RED MUD STACKING

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Abstract

The red mud slurry "stacking" method used in many Alcan Plants has been developed in the 1980's. The aim of this technique is to use minimum space for the disposal of the residue and to rapidly obtain consolidated material. The consistency of the mud slurry plays a key role in the steepness (angle) of the stacking slope.

A small pilot stacking unit was built in order to determine the parameters influencing red mud consistency (expressed as the yield stress). The effect of solids concentration, particle size distribution and degree of remolding were evaluated. A relationship was also established between the mud consistency and the stacking slope observed.

Introduction

The ''stacking" method used for the disposal of thickened tailing is well known in the mineral industry[1,2,3]. It is used by many plants in Alcan. The aim of the technique is to use minimum area for the disposal of the tailings, to rapidly consolidate and rehabilitate the land. The slope of the stacked tailings is a key factor to maximize the amount of tailings that can be disposed of in the stacking area.

The tailings consistency has a direct influence on the slope of the conical shape deposited pile obtained at the stack. At the discharge point, the internal angle of friction of the slurry overcomes the gravitational and dynamic forces of the flow, the slurry slows down and is stopped to its natural angle of repose. The slope is known to vary with the yield stress of the mud as expressed in the Herschel-Bulkley flow model. It was established, in the laboratory, that the solids concentration, the particle size distribution (+100 mesh size fraction) and remolding history have an effect on the yield stress values measured on red mud. However, in the past there was no relationship established between these parameters, the yield stress and the slope obtained at the stack, for Alcan Vaudreuil Works in Jonquière, Québec, Canada.

In order to optimize the stack slope, it was decided to establish a correlation between the mud properties (solids concentration and particle size distribution), the remolding history and the slope obtained at the stack. A pilot unit was built in order to simulate the stacking operation under more controlled conditions. Several stacking techniques were also evaluated in order to better understand the behavior of freshly stacked red mud.

Rheological Characteristics of Red Mud

Concentrated red mud slurries are considered as being pseudoplastic as well as thixotropic fluids, since their viscosity diminishes with an increase in shear rate (i.e. agitation)[4]. Red mud slurries have a "yield stress" which is to say that it requires a minimum shear stress to initiate flow. Finally, the red mud flow properties are strongly dependent on their solids concentration, particle size distribution and flocculation conditions in the deep thickener or last washer.

These red mud properties indicate that the slurries cannot be characterized by one single value for viscosity. In fact, the viscosity changes with conditions and with the history of the mud. The viscosity of red mud may be expressed by the Herschel-Bulkley flow model (generalized Bingham).

$$\tau=\tau_y+K(s)^n$$

where
- τ : shear stress (Pa.sec^{-1})
- τ_y : yield stress (Pa)
- K : fluid consistency index (Pa.sec^n)
- (s): shear rate (sec^{-1})
- n : flow behaviour index (dimensionless)

The yield stress (τ_y) is a parameter of the Herschel-Bulkley flow model intrinsic to the mud (i.e. does not vary with the applied shear stress (τ)). The yield stress corresponds to the value of the minimum shear stress to be applied to break the internal resistance of the mud and to start the flow. A mud with a higher yield stress will produce a stack with a steeper slope. The yield stress is normally the parameter used in the literature to characterize the stacking properties of red mud[4,5].

Equipment and Material Used

Stacking Unit

The pilot test unit was designed to be as flexible as possible. Because it is fully mobile, it can be installed in the plant or at the stacking site. The pilot unit is composed of two distinct parts: the treatment unit or cement mixer and the stacking unit or trailer (Figure 1). The treatment unit is used to modify the rheological characteristics of the slurry. The stacking unit allows us to evaluate the relationship between the slope obtained and the rheological characteristics measured.

The pilot unit has the capacity to test a batch of 15 m^3 of mud. The batch can be homogenized or remolded in the cement mixer. There is also a screw mixer of 3 m^3 located between the cement mixer and the trailer. This screw mixer feeds either a centrifugal pump or a screw conveyer that are then used to transfer the mud to the stacking unit. A flowmeter is used to measure the flowrate of the mud transferred to the trailer.

A mobile excavator is located at the top of the trailer. It is used to move the mud towards the pump when the mud is recirculated to the cement mixer. A filtration system is installed in the trailer. This system allows us to raise the solids concentration up to 62 wt %. At the end of the trailer, there is also a system to collect the lixiviate that is discharged at the foot of the stack.

