Large deep cracks before next layer during the >12 years stack life of bauxite tailings TSF

Tailings surface stacking – a longevity review

Jerold Johnson & Brad Bentley of WesTech Engineering, LLC talk about how paste and thickened tailings facilities stand the test of time

Surface stacking has provided plants with increased storage capacity, improved stability, and conservation of water for decades. It has been used around the world in all type of mines, in dry to wet climates. This paper provides a brief technology introduction for producing Paste & Thickened Tailings (P&TT), using a paste expert team for each process stage (production, transport, geotechnical) and case studies. The longevity of the technology is shown in profiles of three active sites: 1) an iron site operating in Inner Mongolia for over 14 years, 2) an iron site in Republic of South Africa with about 16 years of operation and 3) a bauxite site in Brazil with 15 years of operation. Each of these sites illustrates the benefits from proper design, layout, sizing of equipment, and operation of a surface stack. This is a seasoned technology.

The importance of proper Tailings Storage Facilities (TSF) design and management is paramount to reduce the associated risks of tailings storage. More than 20 years ago, surface stacking technology using P&TT was introduced. It brought with it the claimed benefits of increased water recovery, low-risk TSF, increased site capacity, the ability to be used in wet and dry climates, quick access for remediation, and the ability to be used with most any tailings that satisfy some minimum requirements. After twenty years, it is time to evaluate if these claims have been met. This article reviews three sites, each using surface stacking for around 15 years.

Any discussion about P&TT is best started with a reminder of the unique non-Newtonian properties that are the foundation for all these process claims, how and why it works. These unique properties of P&TT begin with the yield stress that provides a relatively non-settling, non-segregating suspension. Producing a desired yield stress, the paste-type thickener dewaters to a significantly higher wt% solids than a high rate thickener (10-15% higher). This higher underflow density provides rapid drying as the water is drawn to the surface. The deposit has a shallow angle of repose, which will slowly drain any precipitation (free water) to not erode the stack and keep the surface exposed to the air for drying.

P&TT technology is unlike high rate thickening in several critical ways. The paste-type thickener mechanism must include properly designed low-profile rake arms with high raking capacity blades and dewatering pickets. The K-factor will be 5-10 times more than with high rates. With the very deep thickening bed in paste-type thickeners, the high rate rake-lifts concepts/benefits do not apply. These are critical features that must be optimized. All suppliers' designs are not equal. The high rate thickener underflow is a settling slurry and often targets a wt%. However, a P&TT thickener must target a yield stress. By targeting a relatively steady yield stress, the underflow is suited for the downstream process stages.

Each process stage in a P&TT system (dewatering in the thickener, transportation to the TSF, and TSF layout and management) must be designed to handle the yield stress and viscosity at that stage. This requires experts for each process stage. P&TT expertise is not prevalent like knowledge and experience with slurry. Assembling a paste team best addresses this unique material and the different challenges of each site. Each site can consider different layouts, such as two-stage thickening when there is a distance to the TSF. The high rate thickener would be located at the processing plant and transporting the underflow the several km to the TSF. The smaller volume of the underflow and return paste-type thickener overflow reduces the transportation costs compared to producing the P&TT at the plant and transporting this higher viscosity material to the TSF directly. The management of the TSF is less complicated as the paste-type thickener will have some surge capacity for spigot changing. Also, with short P&TT transport lines, it will use less flush water for line shutdowns. Any emergency dump sites would be at the TSF and not by the plant.

A successful installation must start with the thickener performance. WesTech supplied the paste-type thickener for these three longevity site studies. With almost 15 years of operation, the technology is not new, there has been enough operating time to confirm if the promises have been achieved.

