Design of a WesTech HiDensity™ Paste Thickener for Bauxite Tailings

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ABSTRACT

A 45 m diameter WesTech HiDensity™ paste thickener was designed and built to produce thickened tailings from 362 tph of bauxite tails for surface stacking at the CVRD Paragominas bauxite plant in Brazil. A systems design approach was used considering aspects of deposition-to-pipeline-to-pump-to-paste production. Pilot-scale tests were conducted to determine thickener size and expected performance. The paste produced from the pilot plant was deposited in troughs for measurement of drying rate and expected deposition slope. The pilot plant operation provided information for pump and pipeline sizing. This paper discusses the design of the paste thickener in light of the tailings characteristics and pilot operation experiences, which include rheology and results from the pilot plant tests.

1 INTRODUCTION

In April of 2004, Compania Vale do Rio Doce (CVRD) undertook a large expansion of their Alunorte alumina refinery. The feed for this expansion is to be supplied from a new bauxite mine located at Paragominas in the state of Pará, Brazil. The new mine and bauxite preparation mill is being built in two stages, each stage designed to send 5.4 Mt per year of bauxite to the Alunorte refinery. The prepared bauxite is to be transported in a 230 km pipeline to the refinery. The tailings generated at the bauxite preparation mill are to be transported and surface stacked 2 km from the mill at Paragominas. WesTech Engineering, Inc. was selected as the supplier for thickener technology for both stages of the Paragominas project. This paper addresses the thickener design methodology and application of equipment for the paste or thickened tailing disposal portion of this project.

2 PRINCIPLES

Paste and thickened tailings systems for surface stacking and disposal are best designed using an "upstream" design methodology. Beginning at the deposition site, the geotechnical engineer determines the rheological properties needed to achieve the design deposition or stack formation. "Upstream" of the deposition site, the piping systems engineer must not only determine the inlet rheological properties needed to deliver the proper outlet rheology for deposition, but also if that material can be economically transported. Only at this point can the paste systems engineer determine what type of paste thickener device will appropriately achieve the underflow rheology that properly meets the demands of the piping system and subsequent deposition of the thickened tailings. This upstream approach is the best way to adequately address the incremental changes in the slurry rheology as it passes through various unit processes to arrive at the deposition site.

3 METHODOLOGY

3.1 Design Approach

To begin the design process it was necessary to determine a range of achievable yield stress that would be used for preliminary deposition design. Laboratory studies followed by on-site pilot testing provided the data and samples necessary for an "upstream" process design.

3.1.1 Laboratory testing

Laboratory bench testing included flocculation, sedimentation and viscosity measurements. WesTech Engineering, Inc. played a key role in coordinating this test work and in gathering pilot plant data used in full-scale design. From the generated flocculation and settling data, underflow rheology was tested using a vane viscometer. The sedimentation studies and coordinated yield stress data rendered an achievable yield stress range of 50 to 150 Pa corresponding to an underflow concentration of 30 to 40% solids by weight. It was determined that a feed concentration lower than the design feed concentration would produce an optimal settling flux rate in the thickener.

