

Update on the Application of Paste Thickeners for Tailings Disposal - Mine Paste Backfill

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ABSTRACT

Paste thickeners without filters can effectively produce paste for mine backfill requiring slumps of 9 inches and higher, depending on the particle size distribution of the solids. Slumps approaching 8 inches may be produced for certain applications. Early installations of paste thickeners have not effectively utilized an integrated systems design for matching the thickener to the pumping system and the mine backfill plan. The design of a paste backfill process always starts with what is needed by the mine. Requirements for strength and cycle time translate into binder cost and tailings paste slump, whether from a thickener or filter. Producing mine paste backfill using a paste thickener without filtration is a technology that should be considered for the right application.

INTRODUCTION

Although used for thickened tailings disposal of red mud in Australia for many years, the application of a thickener for making paste and thickened tailings outside of alumina is relatively new. Interest and installations in thickened tailings (also called paste) are rapidly growing. Water shortages and environmental pressures are making consideration of thickened tailings necessary in most new projects and in many existing plants. The paste thickeners at the DeBeers CTP plant in Kimberley, South Africa are the latest example of thickened tailings disposal. Houman (2003)

The use of thickeners to produce paste for mine backfill is less developed than for surface disposal but has attractive potential as an alternative to filtration for the right application. This paper describes the recent use of paste thickeners for mine backfill, lessons learned from the early installations, and the integrated approach required for designing a mine backfill process using a paste thickener.

SUMMARY OF PASTE CHARACTERISTICS

A detailed description of a paste is outside the scope of this paper and can be found in other sources such as Boger (1999) and Robinsky (1978). In summary, paste a suspension is characterized by relatively high solids (75-90 wt%) content and non-settling, non-segregating particles. The underground mining industry commonly uses a 12-inch slump cone measurement as an indirect indication of the rheology and solids

content of a tailings paste. The slump and non-settling nature of paste is produced from naturally occurring clays, silts, and fine sands. Tailings from milling or processing are most frequently used for paste backfill. Moisture content for a given slump is determined by the specific gravity and particle size distribution of the solids. Large particles can be added to paste without changing rheological or transport characteristics. Pastes are generally described as Bingham plastics with a yield stress, which is related to the pressure required to make a paste flow. Slump is an indirect measure of yield stress. The high viscosity of pastes makes pipeline design critical. Pastes are generally pseudoplastic where the viscosity decreases with shearing such as in pumping and pipe line flow. The slump of paste produced by a thickener, for example, may be higher than the slump at the end of the pipeline delivering the paste to the mine stope.

PASTE IN MINE BACKFILL

Hydraulic backfill using sand-sized particles from cycloning for mine support has been used for over fifty years. Paste backfill, which incorporates fines as well as coarse particles, such as the complete spectrum of a mill tailings particle size distribution (“total tails”), is a more recent development.

The design of a paste backfill system is dependent on the backfill materials available at the mine site, such as mill tailings. Paste is produced by filtration or thickening. If backfill strength is required, the paste is mixed with a binder, such as portland cement and water is added to adjust the slump as necessary for pumping and pipeline flow. The paste/binder mixture is pumped to the mine borehole for gravity transportation to the stopes. The slump required in the mine is a function of the mining plan and cycle time for accessing stopes. Typically a slump of 6-10 inches is required, and if the tailings are too fine to produce the required strength with binder addition the tailings may be mixed with alluvial sand or crushed rock to produce a wider particle size distribution and higher strengths as described by Landriault (1995). Mine backfill with a paste is also a method of tailings disposal, in which case a binder may not be used.

A paste backfill can be engineered to meet the mine requirements for strength by working with the parameters of paste solids content and the amount of binder addition. Some of the advantages of paste backfill systems over hydraulic sandfill systems are identified by Brackebusch (1994):

- Greater strengths are generated with less cement.
- Decanting water from stopes is unnecessary.
- Generally total tailings can be used, which may solve a mine mass balance problem.
- Lower mining cycle time is possible because strength is achieved earlier.
- Barricades may be eliminated or simplified with low slump paste.
- Flexibility in mining methods is possible, including undercut-and-fill mining.

PREPARING PASTE WITH FILTERS

The conventional method of paste preparation is to dewater the tailings from a mill operation in a high-rate slurry thickener followed by filtration. Filters include drum, disc,

and horizontal vacuum filters. Water may be mixed with the filter cake to achieve the desired slump for transfer to the binder mixer. The thickener may be preceded by a cyclone to remove excess water or fines to a surface disposal site. In some cases the cyclone overflow can be dewatered in a conventional thickener and remixed with cyclone underflow to form a paste (Brackebusch, 1996).

