Developments and Experience with Harvested Tailings Paste Fill Systems

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ABSTRACT

The introduction of harvested tailings paste fill systems in the past five years has enabled many smaller mines to take advantage of the benefits of paste fill technology. The simple modular mixing plants produce good quality paste fill at high placement rates for modest capital expenditure. This in turn, enables more mines to consider fill as part of their operation and, in many cases, increase the life of their operations and the total ore extracted. Additional geotechnical benefits such as local and regional stability are often realised.

Every paste fill system has a unique combination of tailings, process water and binder components that influence the flow and strength properties of the paste fill. Harvested tailings systems have the extra complication of the storage condition of the tailings material. If the tailings are too wet or even saturated, extraction may not be practical. If the tailings are sulphidic, oxidation may have occurred and hard lumps may have formed. Additional neutralisation may be required in the mixing process.

This paper will describe the common features of these systems and the benefits and limitations compared to more conventional fixed paste fill plants. The paper will discuss the design and implementation of some of these systems and highlight experiences that either gave unexpected benefits or showed problems.

1 INTRODUCTION

Paste fill has been widely adopted in mining operations since its original development in Germany in the late seventies. The major component of the mixture is usually unclassified mill tailings, which is dewatered to a paste like consistency using either vacuum filtration and/or deep cone thickener technology. Binders such as cement or pozzolans are added in a mixer to produce a paste backfill that has the required flow and cured strength properties for the operation.

The highest capital and operating cost component of a paste fill plant is the dewatering system. Supplying tailings in slurry form to the plant requires storage and overflow capabilities. Paste plants are typically packaged as multi storey fixed structures with all the requisite mechanical, civil and electrical engineering inputs. Conventional paste fill plants have cost between A$6 M and A$30 M over the last ten years.

Recovering tailings from surface storage facilities enables a simple modular approach to paste backfill production. Building a system around continuous mixing systems enables the use of lower cost components with much simpler engineering inputs. All of the design and quality issues can be addressed, but at a much lower engineering intensity. The distinguishing features of these systems are the supply of the primary feed material at lower water content than the final paste product and the use of a modular continuous mixer located at the distribution point.

This approach makes paste fill a viable option for many smaller mines that would not normally consider backfill, or as an interim approach for new or expanding mines.

Table 1 **List of operating harvested tailings paste fill systems in Australia**

Mine	Paste Fill Materials	Plant Type	Comments
St Ives Gold	Gold tailings and dune sand	Aran Modumix	Plant originally located at Junction Mine but moved to Leviathan
Leinster	Nickel tailings and surface sand	Aran Modumix	Second plant installed, currently not operating
Agnew Gold	Gold tailings	Aran Mobile Plant	Mobile plant used for initial filling at Leviathan then moved to Agnew when Junction plant became available
George Fisher	Base metal tailings	Aran Modumix	Standard plant with roll screen pre-processing
Blair Athol	Surface sediments	Readymix Plant 1	Custom mobile plant designed for coal mine filling operation
Endeavor	Thickened sulphide zinc tailings	Aran Modumix	Innovative harvesting method with lump pre-processing
Raleigh	Gold tailings and palaeo channel sand	Aran Modumix	Standard plant with initial filling using agitator truck transfer
Lanfranchi	Gold tailings	Excel Plant	New plant for nickel operation using pre-existing borehole
Black Swan	Nickel tailings	Readymix Plant 2	Version 2 plant developed from Blair Athol unit

At the time, of writing this paper, several more systems were in feasibility and planning stages in Australia. In addition some other systems are in use in Asia, South America and North America.

2 SYSTEM DESCRIPTION

Mineral processing operations produce finely ground waste materials in the form of slurries. The Paste07 seminar has many papers describing the transport and placement of these materials in thickened paste like pulps into surface storage facilities. At other mines, conventional lower density settling slurries are used and the surface storage facilities cope with the additional drainage and evaporation water.

These surface storage facilities, both conventional and thickened, are of interest to harvested tailings systems when the water content of the tailings has dropped below that of the final mixed paste product. In addition, the tailings must be accessible to and suitable for mobile loading and hauling equipment.

2.1 Materials Harvesting and Extraction Issues

Tailings are usually extracted either by front end loader or by backhoe excavator. In conventional storage facilities where the tailings slurry has been deposited from ring mains around the perimeter, classification of the particles has taken place during deposition. There is a natural trend from the perimeter to the central drainage area of coarse to fine sizing. In addition, because of deposition from different parts of the perimeter, there are frequently overlapping layers of fine and coarse within the extraction area.

Backhoes are preferred for excavation because they can dig into a steep trench and cast the material into a row alongside. During this process, the multiple fine and coarse layers become intermixed and tend to smooth out the sizing variations. The material in the stockpile tends to drain and evaporate further and the water content generally reduces.

