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GeoWaste^{TM} – continuous comingled tailings for large-scale mines

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Abstract

Comingled waste disposal has been used successfully at small-scale mine sites but requires bulldozers, excavators, trucks, high-cost liquid–solid separation, and significant manpower to produce a suitable mixture. Comingling is too costly for large, low value per tonne orebodies and their associated mines. GoldCorp and FLSmidth have collaborated to develop a method of comingling concentrator tailings, named EcoTails^{TM}, with mine waste in a continuous process to produce a stable deposit named GeoWaste^{TM}. GeoWaste will have a placed cost that will be competitive with traditional tailings disposal methods.

GeoWaste is produced by continuously mixing filtered concentrator tailings with crushed waste rock. The filtered tailings cost is minimised by using 'fast filtering' and using a nominal amount of waste rock to provide additional strength to the blended material. The acid rock drainage potential of the waste rock is reduced by minimising void space, thereby increasing the degree of saturation and reducing oxygen flux. The resulting comingled GeoWaste is both geochemically and geotechnically stable. Fast filtering the concentrator tailings also allows for significant water recovery and reuse.

A pilot-scale process to determine the amount and type of continuous mixing required to produce GeoWaste is discussed in the paper. Initial results of small-scale GeoWaste test pads will be presented. Recommendations to implement a full-scale process will be discussed.

Keywords: *EcoTails, GeoWaste, tailings, waste rock*

1 Introduction

Tailings are commonplace in mining. Most tailings are stored within an impoundment contained by a tailings dam. However, tailings dam failures are the most significant environmental liability for a mining project. With mining operations now pursuing lower-grade deposits, higher throughputs are required for profitability. A safe and cost-effective solution for tailings management facilities (TMFs) capable of accommodating 150,000 tonnes per day (tpd) are needed. On average, over the last 30 years, TMFs have experienced 20± dam failures per decade and a third of them caused serious safety and environmental liabilities, including deaths (Roche et al. 2017).

The Samarco failure in Brazil two years ago created a mudslide that travelled 70 km from the dam, killed 19 people (Roche et al. 2017) and has been described as the mining industry's own equivalent of the BP oil spill in the Gulf of Mexico. In terms of the human, economic, and environmental impact and cost, with reparations and liabilities running into the billions of dollars, not to mention the reputational damage and market capitalisation devaluation, disasters such as this major dam failure must be eliminated.

Access to water is becoming increasingly difficult. Mining operations have seen water costs steadily rise. Water availability is also challenging in many prominent mining areas of the world, and stakeholders are challenging mine water usage. Some countries now request mining companies use desalinated water for the majority of their water consumption. In Chile, the water code Código de Aguas restricting the use of water rights in situations of scarcity is under reform. In March 2017, El Salvador became the first country in the world to completely ban metals mining, after a decade-long moratorium, in a unanimous vote to protect the Central American country's dwindling supply of fresh water.

While dewatering tailings using pressure filters has been commonplace for some time, traditional filtered tailings costs are currently too high for high-throughput, low value per tonne ore deposits. Typical filtered tailings using smaller pressure filters and air drying the filter cake to an optimum cake moisture content, and then using trucks for tailings transport and placement has an in-place cost of over USD 4 per tonne. For large-scale, low-grade open pit mines, this cost is too high.

2 When the Colossal had to be bigger

When FLSmidth started developing the Colossal automatic filter press (Figure 1) a little over three years ago, the goal was to optimise the capital and operating costs for filtered tailings operating at large tonnages.

Figure 1 Colossal automatic pressure filter

The Colossal filter can dewater large tailings volumes at rates more than twice that of filters currently available. The water taken out of the process is immediately returned to the plant for reuse. As is typical for a pressure filter operation, further water savings are made possible as less is lost to the environment through evaporation and seepage.

When the Colossal filter was presented to industry, Goldcorp, a large Canadian mining company headquartered in Vancouver, stated the size and speed of the filter was impressive but was still inadequate for large-scale tailings filtration. Each filter needed to process more tailings than even what the Colossal filter could do. The two companies decided to collaborate together to advance the state of filtered tailings technology.

