PASTE THICKENING IRON ORE TAILINGS UPDATE[1]

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Abstract
Paste thickening technology is rapidly emerging as an effective method for handling tailings for water recovery and as an alternative to conventional dams and ponds. This paper describes an example of the use of this technology on iron ore tailings. An 18 m WesTech Deep Bed™ paste thickener is described. Initial startup results are presented showing underflow concentrations over 58 wt% as a non-settling paste. The design of the thickener is discussed, including the feedwell that dilutes the tailings to an optimum concentration for flocculation. The feed is from a 90 m peripherally driven traction thickener. The installation is designed to meet the objectives of water recovery and paste tailings deposition.
Key words: Paste; Tailings; Stacking; Paste thickening.

DESENVOLVIMENTOS RECENTES EM ESPESSAMENTO DE PASTA DE REJEITOS DE MINÉRIO DE FERRO

Resumo
A tecnologia de espessamento de pasta está rapidamente emergindo como um método efetivo na gestão de rejeitos para a recuperação de água e como uma alternativa a diques e barragens convencionais. Este documento apresenta um exemplo do uso desta tecnologia em rejeito de minério de ferro. É descrito um espessador de pasta do tipo WesTech Deep Bed™ com 18 metros de diâmetro. Os resultados iniciais de operação mostram uma concentração do underflow que excede 58 wt% como pasta que não sedimenta. O projeto do espessador é discutido, incluindo o poço de alimentação que dilui os rejeitos a uma concentração ótima para a floculação. A alimentação vem de um espessador de 90 metros com acionamento de tração periférica. A instalação é projetada para atingir os objetivos de recuperação de água e a deposição de rejeitos de pasta.
Palavras-chave: Pasta; Rejeito; Deposição; Espessamento de pasta

INTRODUCTION

At the "2005 IV Brazilian Symposium on Iron Ore" conference the results of pilot scale testing of a paste thickener for iron ore tailings were described. Based on the tests an 18 m diameter WesTech Deep Bed™ paste thickener was designed, installed and started up in 2008. Full-scale design of the thickener, application and initial start up results are discussed in this paper.

The thickener described is part of a process for the application of "paste and thickened tailings" (generically referred to as "paste") technology for tailings disposal. Paste, a suspension of solids that does not settle, from an appropriately designed thickener can have a dry solids concentration approaching filter cake levels for some applications.

These concentrations mean additional water recovery compared to conventionally thickened tailings using "high rate" slurry underflow thickeners producing lower concentrations in the settling solids range. The solids concentration of paste thickener underflow and non-settling character has a rheology that allows the tailings to be deposited on a surface with a slope and without the need for expensive dams. Paste deposited in existing tailings impoundments will extend the life of pond by reducing the number or height of the dam lifts. The use of paste and thickened tailings has become an established alternative conventional disposal the world-wide minerals industry.

Paste Characteristics

Understanding the thickener design, operation, and application described in this paper is aided by knowledge of the rheological characteristics of paste. Paste is generally characterized by a yield stress, which is measured in units of pressure and is related to the force required to make a paste flow. The iron ore tailings paste shown in Figure 1 is an example. The solids concentration of this sample corresponds to a specific yield stress on the "yield stress curve" shown in Figure 2.

Figure 1: Iron ore tailings paste

Figure 2: Yield stress curve

The solids concentration yield stress relationship is significantly determined by specific gravity and particle size distribution of the solids. Rheological and transport characteristics of paste are very dependent on the content of fine particles (less than 20 micron).

Identifying the yield stress curve is important for the design and operation of a paste thickener, downstream pumps and deposition. Under gravity a tailings paste will flow to a point dictated by the yield stress and stop. Therefore the sample shown in Figure 1 has a shape. The paste must move through the thickener and be delivered to the pumping system for transportation to the application point. When deposited, the paste will assume a uniform slope, determined by the yield stress. Figure 3 shows the deposition angles produced from pilot plant testing of iron ore tailings (Slottee, 2005).