Case study 1: China

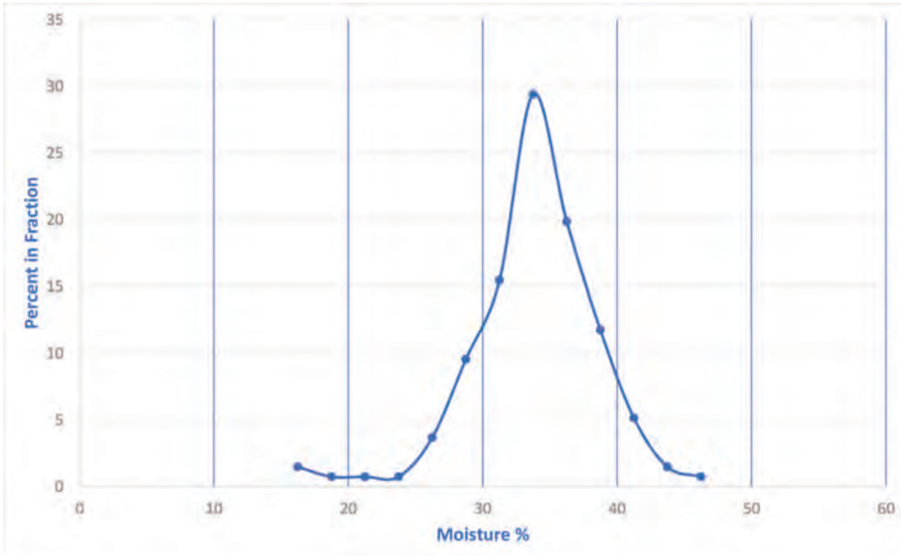
The first site is in the arid climate of Inner Mongolia. This iron mine, Baoto, and the surrounding community receives 2,500 m³/h (11,000 gpm) water pumped from the Yellow River some 130 km (80.8 miles) away. This greenfield plant produces 2,100 t/d of tailings. The TSF plan identified a shallow valley about 5 km (3.1 miles) from the processing plant. The tailings system uses two-stage thickening with a 48 m (157 ft) HiFlo™ high rate thickener at the beneficiating facility recovering a majority of the water and reducing the volume to be pumped to the second stage 20 m (65.6 ft) diameter WesTech Deep Bed™ paste thickener at the TSF site. The paste-type thickener design generally uses a smaller diameter thickener compared to high rate thickeners. These thickeners have steeper floor slopes and taller sidewall heights. At this site, the high rate is producing in the low-50 wt%, the paste-type thickener dewaters further to 70 wt%. The TSF is provided with peripheral spigots. This site deposits a low-yield stress underflow that spreads and fills the TSF, while producing a 1-3% slope. The standard surface stacking management plan with layering of fresh tailings with a dry cycle between layers is used. An advantage of surface stacking technology can be seen in the water balance. This site produces a high rate underflow with 875 m^3/h (3,850 gpm) water. Of this, the paste-type thickener recovers 518 m^3/h (2,280 gpm). This 518 m^3/h is significant as it is 20% of the 2,500 m^3/h of water being pump from the Yellow River. Without the use of the paste-type thickener, the 875 m^3/h of water would have been sent to a slurry pond. In an arid climate with long winters, the potential of recovering much of this water would be low. The use of the surface stack with a paste-type thickener recovered, right at the thickener, 59.1% of the water received from the high rate thickener. The TSF management has been as planned with increased water recovery at the thickener, no free water on the TSF, the rapid drying, and the low-risk TSF being achieved.

Case study 2: South Africa

The second case study is an iron mine, Khumani, in South Africa. For this greenfield sitt, due to the arid climate and available water, the regulators required a minimum water use of 0.09 m^3 per tonne of product*. The use of a surface stack with P&TT was the only acceptable method that met this stringent requirement. The plant has a high-water method (jigs and classification) to recover the iron. The TSF system used two-stage thickening with a 90 m (295 ft) diameter WesTech Titan™ traction high rate thickener at the beneficiation plant. The underflow is sent to an 18 m (59 ft) diameter WesTech Deep Bed paste-type thickener near the TSF. A second phase, two years later, duplicated this system giving total dry tailings of 21,600 t/d. The TSF is in a shallow valley about 5 km from the beneficiation plant and uses the standard surface stack management with layers of non-Newtonian underflow <500 mm thick, diverting to another part of the TSF allowing each layer to dry. The material dries to a low moisture with large cracks before the next layer is placed. Pumping transports the P&TT to periphery distribution spigots with a series of booster centrifugal pumps. Just like the first case study, this site shows the surface stacking claims have being met for more than 15 years.

