APPLICATION OF FLUIDISED BED COLUMN TESTING TO THE ASSESSMENT OF BEACHING AND SEGREGATION CHARACTERISTICS OF MINE TAILINGS

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ABSTRACT

A fluidised bed column test has been developed by the authors with the objective of obtaining data on the segregation and segregated rheology of a tailings slurry as this flows down a beach on a tailings facility. In making use of a column the loss of energy down the beach can be evaluated more efficiently as gravity serves to reduce the energy in the flow stream in addition to friction and viscous forces. Moreover, it is feasible to evaluate the characteristics of the flow stream under laminar conditions. This paper describes the principles of the test, presents typical data, and shows the results of the application of the data to beach prediction modelling.

INTRODUCTION

A slurry flowing down a beach undergoes changes in consistency and rheology as a result of deposition of solids. There is a gradient of density with depth in the slurry stream with the slurry at the depositing bed face at a higher density than the tailings at the surface of the stream. As a result, the deposited tailings have a higher percentage of solids than the average of the flow stream and therefore the deposited tailings entrains less water than the average in the flow stream. Consequently the slurry percent solids progressively reduces with distance down the beach.

As the slurry percent solids reduces so does the rheology which, in turn, impacts both the beach slope as well as the gravitational segregation characteristics of the slurry.

Measurement of the changes in slurry properties with distance down the beach presents practical problems in terms of access to the slurry as well as representative sampling. And even if such issues were overcome it would still not be possible to make predictions in Greenfields situations where no tailings facility exists.

The authors have developed an approach that enables the measurement of the changing slurry properties in a laboratory. The principles on which the approach is based are as follows:

- Particles in a non-homogeneous, settling slurry characteristic of mineral tailings slurries are kept in suspension by energy in the flowing stream. This energy maintains shear stresses that buoy the particles within the suspension.

- Energy is lost through friction and viscous effects in the flowing stream and with this loss there is insufficient energy to continue to suspend all particles resulting in settling out of solids and fluid. Indeed the rate of settling out is directly proportional to the rate of energy loss.
- Energy is scalar (as opposed to a vector) ie it has no direction. The means that the energy loss down a beach can be simulated using gravity in a vertical conduit with gravity providing an additional component in the energy loss process without influencing the flow regimes.

In essence, the authors postulate that the beach flow process can be simulated using a vertical column. This is described in the next section.

FLUIDISED BED COLUMN

Figure 1 shows a schematic of a fluidised bed column developed by the authors. Slurry is maintained in suspension in a tank from which slurry is drawn and pumped up a pipe which serves as fluidised suspension column. Samples are drawn off at several heights to enable the measurement of percent solids, rheology and particle size distribution. The slurry from the top of the column is returned to the tank. Recirculation of the slurry takes place until flow regimes have stabilised.

