinkage. As such, the operator should select an appropriate grain size distribution with a ratio that provides good permeability and sufficient liquidity in the filling slurry. Higher concentrations of filling material are needed which provide reasonable mobility, though as it stands the concentration of the slurry is inversely proportional to mobility. The ideal concentration will provide high slurry fluidity.

(2) The use of intumescent material additives (expansion additives added to the filling material) (Bonchis, Duff, Roberts, & Bosse, 2014): aluminum calcium sulfate, gypsum, iron, lime, alum stone are used as expansion agents. When the expanding agent is incorporated in the slurry, hydration reaction occurs causing the volume of slurry to increase. The gap filling material is filled, so that the filling body is denser and effectively reduces shrinkage.

Studies have shown that with the addition of 10% lime, suction effect increases in the slurry and the expansion can effectively maintain the slurry pick of the top spot rate. This method has only been applied for the guarantee of expansive roof restorations, in part because of the lack of volume contraction from the roof, and in part because the effect of missing filling body on the gap already filled is not obvious.

(3) Using high-water rapid hardening materials: high-water quick-setting materials, also known as high-water cured materials (such as high alumina cement, betonies and other raw materials) are subdivided into two categories of material, A and B. In use, A and B are combined with water or mortar and transported to the site near the filling mixture. After mixing, the wet slurry quickly becomes a highly crystalline solid. These materials have high strength, but on the downside, additional engineering costs and increasing transportation costs make them increasingly less economical (Bonchis, Duff, Roberts, & Bosse, 2014).

3.3 Eliminating the Influence of Water

(1) Human treated patio set (Fu, Li, Qiao, & Li, 2011). Within each patio set, where a person carries out filling line treatment, there are setbacks from the use of round wood (generally external box with nailed back logs, wrapped in gauze and with slats nailed).

(2) With a three-way stopcock and water wash treatment lead pipe (Wang & Park, 2001): a three-way stopcock is installing in the filling wall. This leads the way to achieving the water filling of OTC emissions. Before each filling, the valve opens downward so that water from the filling valve exhaust can lead the way into the outer space area. Next, a period of time is left for the wet sand to slowly close the valve filling the empty area with slurry (which is injected into another outlet of the three-way valve). After filling the pipe is washed: the concentration of slurry in the pipeline is allowed to thicken, and the valve is slowly opened while flushing water discharge through the pipe to the outside wall.

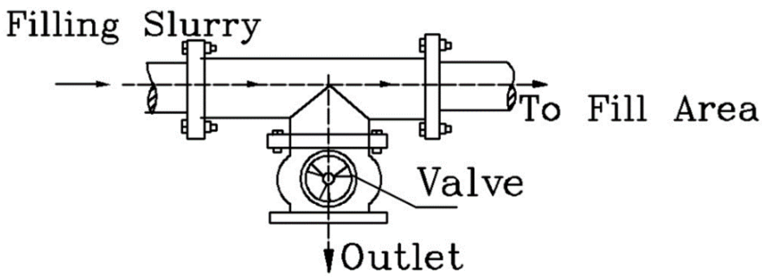

Figure 1. Three-way plug valve schema for stope backfilling

(3) Using filling wells to pump water upward: once filled with water, the pump will empty the area in the upper part and excess water in the slurry will promptly withdraw, continuing to the top of the filling.

(4) Using filter pipes downstream of the discharge: drainage pipes embedded in an empty area in the filling process allow for water in the filling slurry to prolapse through the filter outflow pipes.

3.4 Improving the Filling Process

(1) Partition filling (Liu, Dang, & He, 2012): when filling a stope with a large area, in order to minimize the empty area that fills with the slurry produced by the impact of natural slope angle docking at the top rate, it is necessary to fill the empty area to partition the top pick. The key to success in this process is the size of the top pick partition rather than quality. If the partition is too big the filling process becomes complex and labor-intensive, requiring a large amount of preparatory work. The filling becomes inefficient. In order to reduce the size of the filling hose so that it can access the work area, the partition volume should meet a filling volume. Filling to ensure access is done on the top premise, to minimize the number of partitions. The partitioning method uses natural terrain isolation, separating wood columns and stacked sand bag isolation.

(2) Fractional filling: fractional filling is used to carefully control filling time. The filling takes one day to cure. These time restrictions limit filling into the empty area of slurry volume. It will not fill a single plasma surface because of too much rise, which is greater than the wall can support. Each increase in the height of the filling material is small. At the final stage, the filling material will not shrink due to large natural subsidence and leaves an empty top (Chen, Ji, Zhang, & Wu, 2014).