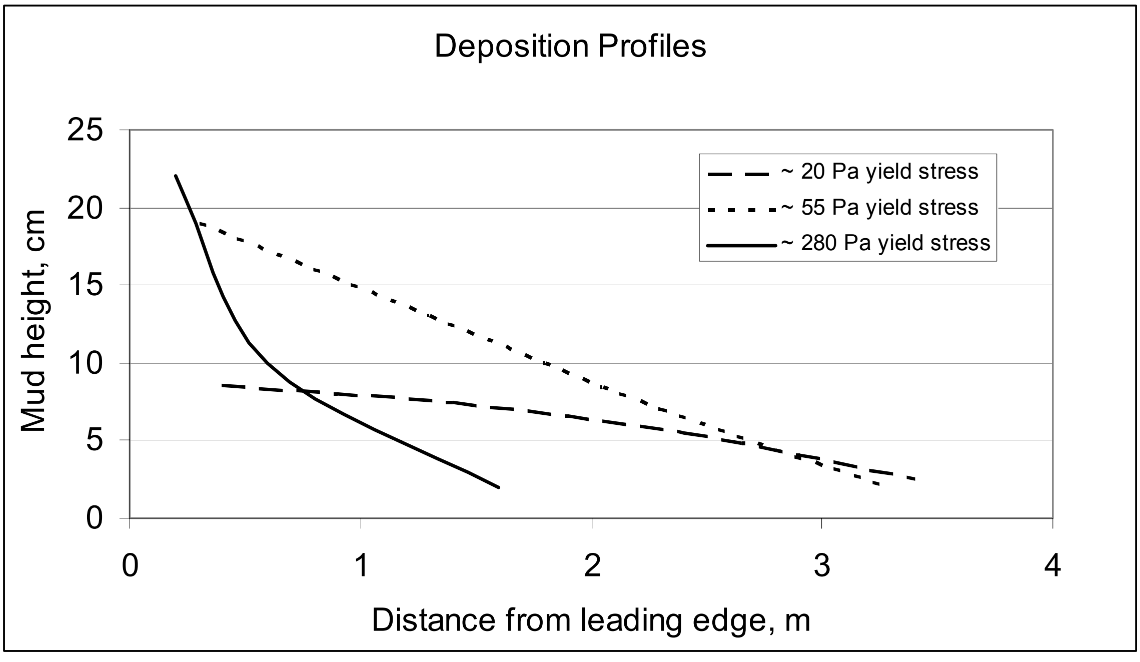

Figure 3: Deposition profiles determined by yield stress

Figure 4 is an example of flume testing for another type of tailings to determine the slope of deposited tailings paste.

Figure 4: Flume testing to determine deposition slope

Pastes are generally pseudoplastic where the viscosity decreases with shearing such as in pumping and pipe line flow. The yield stress of paste produced by a thickener, for example, may be higher than the yield stress at the end of the pipeline delivering the paste to the deposition area. This property affects the design of a paste thickener and selection of underflow pump and pipeline size. More detailed descriptions of paste and applications can be found in sources such as Boger (1999) and Robinsky (1978) and for pipeline design, Paterson (2003).
An integrated approach to process design is required to match the performance of the thickener, pumping system, and application on a common rheological basis, determined by testing. Matching rheologies between these three steps ensures that the paste delivered to the end of the pipeline meets the needs of the application with respect to throughput rate, and deposition slope.

Paste Thickener Design

The concept of paste thickener design is reviewed in the predecessor paper to this conference publication (Slottee, 2005). The deep cone style paste thickener is characterized by a height to diameter ratio typically greater than one to one. This aspect ratio, combined with a floor slope of 30 degrees allows high yield stress (and therefore high solids concentration) paste to be discharged. The high density style paste thickener has an aspect ratio less than one but with sidewall and mud bed heights significantly higher than conventional thickeners. This type of thickener discharges lower yield stress paste but because of the shallow floor slope much larger diameters are feasible than for the deep cone thickener. In both cases unit areas (m^2/tph) for paste thickeners are smaller than for conventional and high-rate thickeners.