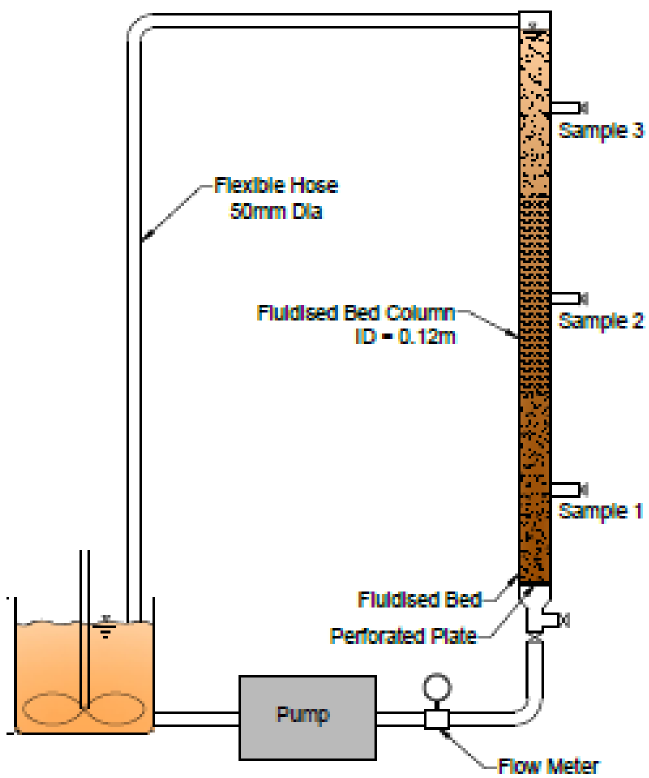


Figure 1 Schematic showing fluidised bed column set up

As the slurry flows up the column energy induced by the pump is lost through friction, viscous effects as well as gravity. Stream power is energy per unit time and can be calculated from the equation:

$$P = Q\varrho gH \tag{1}$$

P is the stream power, Q is the flow rate, ϱ is the slurry density and H is the elevation above datum which can be taken as the base of the column.

The loss of stream power means that not all particles can be suspended with increasing elevation in the column. A sample drawn at a given elevation is therefore representative of the slurry at that elevation and the percent solids, rheology and particle size distribution of the sample will be representative of the slurry at that elevation. More importantly, the sample characteristics can be related to the stream power at that elevation.

By sampling at a number of points changes in percent solids, rheology and particle size distribution can be trended against stream power.

APPLICATION TO BEACH PREDICTION

The stream power-entropy method of beach prediction developed by McPhail [1995, 2008, and 2014] and Charlebois et al [2013] determines the beach profile from changes in stream power from the discharge to the end of the beach. The value of the stream power at any point along the beach as well as the change in stream power from point to point along the beach are applied together with Bernoulli, continuity and force-momentum flux to determine the flow depth and velocity down the beach. An iterative calculation process is employed friction and viscous force energy loss determined from the slurry rheology. A closed solution is obtained when the calculated shear stresses in the flow stream down the beach match the shear stresses from the flow curve at the same shear rates.

Incorporation of the relationship between stream power and percent solids for the slurry at points down the beach enables more accurate application of the appropriate rheology in the beach simulation process. This is achieved by including correlations between percent solids and the rheological parameters as obtained from rheological testing.

FLUIDISED BED COLUMN TESTING ON COPPER TAILINGS

Unflocculated copper tailings have been circulated through the column at three percent solids, 55%, 60% and 65% by weight. For each percent solids the following process has been followed:

- The tailings have been circulated for 40 minutes with samples recovered from the feed to the column, the three sampled points up the column, and from the overflow from the column, at 10, 20 and 30 minutes.
- Measurements of percent solids as well as rheology (using a rotary viscometer) have been made on each of the samples.
- On samples from the three sample points up the column measurements of particle size distribution and rheology using a flume rheometer supplemented by rotary viscometer testing on samples from the flume rheometer have been carried out.

RESULTS

The results of the measurements made on the samples are summarised in the ensuing subsections. The results only for the 30 minute samples are set out as it was found that the results were more consistent indicating that the column takes time to stabilise.

Percent solids tests

Figure 2 shows the variation in percent solids with stream power calculated using equation 1 from the elevation of the sampling point up the column, applying the slurry density determined from the tests on the samples from the sample points, and subtracting the sampling flow rate from the prior flow rate, for the 55%, 60% and 65% solids tests.