To reduce the scale and cost of the dewatering solution, FLSmidth increased the speed of the filter process including reducing the air blow. The rapid filtering process is referred to as 'fast filtering' by the team. This reduced the filtration time significantly, allowing more batches per hour and higher unit capacities. However, it also reduced the volume of water removed from the filter cake produced. The resulting higher cake moisture content introduces geotechnical issues within the tailings stack (sometimes erroneously referred to as a dry stack).

To give the tailings stack the required strength needed when the higher cake moisture tailings are deposited, the team decided to comingle waste rock with the tailings to add the needed strength. Mixing the low-moisture waste rock with the higher moisture tailings gives a product with an average moisture that is acceptable. The coarser rock particles also add shear strength and provide a higher density to the pile. Comingling tailings with waste rock has been around hundreds of years, however, combining fast filtering with comingling on a continuous basis gave birth to the EcoTails^{TM} program.

Historically, comingling has been challenging. Typically four to five tonnes of waste rock are required for each tonne of tailings, and blending the resulting large volume of material has been challenging (Wickland et al. 2011). Transporting large waste volumes is also unattractive to mining companies. With EcoTails, much less waste rock is required since the tailings are dewatered, and blending can be accomplished during transport. EcoTails mix ratios are designed for individual site requirements.

Another benefit of mixing tailings with waste rock is to reduce the void ratio and permeability of the waste rock pile (Wickland et al. 2006). The lower void ratio, coupled with a near-optimum moisture content, has the potential for reducing acid rock drainage (ARD) within the tailings stack. Acid rock drainage requires water and oxygen to thrive. Waste rock piles with the potential to generate ARD typically experience acid drainage because seepage is exposed to oxygen. By reducing the porosity within the tailings stack, and introducing moisture to fill much of the remaining void spaces, oxygen flow through the pile is prevented and ARD can be greatly reduced.

The EcoTails project, which produces GeoWaste designed specifically for each site, can produce a material that is geotechnically and geochemically stable.

3 Healthier mine economy with EcoTails

Traditional tailings storage has a cost averaging about USD 1.50/t. Sites requiring a dam for tailings storage adds to this cost. Water costs are generally ignored unless desalination is required, but in water stressed environments the cost of water can be high. Providing desalination water for some mines presently exceed USD 4/t. The target costs for EcoTails are competitive with traditional tailings costs, with an all-in cost of less than USD 2/t. Eliminating the need for a tailings dam, reducing the demand for fresh water, containing the waste rock and tailings within a smaller footprint, and eliminating a large fraction of the haul fleet further enhances the attractiveness of EcoTails.

Saving water can save significant money in arid climates. For example, filtering mine tailings enables mines to reuse up to 95% of their process water. This has a measurable benefit in countries where water is scarce, including Chile, Peru and other South American markets, as well as parts of the African continent. For instance, switching from a traditional cyclone sand dam to a filtered tailings solution reduces the water ratio from 0.7 to 0.2, leading to water savings of 50,000 m^3 per day for a 100 ktpd operation. At a water cost of USD 5/m^3, the cost in several locations in South America, this saves almost a USD 1 billion in water costs over 10 years.

4 GeoWaste – the key to making it work

For EcoTails to work economically, GeoWaste must be produced in a continuous manner. Traditional tailings and waste rock comingling has been around for over a century but used trucks and shovels to mix the two streams together. This is too expensive for a large-tonnage open pit mine. The concept of GeoWaste is to use conveyors for transport, and use the energy from the conveyors and specially designed transfer chutes to blend the material. Field testing was performed to test the conveyor and transfer chute mixing concept. Figure 2 depicts how GeoWaste can be implemented.