Viscometer

Yield stress measurements were realized with a Haake VT-500 viscometer equipped with the vane sensor FL-100. The yield stress measurement technique has been described by Nguyen and Boger[4]. It essentially consists of placing a vane type sensor in the mud sample and applying a low rotational speed.

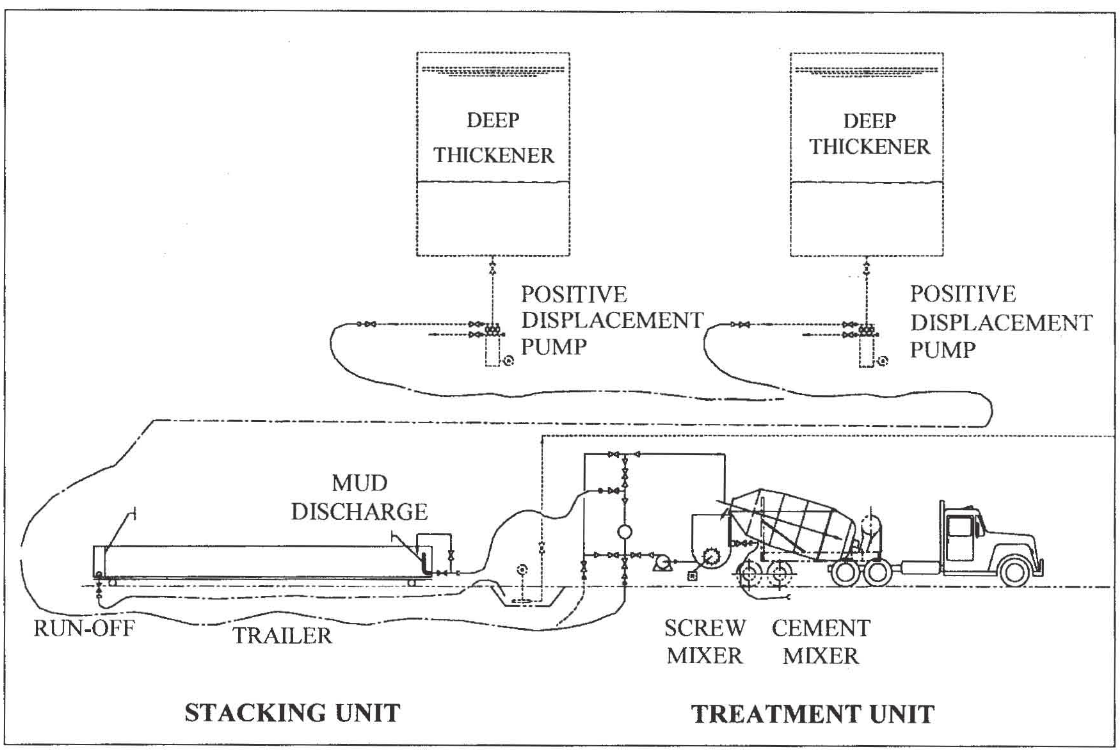

Figure 1: Flow sheet of the stacking pilot unit.

Red Mud Samples

For these tests, red mud was sampled at the deep thickener underflow. The mud could be stacked directly in the trailer or a batch of 15 m^3 sample could be either homogenized or remolded in the cement mixer. The red mud characteristics were varied according to the test specifications. Then, for each condition, the mud was stacked in the trailer and the slopes were measured.

Results of the Red Mud Stacking Experiments

Several stacking experiments were realized over a period of 2 months. In the first series of tests, red mud characteristics were varied in order to see their influence on the slope. The solids concentration, particle size distribution and effect of remolding were varied to see their influence on the slope of the stack and the yield stress was investigated. In the second series of tests, various discharge techniques and the effect of resting time were observed and evaluated.

Variation of Mud Characteristics

Influence of the Solids Concentration on the Slope. The homogenized red mud was remolded and filtered in order to increase its solids concentration to about 60 wt %. It was stacked in the trailer and the slope measured. The mud was then re-pumped into the cement mixer and diluted with wash liquor to lower its solids concentration. The same procedure was repeated for various solids concentrations.

A relationship was established between the solids concentration and the slope obtained in the experimental stack (Figure 2). As expected, there was a direct relationship between the solids concentration and the slope.

Influence the Particle Size Distribution on the Slope. The particle size distribution has a great influence on the red mud viscosity. A coarser distribution will result in a decrease of the yield stress measured for the same solids concentration. For red mud, the Bayer sand content (+100 mesh fraction) is the fraction that was specially targeted to test its effect on the viscosity.