PREPARING PASTE WITH A PASTE THICKENER

The slump and solids content required for paste backfill is determined by the mining plan which includes such parameters as mining method, cycle time for accessing stopes, binder (such as cement) requirement, safety (such as controlling rock bursts), availability of backfill material, the mine layout and so forth. The lowest slumps (high solids content) of this range require filtration. The highest slumps (lower solids content) can be produced by a paste thickener as an alternative to filtration. There are no hard criteria for distinguishing where the paste thickener option becomes viable. Considering only the process performance of a paste thickener, experience with pilot and full-scale operations suggests for slumps higher than 9 inches, the paste thickener is an alternative for producing paste without filtration. For slumps between 8 and 9 inches, the paste thickener should be evaluated as a possibility. For slumps of 8 inches and lower, the paste thickener is unlikely to be an option. These operating ranges are strongly determined by solids particle size, throughput rate, and pumping/pipeline shear. For example, designing to produce 9-inch slump paste for 800 t/hr solids may require an economically or mechanically impractical thickener design, problems that may not apply for a 9-inch slump, 80 t/hr solids design. Paste has a shearing properties affected by pumping and pipeline flow. The delivered slump to the slope is affected by the transportation distance and method of transporting (centrifugal, positive displacement, gravity, etc.) Figure 1 shows a typical flowsheet for preparing paste with addition of a binder.

Thickeners, including paste thickeners, are fundamentally continuous processes. In many cases the paste is intermittently required in the mine, depending on the mining plan.

Development of procedures and mechanical design to meet a requirement for discontinuous operation has been a significant development for a paste thickener in mine backfill. In these cases the paste thickener is operated as a semi-batch process where the paste may be stored for several hours or even days depending on the mining cycle time. Experience has shown a properly designed paste thickener can function effectively in semi-batch operation in part because a paste is fundamentally non-settling and paste thickeners are designed

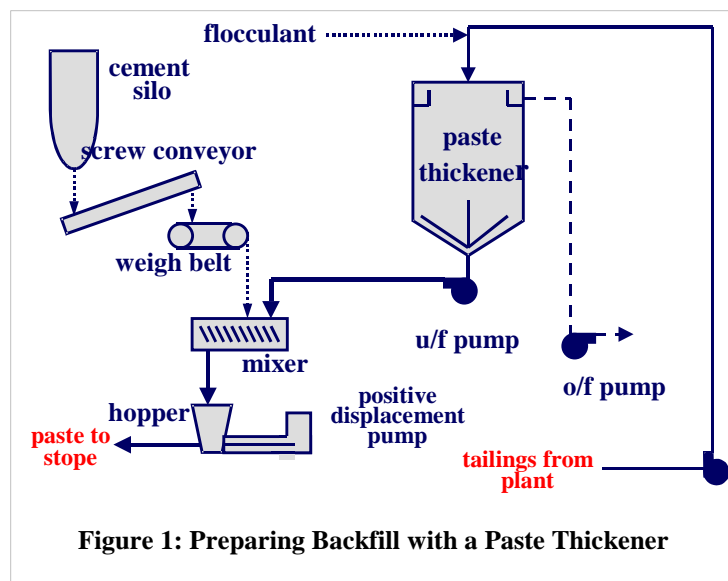


Figure 1: Preparing Backfill with a Paste Thickener

with exceptionally high torque capacity for the raking mechanism. Storage time, the resulting underflow slump and solids content must be matched with the mining plan cycle time.

MINE BACKFILL INSTALLATIONS USING A PASTE THICKENER

There are many examples of paste backfill prepared with filter. The use of paste thickeners without a filter is less well established. In recent years mine paste backfill installations have provided valuable information about the proper way to design a system in which the paste is prepared by a thickener.

Example 1

The paste plant consists of a thickener, cement silo, building housing the flocculant preparation system, electrical and control panel, and a positive displacement pump. The thickener operates by making and storing paste produced from cycloned base metal tailings (s.g. 3.2-3.4) from the mine. The during the backfill portion of the cycle the stored paste is pumped at slumps of as low as 9 ½ inches (measured at discharge of the thickener centrifugal underflow pump) and solids content of as high as 79-80 wt% to a mixer for cement addition.