In some tailings facilities, the surface layers can dry out completely, and in the presence of dissolved salts, can form hard crusts. Since the mixers used for paste fill are not designed to break down large lumps, these must either be screened out or crushed down to an acceptable size. Steel (2007) describes the use of a roll crusher to achieve this at George Fisher Mine. Lumps that travel intact through the mixer tend to break down in transit through the reticulation system as additional mixing takes place. None of the authors have seen lumps at the discharge end of the pipes, but some blockages in the boreholes have been blamed on lumps.

The opposite problem can occur if the tailings are saturated. This would apply to most recently used storage facilities where drainage is still ongoing. Any excavation must only take place in the unsaturated zone since only this material will meet the criterion for paste production in the plant. In one tailings facility, the contractor devised an innovative plough arrangement. In this example, the upper one to two hundred millimetres of tailings were scraped off the surface and stacked in a pile and allowed to dry. This was sufficient to drop the water content to acceptable levels. In this case, further conditioning using a roll crusher was also required.

Sulphide tailings can be subject to oxidation, which has two effects on the harvesting operations. The first is that the water within the tailings can be aggressively acidic with possible damage to mobile equipment and can have severe effects on cement addition at the mixing stage. The acidic liquor can be neutralised with lime in the mixer.

In several operations, other materials are also being harvested to improve the cost profile or performance characteristics of the paste fill. At St Ives Gold operations, dry dune sand is extracted and transported to the mixing site. At two other operations, one in Asia and one in Peru (Paniagua, 2005), volcanic tuff is added to the mix. Volcanic materials contribute both coarse and very fine particle sizes.

At one mine, coarse sand was added to the tailings mix in order to improve the strength characteristics. However, it was discovered that the sand was contaminated with a swelling clay and this caused significant problems with flow properties and led to blocked reticulation pipes.

2.2 Transport Issues

Generally speaking, transport of the harvested materials has not presented any particular problems. Loading of the trucks with front end loaders or excavators has proved suitable and both end tipping and side tipping trailers have been used successfully. St Ives Gold have used tandem end tipping trailers to transport tailings as far as eleven kilometres from the storage facility to the stockpile area at the plant.

The cost of loading and transporting the tailings (and other materials) represents an additional operating cost above the operation of a conventional paste plant. This partially offsets the savings from the elimination of large scale dewatering systems (vacuum filters or thickeners).

At some mines, ore is transported some distance from the mine to the mill. Back loading of tailings in these ore trucks has been considered for a couple of potential paste fill operations, but only one has been implemented to date.

The single most important issue with handling any of the backfill materials is to ensure that none of it is contaminated with clays, aggregate or any organic material.

2.3 Plant Operations

The modular paste plant is usually located adjacent to or above the reticulation system for the mine. For this reason, the paste fill can be delivered by gravity into the underground workings. All of the harvested tailings systems to date have been located in this way. This contrasts with most conventional paste fill plants overseas where the need to operate the plant as an extension of the mill has then required the use of expensive pumping systems. In Australia, separate conventional paste plants are common.

Around the plant, stockpiles of the component materials are established. These must be arranged for safe and easy access of the heavy transport equipment, but must also be located conveniently for a front end loader to excavate and load into the plant feed hoppers.

The base of the stockpile area must be prepared to ensure that no contamination of the fill materials occurs. Laying down a hard layer of sand has proved to be an effective base since the contrasting colour with the tailings immediately shows up any over digging.

If the tailings are lumpy from clay balls, oxidised lumps or dry salted pieces, then the feed must be pre-conditioned before the mixing process. Steel (2007) describes the effective use of a roller with a screen size rejecting all sizes >16 mm for base metal tailings. Paniagua (2005) describes screening out either >9.5 mm or >19 mm for volcanic tuff. Li et al. (2003) discuss screening of dune sand at >25 mm to eliminate organic materials.

The mixing plant operates on a volumetric basis and doses the binder and trim water on the calculated tonnages. Therefore it is important to know the bulk density of the feed materials and the water content. Since the water content of the tailings may vary from day to day and be subject to rainfall exposure, frequent water content measurements are required. The most accurate method is to use microwave sensors in the loading hopper or feed conveyors. Frequent grab samples can be dried in an oven to correlate these readings.

Alternately, the paste fill product can be sampled at the discharge end of the mixer and the rheological (flow) properties measured. The simplest method is to collect a small (100 ml) sample and measure the yield stress in a vane shear rheometer. This test is highly repeatable and the mix water adjusted to meet the set target.

Slump testing is commonly carried out and for a particular operation the mix water can be adjusted to meet a slump target for either cone or cylindrical measurement methods.

It is particularly important for the operator to observe the mixed paste fill product, both to be aware of any short-term variations, or more importantly, to look for lumps of poorly mixed paste that could cause sudden problems in the reticulation system.