The homogenized red mud was remolded, stacked in the trailer and the slope measured. The mud was then re-pumped into the cement mixer and Bayer sand was added. The solids concentration was readjusted to its initial value with wash liquor of the same soda concentration. The same procedure was repeated for various sand content levels.

A relationship was established between the sand content and the slope at constant solids concentration (Figure 3). There is a direct relationship between the sands content and the slope.

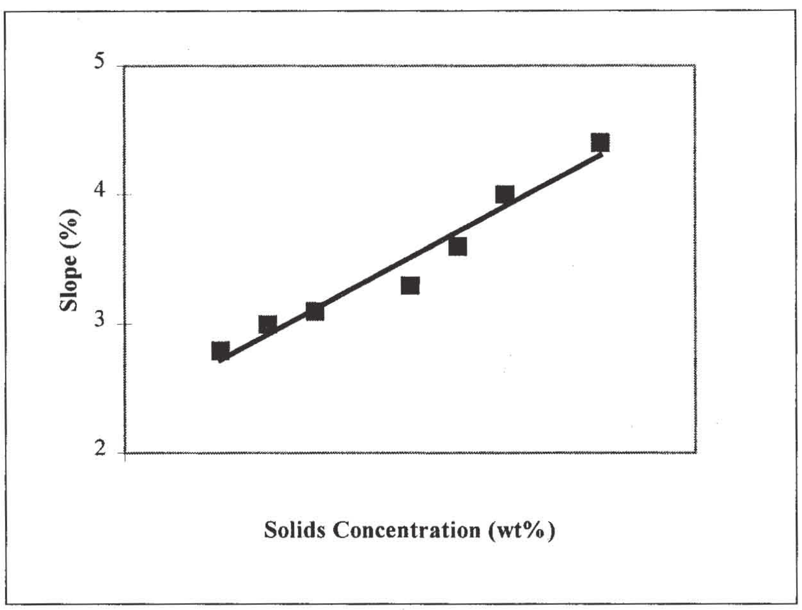

Figure 2: Slope as a Function of Solids Concentration.

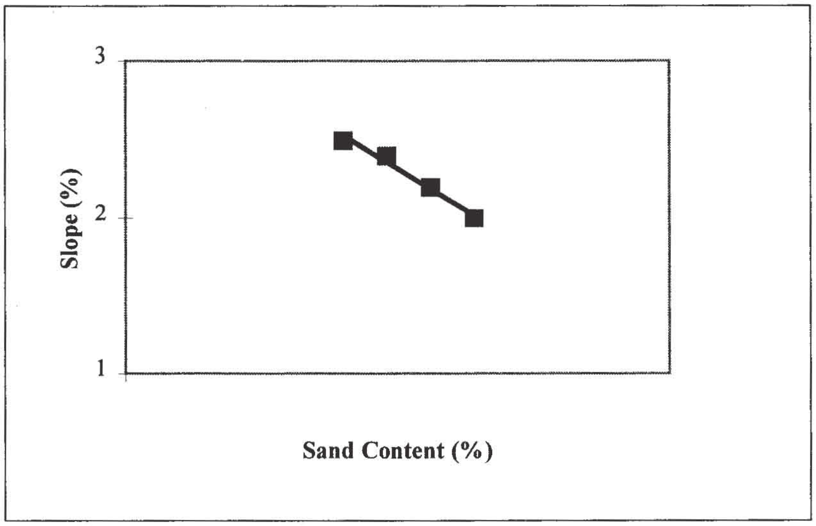

Figure 3: Slope as a Function of Sand Content.

Influence of Remolding on the Slope. It is known that the remolding rate has mud consistency. In the laboratory, it is possible to observe mud liquefaction and a decrease of the yield stress value.

The unremolded red mud was sampled at the deep thickener underflow, stacked in the trailer and the slope measured. The mud was re-pumped into the cement mixer, further remolded and then stacked in the trailer.

A relationship has been established between the degree of remolding and the slope obtained on the experimental stack (Figure 4). As it was expected, there is a direct relationship between the degree of remolding and the slope.

Influence of the Yield Stress on the Slope: The yield stress has been measured, as a routine measurement, in all the tests shown previously. Figure 5 shows that there is a direct correlation between this rheological parameter and the slope obtained.