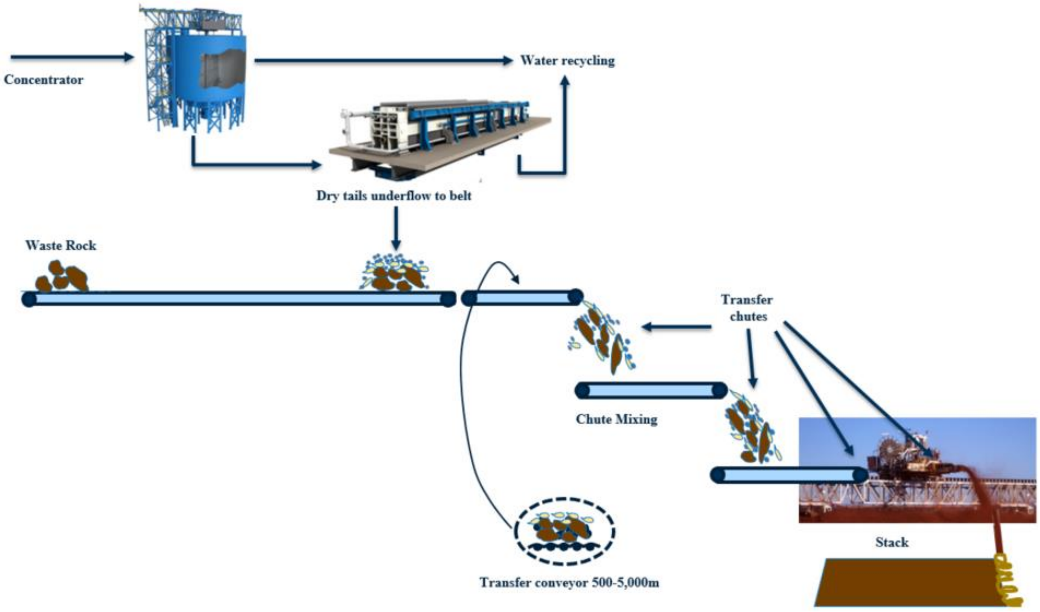

Figure 2 How to make GeoWaste

5 GeoWaste field testing

At one of Goldcorp's mine sites, the EcoTails team conducted some side-by-side blending tests. One set of material was mixed using traditional trucks and shovels, and the other set of tests used conveyors and transfer chutes to achieve the blending. Several ratios of waste rock to tailings were tested, and the primary test discussed herein used a 1:1 waste rock to tailings ration by weight.

Two stockpiles were created prior to the field tests – one stockpile of air-dried whole slurry tailings and another of -400 mm waste rock (Figure 3). Water was added to the air-dried tailings stockpile prior to blending tests using a conventional water truck and then mixed with an excavator to simulate the pressure filter-discharged moisture content. The target moisture content specification was set at 18% (±2%) moisture by weight (Mwater/Mtotal). From bench-scale filtration tests, the target moisture content of the tailings stockpile was set at 18%.

Figure 3 Water being added to an air-dried tailings stockpile followed by excavator mixing

Five control samples were collected from the waste rock and tailings stockpiles prior to blending tests to measure pre-test moisture contents (Figure 4). Each sample was collected in a five gallon bucket. After adding water, the average moisture content of the tailings stockpile was measured in the lab at approximately 16% (by weight), which was within the acceptable specification range. The average waste rock moisture content was measured in the lab at 0.5% by weight.

Figure 4 Control sample collection of wetted air-dried tailings stockpile prior to blending tests

Three grasshopper conveyors were used to mix the tailings and waste rock. The grasshopper conveyors were arranged in a triangular overlapping fashion as shown in Figures 5 and 6.