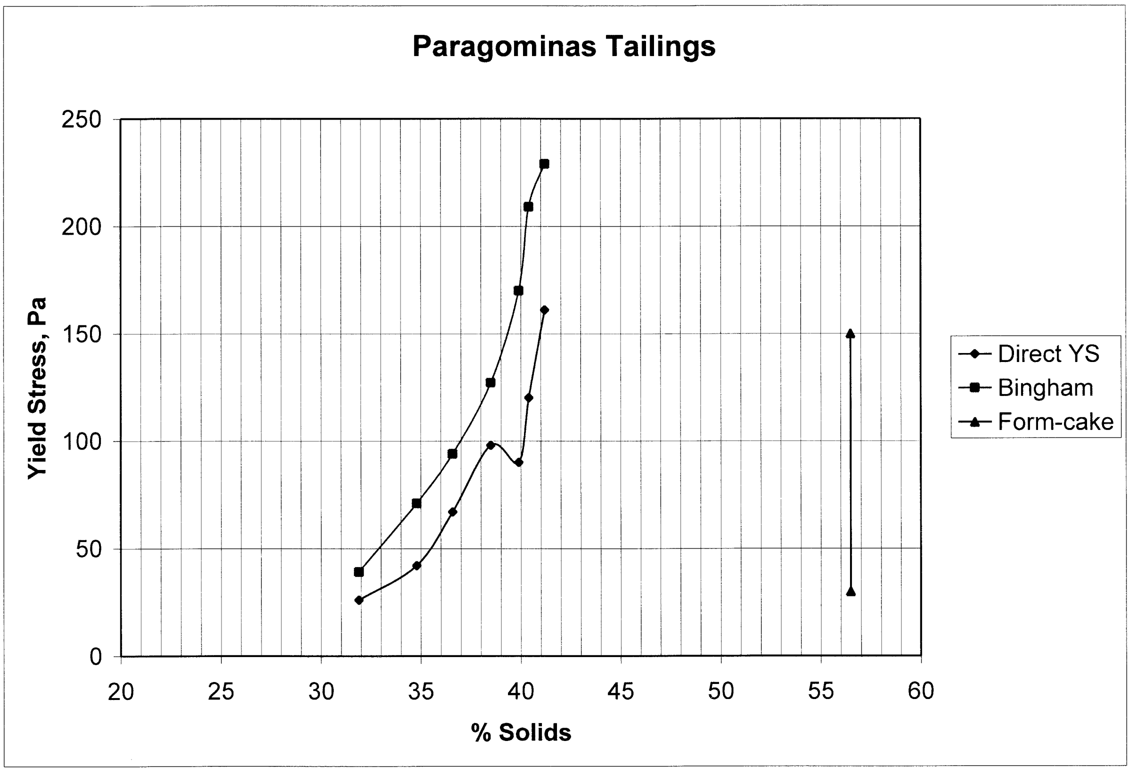

Figure 1 Paragominas tailings yield stress curve

Figure 2 Cylinder slump test

This coordinated test data was shared directly with the pipeline delivery systems engineer and the deposition engineer. Each party was able to do preliminary investigations with confidence as each used consistent and cooperative data. Confirmation of design, based on the laboratory samples was done by means of pilot testing.

3.1.2 Pilot testing

A 1 m diameter WesTech pilot DeepBed™ Paste Thickener was sent to site for the pilot testing. Feed material was blended from drill core samples collected by CVRD staff.

The pilot plant was operated at site for a period of two weeks. Over that time raw ore samples from various locations of the deposit were processed to qualify anticipated feed variations. The pilot plant generated a sufficient volume of samples for the geotechnical engineer to test the deposition design and set the required deposition rheology. Samples were also provided to the pipeline and pumping engineer for testing to determine the parameters of the transport system.

The majority of the material produced in the pilot plant thickener was used for deposition flume tests. These tests demonstrated and confirmed layer application rates and slope angles to determine the surface stacking. Different rheologies were tested for stacking slope, consolidation and drying rate.

Figure 3 Paste pilot unit

Figure 4 Beach slope

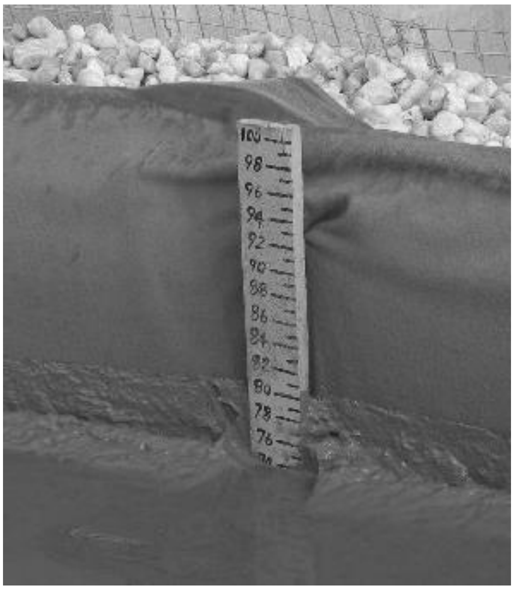

Figure 5 Layer thickness

Figure 6 Deposition flumes

3.1.3 *Pilot testing results*

Laboratory tests were confirmed by pilot plant operation. Maximum hydraulic loading in the paste thickener was determined to be 2.25 $m^3/m^2/hr$, with an optimal settling flux of roughly 1200 $kg/m^2/hr$ at a concentration of 6.5% solids by weight. Underflow rheology of 50 to 150 Pa could be achieved by varying the solids detention time. These yield stress values correspond to underflow densities of 30 to 40% solids by weight.