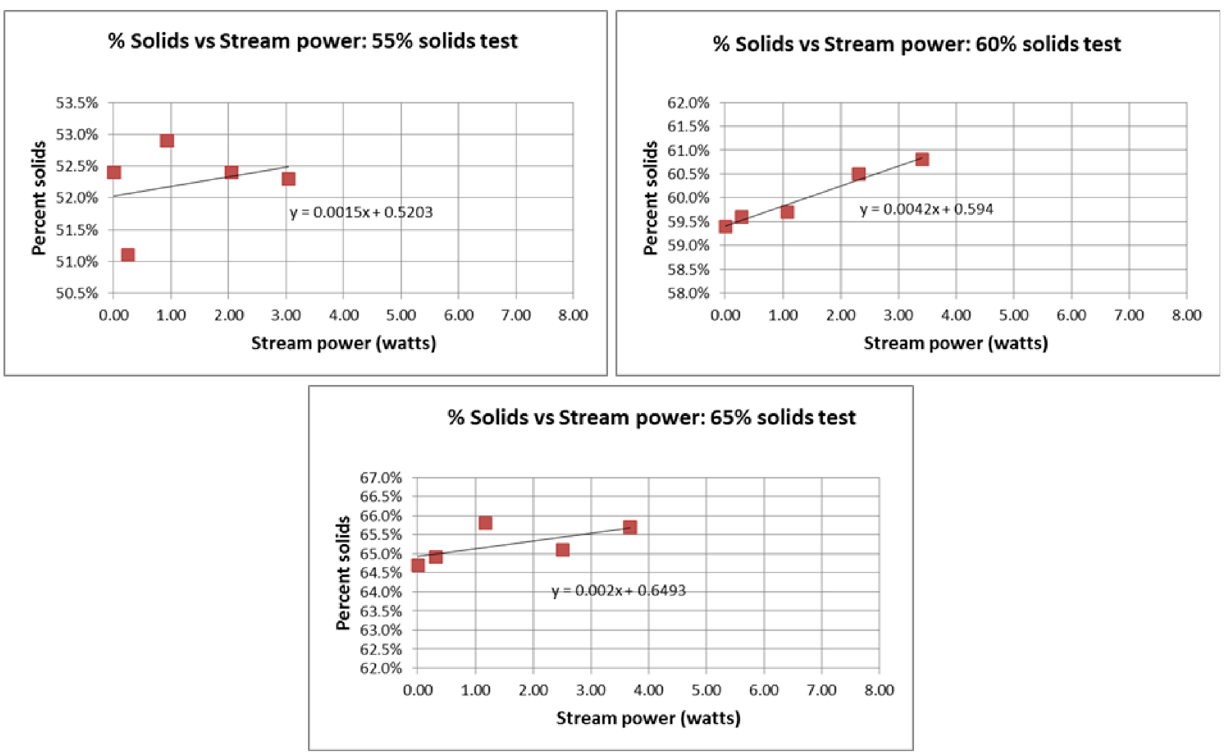


Figure 2 Variation of percent solids up the column

It is of interest to note that the variations are similar between percent solids samples and while not insignificant, the variations with height up the column are relatively small for the sample tested. It is likely, given the scatter of the results for the 55% solids test that the column had not yet stabilised after 30 minutes

Particle size distribution tests

Figure 3 shows the results of particle size distribution tests on samples from the three sample points for each percent solids tested.