(3) Multi-point cutting filling (Chen, Ji, Zhang, & Wu, 2014): this method is used for filling slurry with poor liquidity, in order to avoid filling blind. In the case of conditions that increase the number of cutting points, where the gravity gradient of filling slurry is small, the top filling rate increases accordingly. Multi-point cutting can be divided into three seedforms:

First, the stope roof is filled with hanging tubes by drilling holes in the filling tube

Second, multi-root canal filling is used

Third; multiple holes are drilled, filling holes in the middle of the roadway to the stope and filling the stope by filling holes

(4) Forced top pick:

[1] The mortar pumps method. This is applicable where at the end of the filling and contraction settlement the gob missed the top, but for whatever reason the top pick system cannot continue to be used. Air and mortar are pumped into the top area that has been missed, due e.g. to a crimp in the top of the slurry pump tube. The system puts out a short range, high concentration, filling wash. The water precipitates better control or facilitates the cancellation of top pick filling.

[2] The blasting method. This is used to further improve the quality of the filling. It is done via a controlled blasting of the upper rock caving and rock hulking (using a broken expansion coefficient of about 0.3-0.7). This ensures timely roof caving and compact top pick.

(5) Erecting a temporary retaining wall to settle compensation (Zhong et al., 2015): since, at the end of the filling and solidification process, the slurry settlement will shrink, the erection of a temporary filling retaining wall (and filling part of the slurry under pressure) is a way to compensate for this decline in filling body volume.

(6) Filling the main area with the primary filling system and simultaneously filling the top pick with a small filling system (Zhou et al., 2012, Gürtunca, Leach, York, & Treloar, n.d.): this method is applicable where rock is less stable and the filling of the empty area requires a higher top. After filling several times with a small underground mortar pump, consisting of a small, homemade mixing bucket system and with access to high concentrations of top filling, this method can work where there is too low a working efficiency of top pick in the local supplement applications.

(7) Noting the empty top pressure, or high concentrations of concrete filling material (Ford, Price, Cooper, & Waters, 2014): this involves using drilling and concrete pouring machines, and injection under pressure of concrete or high concentrations of filling material into the empty top. This is applicable in situations where the filling material has low water content. The solidification process after pressure injection is almost constant, effectively enhancing the quality of top access.

(8) Post artificial top creation (Santamouris, 2014): in the case of gently and slightly inclined deposits, artificial top picks are more common. When filling a body only 0.5-0.8 meters from the roof, masonry mortar can be used and subsequently wiped with a stone top. Of course, waste rock and mine timber can also manually be thrown into this top space; but this method is labor-intensive, inefficient, and subjects workers to poor working conditions.

3.4 Management Methods

(1) Improving operating procedures and filling management: specially trained mine staff who understand the physical and mechanical properties of filling slurry can deploy a variety of cutting-edge technologies and means of access. The development of relevant operating procedures, the use of set bonuses, and other techniques are essential to motivate workers and mobilize their enthusiasm. It is critical that they are encouraged to take the initiative and to innovate, striving to improve the process of top pick filling.

(2) Reducing worker error and strictly quality-controlling projects:

[1] Drilling projects must be carrier out in a timely manner after construction blocks, to prevent running pulp (Vaszita, 2014).

[2] Solid wall construction and the process of wall filling must occur according to design requirements, to avoid filling instability and collapse. Once this work has been carried out in a timely manner and approved, the next step can be carried out.

[3] Improving roof monitoring (Santamouris, 2014): holes can be drilled to serve as observation wells. After filling, the top pick can be filled with water or slurry spill in the roof of an empty field in order to determine whether the filling is fully completed. It is also possible to install a viewing window to monitor filling progress.

4. Conclusions

As a result of the top of stope filling, a problem has arisen which affects the rate of top pick filling in many multi-level surfaces. Relevant factors can be broadly divided into stope filling conditions, filling slurry characteristics (including the filling process) and human factors. In order to improve top filling rate it is important to take examples from different angles corresponding to treatment measures.

This paper has analysed proposals in five areas: creating good stope conditions; optimizing the preparation of the slurry filling process; eliminating the effects of water; improving the filling process; and improving the management of mine workers.

By presenting research on improving the rate of top pick filling relevant to all of the various conditions under which different mines produce empty tops, and suggesting appropriate technical measures in response, this paper contributes to improving top pick filling rate in mines internationally.

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