The deposition testing lead to a selection of an optimum layer thickness. Wet and dry season desiccation rates were tested and both rendered similar results, as rainwater tended to run off of the deposition rather than contributing to the moisture content. The pilot studies also confirmed that 2-3% slopes could be achieved with fully sheared end of pipeline material.

The main design factor in the transport system was the client's desire to pump with centrifugal pumps rather than positive displacement type. The testing demonstrated that with the use of centrifugal pumps, the proper end of pipeline material could be delivered, provided the thickener underflow produce a paste or thickened tailings material with 50 Pa yield stress.

Together, a well designed paste thickener will feed a properly designed pipeline transport system that will economically feed a properly designed disposal stack. The pipeline transports thickened tailings over 2 km and delivers an appropriate rheology for the 2-3% design deposition slope without the need for positive displacement pumps.

3.2 Paste Thickener Design

Stage one of the Paragominas Bauxite Plant is expected to produce 362 t/hr of fine tailings. The combination of high tonnage and high yield stress underflow material requires careful consideration to determine the appropriate thickener technology for these conditions. Two types of paste thickeners were considered for this service.

3.2.1 WesTech DeepBed™ thickener technology

WesTech DeepBed™ paste thickeners (sometimes referred to generically as deep cone type thickeners) are characterised by a height to diameter ratio between one and two, a bottom cone angle of 15-45º, and a bridge mounted drive. Diameters are limited to about 24 m for this type of paste thickener. The mud bed height is much higher (by several meters) and the slurry detention time much longer than that of a high rate thickener. This compensates for the effect of smaller area on underflow solids concentration of the paste thickener. This style of thickener is designed to produce the highest possible solids concentrations and yield stresses (lowest slumps) for a paste thickener. In this application a DeepBed™ thickener would be able to achieve underflow rheology of 30 to 150 Pa.

3.2.2 High density thickener technology

High density paste thickeners produce paste with lower viscosities and underflow solids concentrations. Diameters range to 50 m with a height to diameter ratio less than one. This allows for economical on ground construction and consequently much larger diameters and higher tonnage throughput than for DeepBed™ thickeners. The cone is less steep compared to the deep cone type thickener (10º to 15º as an example). The mud bed depth is higher than that of slurry thickeners to provide compression volume and depth. A WesTech HiDensity™ paste thickener in this application would be able to achieve underflow rheology of 30 to 75 Pa.

3.2.3 Technology selection

Consideration was given to both of the above paste thickening technologies. Both were expected to meet the technical requirements of the application to produce the 50 Pa high yield stress tailings suitable for stacking. Due to the high tonnage, multiple DeepBed™ thickeners would have been required. Conversely a single larger diameter HiDensity™ unit could produce the required tonnage at the proper underflow yield stress. A significant portion of the capital expense of a paste thickener is in the tank vessel. DeepBed™ thickeners are generally found in elevated tanks while HiDensity™ units can be configured with a less costly "on ground" design.

Since both technologies were technically acceptable, commercial considerations resulted in the selection of a 45 m diameter WesTech HiDensity™ Paste Thickener with an 8 m sidewall height. The floor slope is steeper than conventional slurry thickeners. The mud bed depth is also higher to produce the compression required for forming appropriate paste yield stress. A 5.4 million Nm drive and raking system are designed to move the thick paste to the thickener outlet and underflow pumps without the use of rake lifts. A specially designed feed dilution system was incorporated to optimise flocculent dispersion and to minimise flocculent consumption.