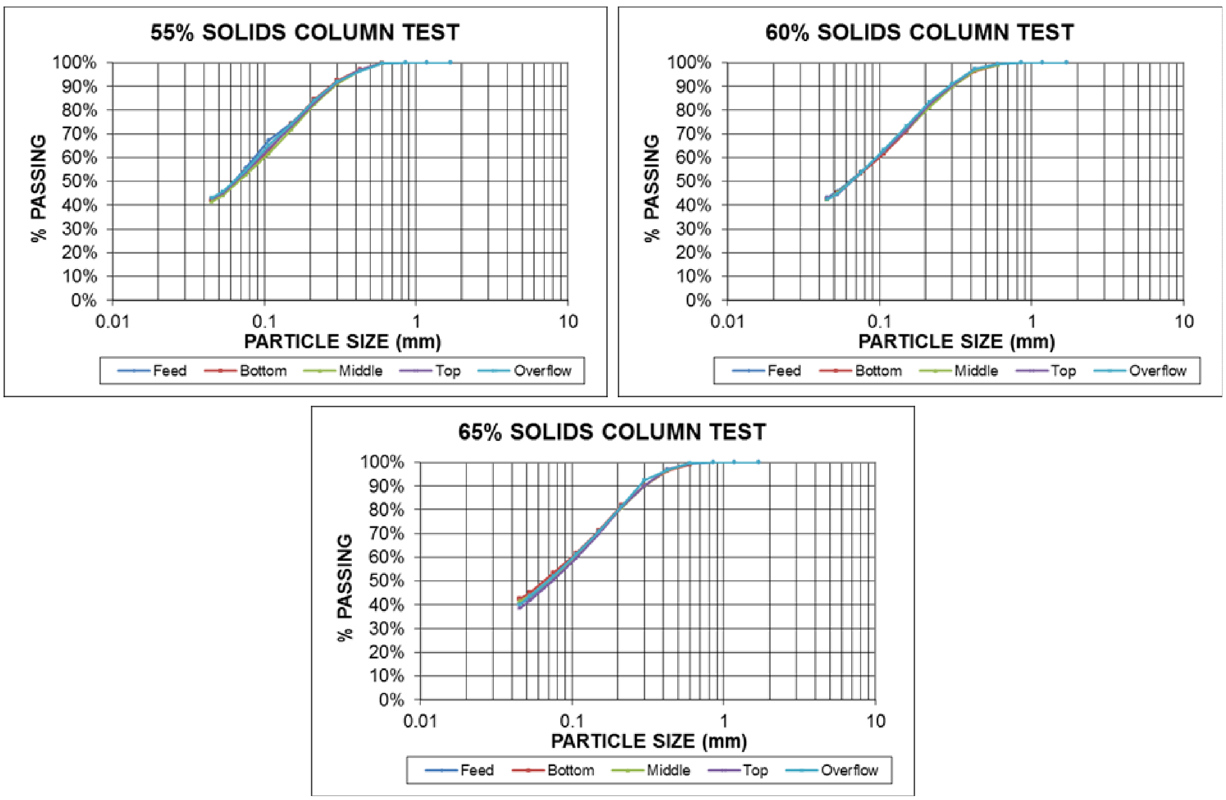


Figure 3 Variation of particle size distribution up the column

It is evident that there is practically no segregation up the column. This is in line with observations on copper tailings facilities where gravitational segregation is observed to be low.

Rotary viscometer tests

The results of rotary viscometer tests from which Bingham plastic parameters have been derived are shown in Figure 4