Case study 3: Brazil

The third case study is a bauxite plant, Paragominas, in northern Brazil. This greenfield plant is in a semi-tropic climate averaging 1.8 m of rainfall annually. The site now has installed a second phase using parallel circuits, each with a WesTech 70 m concentrate thickener and a WesTech 45 m HiDensity™ thickener for the tailings. The concentrate is pumped to the aluminium plant and the non-Newtonian tailings are surface stacked. An important takeaway from this site is that there is no real limit to how fine the particles can be for surface stacks with P&TT. There is a rule of thumb for the minimum amount of fines. It states that 20% of the weight must be finer than 20 µm. However, there is no maximum for minus 20 µm material. As the amount of material passing 20 µm increases, the yield stress versus wt% relationship simply shifts to lower wt%. For example, as presented earlier in case study 1, the proper yield stress was achieved at 70 wt% solids. For this bauxite site, the stream characteristics (particle size distribution, mineralogy, etc. combine to have the proper yield stress produced at 35 wt% solids. With the proper yield stress achieved, the rapid drying, angle repose, and ease of TSF management are the same for both sites. Periphery spigots are used for normal surface stacking site management techniques, layered deposition with drying cycles. The 35 wt% non-Newtonian underflow is placed in <0.5m depths, then allowed to dry 4-8 weeks to reach 65 wt% between layers. This case study provides very strong evidence for low-risk of failure TSF because the mine conducted a drill-core study of the TSF. The construction of the TSF is in a valley next to the beneficiation plant and includes features like diverting the river in the valley around the TSF, dividing the TSF into two areas with a berm between them. This provides access for periphery spigots for deposition across, as well as around its TSF. The mine's evaluation of the success of their TSF used drill cores collected from the full TSF on a relative grid pattern. The cores were analysed in 0.5 m sections. With the TSF being in operation for more than 12 years at the time of the study, part of the stack was over 30 m deep. The samples were analysed for moisture content, PSD, and the yield stress of the material. An article** concluded that there was "significant homogeneity in terms of physical character regardless of spatial distribution." The moisture content to 30 m deep was a relatively consistent 33-34% (see distribution figure). The rheology study reported apparent viscosity of 30 MPa.s, a very stable material that would require "huge energy to make it flow." The final moisture was independent of variables like season, discharge flow rate, and layer depth.



Moisture distribution curve for 0.5 m sections of up to 30 m deep drill cores

The desirable benefits of surface stack with P&TT have been realized for these three case studies. The TSFs are very stable with no free water. The technology predicted increase in water recovery is significant and a major cost advantage. Rapid drying in wet or dry climates is a function of the high solids content and the deposition method. Drill-core study of an active site showed the uniform moisture content through 12 years of operation, a stable low-risk TSF. These benefits are easily achieved with the straight forward TSF management. The P&TT technology deserves high marks with a proven track record, the path has been tried. Starting with the critical function of producing the non-Newtonian underflow and through the subsequent stages, these combine for successful surface stack installations. IM

*T. du Toit, M. Crozier, 'Khumani Iron Ore Mine Paste Disposal and Water Recovery', The Journal of The Southern African Institute of Mining and Metallurgy, Volume 112, March 2012.
**Bretas, et.al., 'Geotechnical and Rheological Characterization of Bauxite Mining Tailings', 7th International Conference on Tailings Management, Chile 2021.