18 m Diameter Paste Thickener Example

<u>Thickener Process Design</u>
PasteThick™ Associates participated on a team with ECMP, a geotechnical design consultant, and Paterson & Cooke, a pipeline designer for the greenfield project described in this example.

An 18 m diameter deep cone style paste thickener was recommended for the application to produce a thickened tailings slurry with non-settling paste property above a minimum solids concentration for deposition in a residue disposal dam. The target paste characteristics incorporated pumping feasibility and the desired angle of repose at the deposition site. Water recovery was also a significant driving force for installation of this project. The overflow from the thickener is returned to the plant for supplementing process water.

The paste disposal system included placing the thickener at the deposition site, approximately 4.5 km from the main plant. The feed to the paste thickener is from a 90 m WesTech traction thickener located at the plant. The traction thickener, shown in Figure 5, is designed to recover the bulk of the water from the dilute tailings stream prior to the paste thickener. A traction driven design is required because of the large diameter and high torque required for this thickening step. The traction thickener is a caisson (column) type thickener where the center column carries the weight of a mechanism driven by a tractor with steel traction wheels on the periphery of the tank. The tanks are concrete construction. The generated torque can be very high compared to other types of thickeners; up to 13,000,000 Nm. Lifts are not used or needed because the high torque capability allows virtually any mud condition to be handled. The underflow from the traction thickener is controlled on flow rate to prevent sanding in the line and provide a relatively constant feed flow rate to the paste thickener.

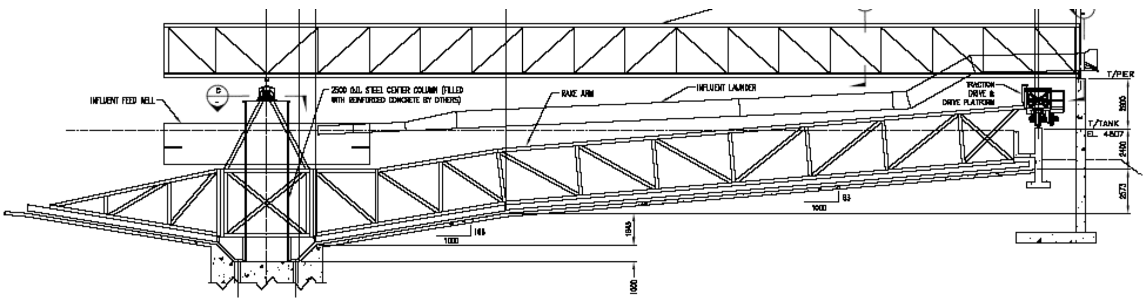

Figure 5: WesTech traction thickener

The nominal tailings rate to the paste thickener is 220 t/hr dry solids at 29% solids concentration. Pilot plant and bench scale testing predicted a concentration of 10-15% is optimum for flocculation. This is accomplished internally in the thickener by using a ported feedwell that allows thickener supernatant to flow into the feedwell, diluting the feed, as shown in Figure 6. Flocculant nozzles are placed at the dilution ports.

Figure 6: Feedwell showing supernatant dilutant flowing through a port, past the flocculant nozzle

The paste thickener can handle throughput rates as high as 450 t/hr for short periods. This peak tonnage under nominal plant conditions would be associated with a very high solids concentration in the paste thickener feed. To allow the large range in feed solids concentration the system is equipped for external feed dilution if required.

Underflow concentration of at least 58% and as high as 70% are expected to be achieved, depending on solids density and particle size distribution. Underflow concentration will be restricted to the limitations of the pumping system and the required deposition slope. The solids concentration of any thickener, including paste thickeners, is a function of the particle size distribution of the solids. Coarser distributions produce higher solids concentrations. The particle size distribution, measured during the pilot plant testing and shown in Figure 7 produced concentrations in the paste range.