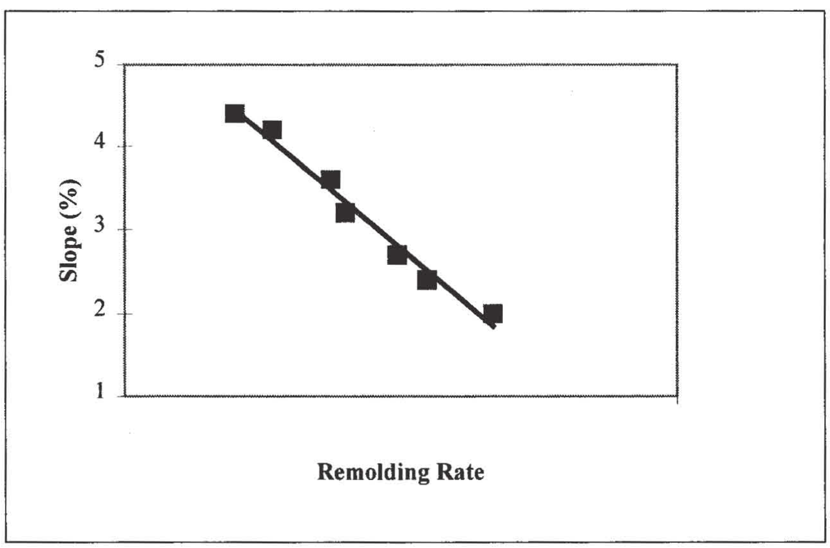

Figure 4: Slope as a Function of Remolding Rate.

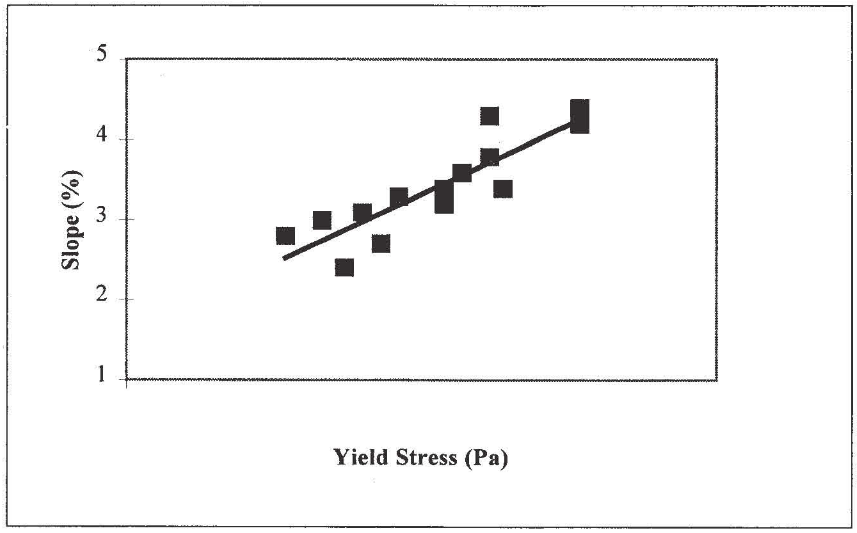

Figure 5: Slope as a Function of Yield Stress.

Variation of the Stacking Technique

During the stacking test, the discharge method and the resting time have been varied to see their influence on the stack.

Influence of the Discharge Method. In order to stack, red mud slurry must overcome the gravitational and dynamics forces of the flow, which may be very important. In the stacking test, several discharge methods were tested; open pipe, discharge tower and screw conveyer. It was possible to observe clearly that the discharge tower reduced the flow speed significantly and was creating less erosion of the stacked red mud underneath. Accordingly, the slope measured was much higher with this discharge method (+0.5 to 1 %).

Influence of the Resting Time. Once a layer of mud is deposited on the pile, it is important that it stays put and does not slide to the toe of the dike. The resting time ("t") is defined as the time elapsed between the deposition of two consecutive layers of mud. The stability of the deposited layer of mud is explained in Figure 6.

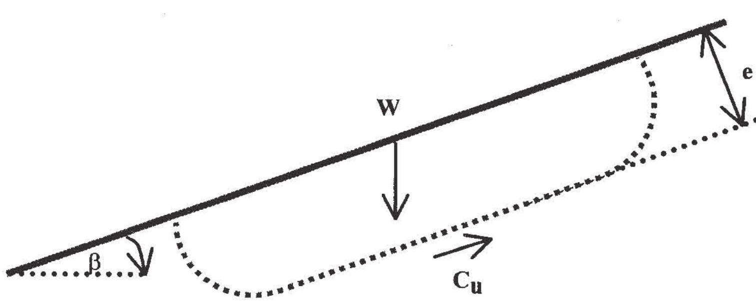

Figure 6: Simplified Stability Analysis.