3.2.4 WesTech HiDensity™ thickener design

Design of a HiDensity™ thickener mechanism is challenging not only from a process perspective, but also with respect to the mechanical design. Development of numerical methods for predicting and determining torque required in paste thickeners is an ongoing process. Significant research is advancing which can relate actual torque needed in a paste thickener (for a given geometry) to the yield stress of the solids that are being conveyed. Unfortunately that research has not reached a point where manufacturers are confident enough to design paste thickeners based on those predictions.

Figure 7 Paste thickener drive

Most thickener manufacturers have developed more empirical methods for assuring adequate driving force for the high yield stress materials found in paste thickeners. The generally acceptable method is with "K" factors. The relationship for torque as a function of tank diameter is given as: $T=KD^2$ where T is torque in Newton-metres (Nm), D is tank diameter in metres (m) and K is an empirical correlating factor with units of Newtons per meter (Nm). Conventional applications of thickeners in minerals service have "K" factors ranging from 200 to 500 N/m. Paste thickeners will have normal "K" factors from 2000 to 5000 N/m. Historical experience and sample testing are the main tools the thickener designer has to determine what torque to use. The yield stress curve will usually influence the level of conservativeness used in "K" factor determination. For the Paragominas thickener, the yield stress to be delivered was felt to be in a reasonable range for control and operation in the thickener. Based on confidence gained through the laboratory and pilot test work, a "K" factor of 2675 N/m was chosen for this application.

Once the thickener drive torque of 5.4 million Nm was determined, the raking system had to be configured to adequately convey the 362 t/hr design solids loading. Solids transport is an important aspect of paste thickener design, as inadequate transport will lead to rat-holing and inconsistent operation. Scraper blade attack angle, blade depth, blade path overlap and rotational speed are the variables to consider in scraper design. Radial conveying systems are an enigma because the relative high speed of the transport at the full radius is significantly higher than that of the centre area of the tank. Basically the transport capacity diminishes as the solids approach the discharge area of the tank. The use of secondary scraper arms with progressive depth blades and variable blade pitch help to make up the transport capacity shortfall due to the linear speed decrease near the centre.

In addition to the rake blade scraper system, the WesTech HiDensity™ paste thickener uses a series of vertical dewatering pickets. The pickets not only provide localised shear to collapse the gel matrix of the paste material, but also open channels that allow the interstitial liquid to rise through the solids bed with less impedance.

Figure 8 Rake system

With a blade conveying and dewatering system design determined, it is necessary to configure a structural support that will not only support the blade and picket system, but also transmit the high torque generated by the drive unit. A low profile support structure allows more of the torque energy to be utilised for solids transport. Higher support structure profile consumes excessive amounts of torque due to drag of the high yield stress suspension passing over the structure.

The laboratory test work determined that this bauxite tailing material had optimal settling characteristics when flocculated at lower than feed concentration. The need for feed dilution would be beneficial, to improve not only the settling flux, but also reduce the amount of flocculent required. A WesTech Multiport™ feedwell was used to achieve the dilution and optimise the unit flux rate. The Multiport™ feedwell uses the natural density differential between the inside and outside of the feedwell to draw overflow water through gated ports at the top of the feedwell. Flocculent is blended with this overflow water to better distribute polymer and increase the interaction of the chemicals with the solids in feed slurry.

Figure 9 Multiport™ feedwell

4 CONCLUSIONS

For the Paragominas Bauxite Plant, CVRD decided to use an environmentally sound method of tailings disposal. Even though the application involves high tonnages, with an integrated upstream design approach and the economies of scale of a HiDensity™ paste thickener, a commercially viable solution was provided. Applying the principles of an upstream design methodology is the best way to ensure the proper integration of unit processes and deliver a reliable paste or thickener tailings system.

WesTech demonstrated that paste applications with high tonnage can be economically solved through the use of HiDensity™ paste thickeners. These large diameter paste thickeners produce underflow material with yield stresses suitable for most surface stacking operations. Although careful consideration in both process design and mechanical design of the thickener is crucial, the most important aspect is a cooperative design effort between geotech, pipeline and thickener designers.

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