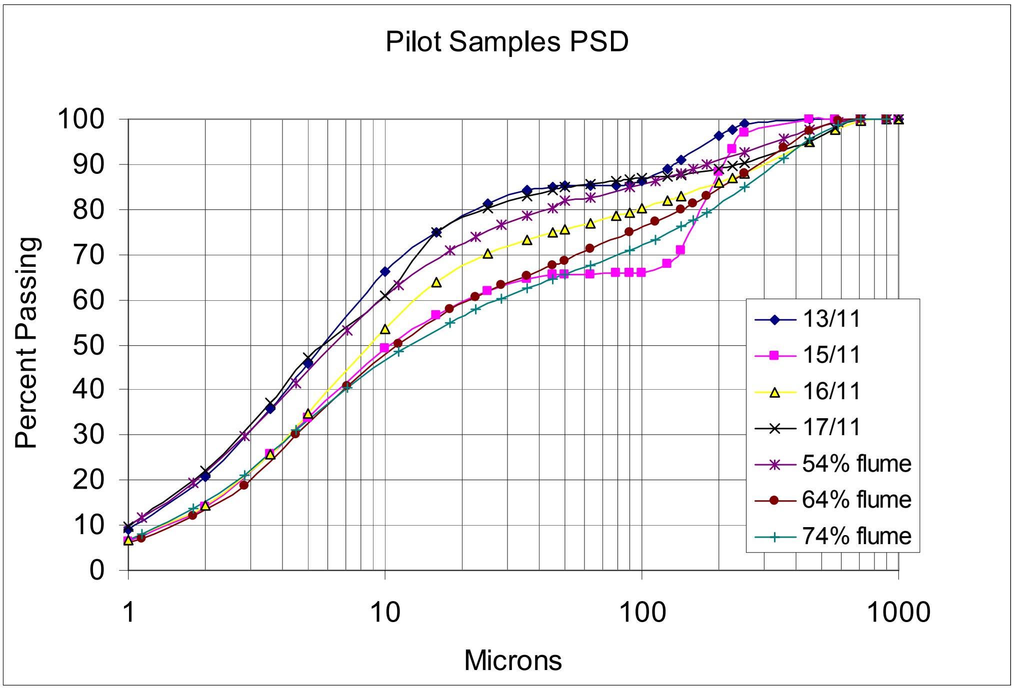

Figure 7: Particle size distribution of iron ore tailings from pilot testing

Centrifugal pumps transport the paste thickener underflow. The pumps are based on an underflow concentration of 58% and the associated rheology. Under worst case tonnage four pumps in series are required. Special high pressure pump volute casings are required for the 4th stage pumps to accommodate the high pressures. The initial pumping distance to the dam is 2 km.

Paste Deposition Design

A 4 km long dam constructed of overburden is located adjacent to the paste plant. Paste is discharged to the impoundment from spigots located along the dam. The paste will also be used to backfill mined out pits throughout the life of the mine. Rain water and any seepage from the deposited tails will be collected in a pond and returned to the plant.

Depositing the tailings as a paste at 58% solids concentration has the following benefits:

- Enhance the consolidation of the fine residue material ensuring low permeability with little or no drainage for the life of the facility.
- Ensure the best utilization of volume capacity by increasing stored tons of solids per unit volume.
- Optimize total water recovery with less water lost through evaporation and seepage.

The initial predicted beach angle is 1-2% which will create a surface geometry that will result in a supernatant pool.

Thickener Mechanical Design

The WesTech Deep Bed™ paste thickener, shown in Figures 8 and 9, is 18 m diameter with a 12 m side wall height and 30 degree cone. The drive torque is 189,000 Nm (duty rated).