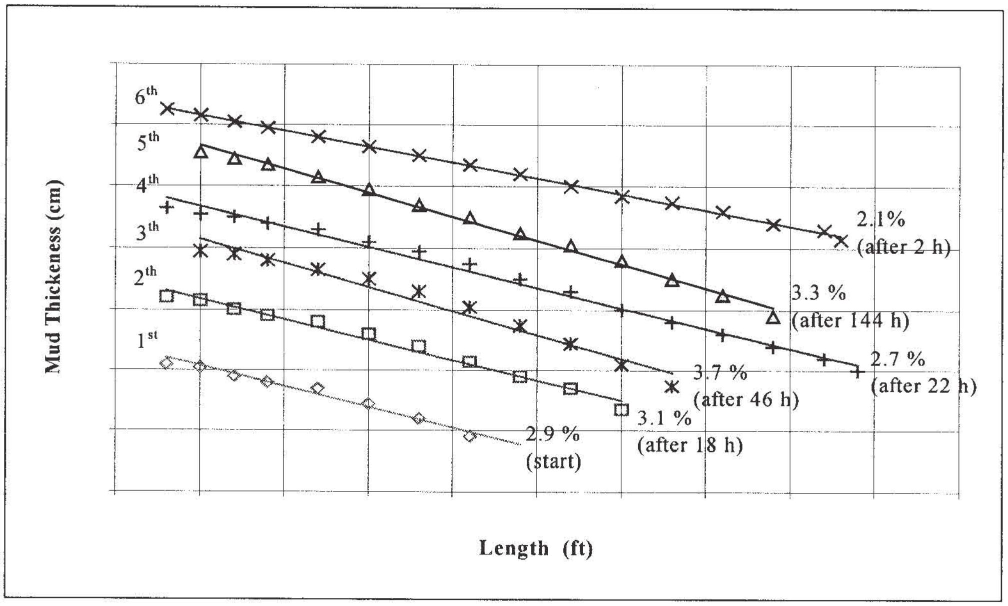

Figure 7: Stacking Layers by Layers.

The forces acting on a layer of deposited mud are essentially the shear strength of the material (yield stress or C_u) and its weight component acting down the slope (w). The force of gravity acts on the mass of the slab and causes it to slide down the slope. The only force opposed to sliding is the shear strength. The slope is stable when the ideal thickness of mud is deposited.

When the sequence of deposition is too rapid, a new layer of mud will be deposited on a "relatively" new layer of mud underneath, which is more or less consolidated. The real thickness of unconsolidated material is then equivalent to the thickness of both layers added together. The increase in thickness of unconsolidated material may cause the slide of the whole slab. But if the resting time is sufficient enough, the first layer will have time to consolidate (i.e. regain strength) and a second layer of mud can be deposited without sliding.

In the pilot test, 4 cubic meters of red mud was stacked with a slope of 2.9 %. Then after 18 hours, a second layer of the same mud (same volume) was poured. The slope measured was 3.1 %. After 46 hours, a third layer was deposited (same mud, same volume) and the slope was 3.7 %. The fourth layer was deposited after 22 hours and the slope was decreased back to 2.7 %. It was then concluded that ≈20 hours was not sufficient to significantly increase the shear stress (yield stress) and avoid the sliding of mud.

Then, it was decided to re-stack a fifth layer of mud. The resting time was fixed at 144 hours. The slope obtained increased to 3.3 %. A sixth and final layer was deposited after only 2 hours of resting time. The slope dropped down to 2.1 %.

Conclusions

The slope of the stacked mud is affected by the solids concentration, particle size distribution and the remolding state of the mud. The yield stress measured at the line outlet can be used as a tool to characterize quantitatively the consistency or viscosity of the mud and to predict the slope on mud stack. This unique measurement combines the effects of solids concentration, sand fraction and degree of remolding.

The discharge method has an influence on the slope obtained. A gentle discharge system that allows a split of the flow gives the best slope results (0.5 to 1 % more). Once the stack is built, it is very important to let sufficient resting time before putting another layer of mud. As seen previously, one can expect a drop in the slope up to around 1 % if not enough time is allowed.

References

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