Figure 5 Three grasshopper conveyors in a triangular overlapping arrangement

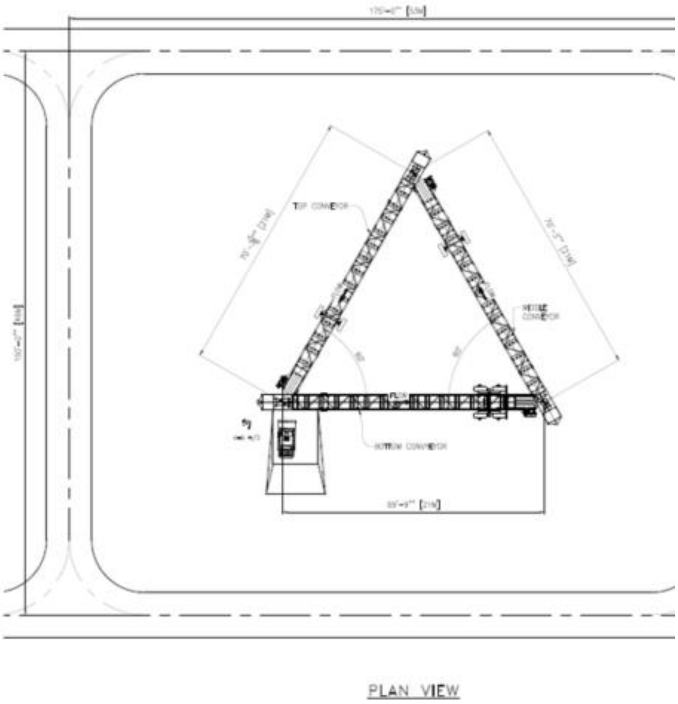

Figure 6 Three grasshopper conveyors in a triangular overlapping arrangement

In order to produce a specified mixture ratio (by dry weight) of GeoWaste, a Bobcat loader and scale were used as shown in Figure 7. The Bobcat loader was used to place the specified weight of waste rock on the conveyor belt. A layer of tailings was overlain on the waste rock at the selected mix ratio of tailings.

Figure 7 Tailings being placed on top of waste rock

The conveyor belt was advanced very slowly to allow two more sections or volumes of waste rock with tailings on top to be placed on the belt. These three sections of layered tailings and waste rock were run through three transfer chutes to build the blended GeoWaste pile.

A GeoWaste pile approximately 1.5 m high was collected with side slopes at angle of repose. The weight of the GeoWaste pile blended with the grasshopper conveyors was approximately 6,000 to 6,500 kg as shown in Figure 8.

Figure 8 Grasshopper-blended GeoWaste test pile after three transfer chutes

A second GeoWaste test pile was created immediately adjacent to the grasshopper blended test pile. This test pile used the same tailings and waste rock from the stockpiles as the grasshopper blending tests. An excavator was used to blend the tailings and waste rock. This pile is shown in Figure 9.

One sample was collected from each of the test piles to measure the pre-consolidation moisture content. Each sample was collected in a five gallon bucket. The samples were given to a laboratory to perform oven drying tests to measure moisture content.

Figure 9 Mobile equipment-blended GeoWaste test pile

Both test piles were immediately covered with a piece of linear low-density polyethylene liner to minimise drying and moisture loss over the prescribed three day consolidation period.

After three days of consolidation, in situ bulk density tests were performed at the top, middle and bottom of each test pile (grasshopper-blended and mobile equipment-blended using an excavator). Samples from the bulk density tests were collected to measure moisture. Each sample was collected in a five gallon bucket.

6 Test results

Test results indicate that the moisture content measured in the GeoWaste test pile created using the grasshoppers was the same (±1%) as the test pile created using mobile equipment consisting of trucks and shovels. Immediately after blending, the moisture content (by weight) was measured at 10.1 and 10.2% in the grasshopper-blended test pile and the mobile equipment-blended test pile, respectively. After three days of test pile consolidation and drying, the moisture contents decreased in both test piles by about the same amount. This drying or reduction in moisture content near the surface of the test piles is expected given the climatic conditions at site. On visual inspection, both test piles appeared similar in terms of the degree of mixing between tailings and waste rock. Bulk density tests also produced similar values in both GeoWaste test piles with maximum bulk densities measured at the test pile bottoms. These mixing test results confirm that the GeoWaste material produced using truck and shovel equipment is the same as the material produced using conveyors and transfer chutes. Plans are being made to take the technology to a demonstration-size level.

7 Conclusion

GoldCorp and FLSmidth have successfully collaborated to develop a method of comingling concentrator tailings, named EcoTails™, with mine waste in a continuous process to produce a stable deposit named GeoWaste™. GeoWaste will have a placed cost that will be competitive with traditional tailings disposal methods.

GeoWaste is produced by continuously mixing filtered concentrator tailings with crushed waste rock. The filtered tailings cost is minimised by using fast filtering and using a nominal amount of waste rock to provide additional strength to the blended material. The resulting comingled GeoWaste is both geochemically and geotechnically stable.

Field testwork demonstrated that GeoWaste produced by conveyors and transfer chutes was mixed as well as material mixed by truck and shovel mobile equipment. Average moisture content and bulk densities were similar in both cases.

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