Successful mixing of the components to make paste with the correct mix combinations and flow properties is the key to a workable paste fill system. Accurate dosing is essential but the mixing environment needs to be as intensive as possible. The most common arrangement is to use mixers with a pair of contra-rotating shafts fitted with a range of flat paddles. In some of the operations, some of the paddles have been reversed in direction to force the mix to recirculate within the mixer in order to increase the mixing time. Where clay lumps have been observed, two rows of knife blade like paddles located just below the delivery chute have improved the mixing in some cases.

2.4 Reticulation and Delivery

The reticulation and delivery of paste fill into the mine is essentially identical for harvested tailings paste plants and conventional filtration paste plants. Hence this topic will not be covered in any detail.

One important aspect however, is to ensure that pressure sensing devices are installed at the base of the surface borehole so that the operator is always aware of the status of the paste fill in the delivery system. This pressure reading becomes a proxy for the flow properties of the paste and at some plants is an important monitored reading used by the operator to perform fine adjustments to the mix.

This pressure sensor also provides early warning of possible line blockages caused by unexpected changes in the paste production process. If a high pressure level alarm is set, the operator can immediately initiate a “plant shut down and flush” operation to prevent blockages from occurring.

As with all paste fill systems, it is essential that a large volume of water is available for rapid discharge into the reticulation network to flush out the paste before its starts to set. In most operations compressed air is also used to do a final blow clean of the pipes.

3 TESTWORK AND TRIALS FOR DESIGN PURPOSES

Every mine site has a unique combination of ore and tailings mineralogy, process water chemistry and underground mining geometry. It is possible to make some simple assumptions for scoping studies, but it is essential that a comprehensive test work program is undertaken to investigate the properties of the materials under consideration.

The materials to be tested should be as representative of the actual materials as is practical. For example, samples should be collected from the tailings dam over an area and depth that matches the volume to be excavated. The prosed extraction site should be augered over the representative volume with samples collected at known vertical intervals and plan positions. These samples should be subjected to sizing and water content analysis. Some of the samples should be tested for mineralogy and solid densities.

These data will provide spatial information on tailings variability and highlight possible excavation difficulties or sequencing issues.

To prepare the samples for rheology and strength testing, they need to be combined in a way that represents the planned excavation method. This may be a simple mixing together of all samples to provide one bulk sample, or to identify some parts of the facility that will not be excavated.

All testwork should be carried out using local process water and the proposed local binder materials. It is useful to reference each test program back to a common control set of high quality water and cement to enable comparisons between different operations.

The objective of the test programs is to identify the paste fill mixes and recipes needed to provide the required strengths at the target curing time. Initially the first stage test programs confirm suitability of the materials and likely binder dosing to test the feasibility and economics of the system under consideration. Later, more comprehensive programs are required to identify the particular recipes to be mixed and placed underground. These data are required for the programming of the control system of the paste mixer.

In addition to the laboratory scale sample collection and testing it is essential to carry out an early trial using mobile equipment to confirm the ability to access, excavate and handle the materials at the tailings facility. Problems such as poor trafficability or unexpectedly high water tables should be identified at this time prior to commitment to this type of backfill system.

Testing continues through to plant commissioning to again confirm the original design assumptions, trial results and testwork programs. Higher variability of results compared to the laboratory work can be expected because the mixing conditions are necessarily less ideal.

4 CONCLUSIONS

Harvested tailings paste fill systems are now being widely used in some Australian mining operations and at other mines overseas. The lower capital cost of the surface plant and infrastructure is typically one third of the cost of conventional plants and are often acceptable to small to medium sized operations, or those with a limited life span. The lower capital cost is partially offset by additional excavation and transport costs.

The modular nature of the plants result in simpler civil and services engineering requirements, and in some cases the plants can be relocated to other sites or leased to other mines.

The major problems encountered to date relate to clay and sulphide minerals in the tailings or sand components. There is more variability in paste quality compared with conventional paste fill systems but the adoption of harvested tailings systems has introduced significant backfill benefits to mines that would not have previously considered the option.

This, in turn has led to improved ground conditions underground, increased resource extraction and longer life mines.

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REFERENCES

Li, T., Singh, U., Coxon, J., Grice, A.G. and Sainsbury, D. (2003) Development and application of paste fill using dry tailings. International Seminar on Paste and Thickened Tailings, Melbourne, Australia, March 2003.

Paniagua, J.V. (2005) Aplicación del relleno mixto en pasta en una mina de oro, 14^{e} Simposium de Ingeniera en Minas, Santiago, 23-26 August 2005.

Steel, J.D. (2007) From tailings dam to stope, 10th International Seminar on Paste and Thickened Tailings, Paste 07, ACG, Perth, Australia.