Example 2

The paste plant consists of a thickener, cement silo, building housing the flocculant preparation system, electrical and control panel, and a positive displacement pump. Using base metal mill tailings (s.g. 2.7-2.9), the thickener has produced 8-9 inch slumps and 76-78 wt% solids, after underflow pumping. High cement consumption has been a problem, which is related to the paste moisture content and the strengths required in the mine.

Example 3

The plant uses paste backfill, using a mixture of thickened tailings and cement to fill excavated stopes to improve the structural integrity of fill, allow for underhand cut and fill mining methods, and reduce dilution by reducing the amount of sand from fill that is recycled back into the mill in the primary ore. The paste backfill system uses a paste thickener and filter combination to produce 76 wt% solids.

Example 4

OCI Chemical Corporation, located in Wyoming in the U.S. produces soda ash (Na_2CO_3) from the ore trona using a dissolution/recrystallization process. A tailings washing circuit (countercurrent decantation) uses a paste thickener as the last stage. The thickener produces paste underflow that is pumped underground without cement for tailings disposal. OCI (2004)

DESIGNING A MINE PASTE BACKFILL SYSTEM WITH A PASTE THICKENER

The installations described above show that for an appropriate application a paste thickener can effectively produce the required paste for backfill. However, operation and design of backfill systems using paste thickeners have not been without problems. The problems resulted, not from the thickener, but because an integrated systems design approach was not used to match the paste thickener with paste transportation, binder (cement) addition, paste setup time, backfill strength, and other issues related to mining methods.

An integrated systems design of thickened tailings and paste processes, whether for surface disposal or mine backfill, is essential for the successful operation. Jewell (2002) The systems approach recognizes that rheological properties of a paste are a common design basis from the thickener to the pumps and pipeline design and to the application. Designing one part of the process, such as the thickener, without integrating the rheology of the thickener underflow with the transportation system, binder requirements, and mining plan will usually lead to problems.

Cement Usage

In the project design phase definitive determination of the strength requirements for the stope backfill must be completed before the backfill preparation process is designed. For one installation, not effectively using this approach resulted in unacceptable cement costs. In hindsight it is possible that the mine required underflow solids content outside the range of a paste thickener. Definitive determination of required strength and cement content and the necessary paste solids content should be made before specifying the paste production system performance and choosing the tailings dewatering technology.

Tailings Particle Size

The particle size distribution of the feed stream to a thickener is a primary influence on paste moisture content and ultimately cemented backfill strength. The design of a paste thickener must be matched with the expected particle size of the backfill solids. In one instance this particle size distribution was too fine to generate the required thickener paste necessary for stope strength at the design cement requirement. The solution was to install a cyclone to coarsen the feed to the thickener and, therefore, the underflow.

Cycle Time

Cemented stopes must reach the required strength in a time period that allows the mining activity (blasting, hauling, etc) to proceed on schedule. In addition to specifying required underflow solids content or slump, the mine backfill design must specify thickener cycle time. Matching the paste thickener operation with the mine cycle time requires a design for the necessary holding time in the thickener, and an operating procedure to produce the required paste characteristics on a cycle time required by the mine.

Pipe Wear, Pump Design

Pipeline wear is always a problem for incorrectly designed tailings distribution systems. Mine backfill paste tends to be a highly non-Newtonian suspension, which means there is no generally available database for pump and pipe sizing. Early paste thickener installations have demonstrated that paste produced from a thickener is no less subject to these issues than is paste from a filter. Specialists in this field of paste transportation must be part of the design team interacting with the designer of the paste thickener.

CONCLUSIONS

With the right particle size distribution, paste thickeners without filters can effectively produce paste for mine backfill requiring slumps of 9 inches and higher, after shearing. Depending on the application slumps approaching 8 inches may be produced. For applicable tailings and backfill requirements, the paste thickener offers an alternative to filtration for the production of paste.

The design of a paste backfill process always starts with what is needed by the mine. Requirements for strength and cycle time translate into binder cost and tailings paste slump, whether from a thickener or filter. If a paste thickener can produce the required slump at the discharge of the centrifugal underflow pump, then it becomes an option to filtration for paste production and the evaluation can proceed to capital cost and operating expense analysis.

Paste backfill using a paste thickener is a developing application. Early installations of paste thickeners have not effectively utilized an integrated systems design for matching the thickener to the pumping system and the mine backfill plan. Producing mine paste backfill using a paste thickener without filtration is an effective technology for the right application.

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