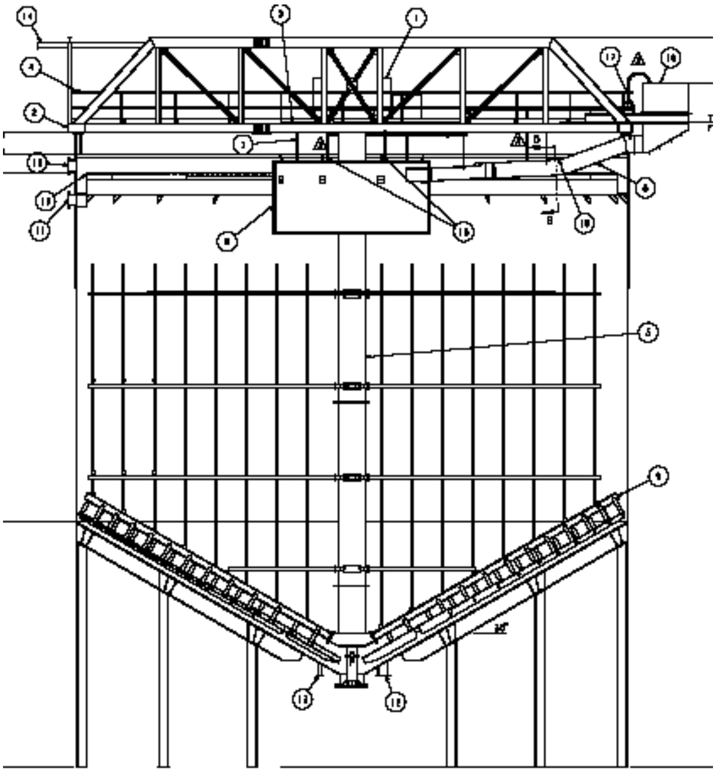

Figure 8: General arrangement of the 18 m WesTech Deep Bed™ paste thickener

The high side wall height allows the mud bed within the thickener to rise and fall to accommodate the varying feed conditions. Bed levels are measured by a pressure device attached to the bottom of the thickener and reflect the bed level. Vertical pickets create pathways through the mud bed for water to escape. There is no lifting device as the torque capability is sufficient to overcome very high mud viscosities.

Figure 9: 18 m diameter WesTech Deep Bed™ paste thickener

The thickener is serviced by a centrifugal underflow pumps with a spare. The function of the pump is to first, control the level in the thickener, maintaining the desired underflow characteristics, and second, deliver the underflow to the deposition site. Overflow is collected in a tank and pumped back to the plant. The thickener is serviced with a flocculant make-up and dosing system and controlled by a supervisory control and data acquisition system housed in a control room near the thickener.

Startup Results

The initial performance of paste thickener is subject to the on-going startup of the plant producing the tailings. At the time of this publication the thickener was producing underflow solids as high as 58% or 1.79 g/ml density, assuming a solids specific gravity of 4.1, with estimated yield stresses of over 50 Pa. Density as high as 1.95 g/ml has been achieved which is about 64% solids. Overflow clarity is acceptable for returning to the plant.
The underflow is non-settling paste. Deposition is in the early stages and more results will be presented at the 2nd International Symposium on Iron Ore. Observations suggest at least a 1% slope will be achieved. Figure 10 shows the deposition at the time of startup. Note the depression in the non-settling tailings suspension that is indicative of the presence of a significant yield stress.

Figure 10: Initial paste deposition – note depression indicating yield stress

CONCLUSIONS

This paper presents an example of the use of this technology for iron ore tailings thickening. For this application the paste thickener is successfully operated from a location remote from the plant, producing an underflow meeting the deposition criteria of a non-settling paste that forms a slope, at an underflow solids concentration as high as 64%.
Paste thickening technology is rapidly emerging as an effective method for handling tailings for water recovery and an alternative to conventional dams and ponds. Iron ore tailings handling will benefit by considering the advantages of paste thickening including water recovery and reduced cost tailings impoundments.
The project is in the initial stages of startup and longer term results will be presented at the “2nd International Symposium on Iron Ore”.

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