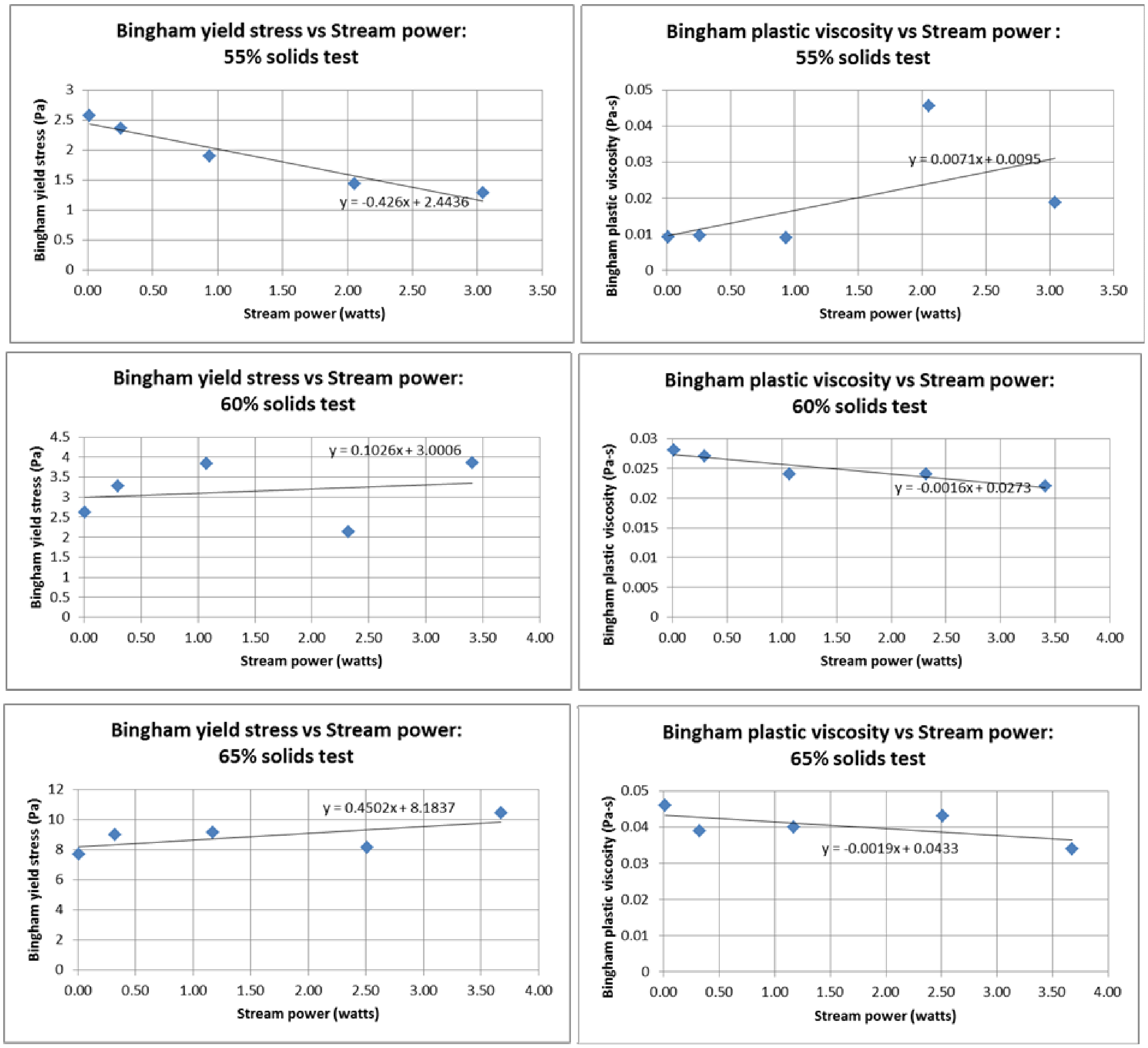


Figure 4 Bingham parameters from rotary viscometer testing on the feed, column and overflow samples

It is evident that the change in percent solids has a measurable effect on the Bingham yield stress and Bingham viscosity. The contrary trend for the 55% solids is a further indication that the column had not stabilised.

Flume rheometer tests

Rotary viscometer tests are unreliable at low shear rates but are generally useful above $50s^{-1}$. Flume rheometer testing enables the flow curve from 1 to $50s^{-1}$ to be estimated. A typical result is indicated in Figure 5

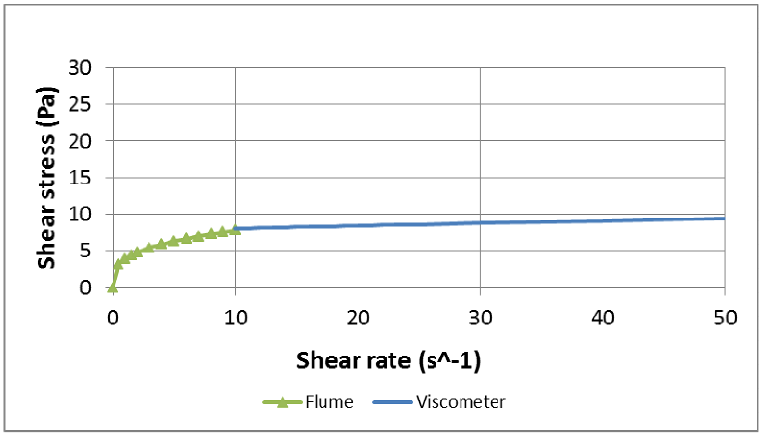


Figure 5 Typical flow curve made up of flume and rotary viscometer measurements

Correlations of the flume and rotary viscometer test results against percent solids for the three sample points are indicated in Figures 6 to 8.

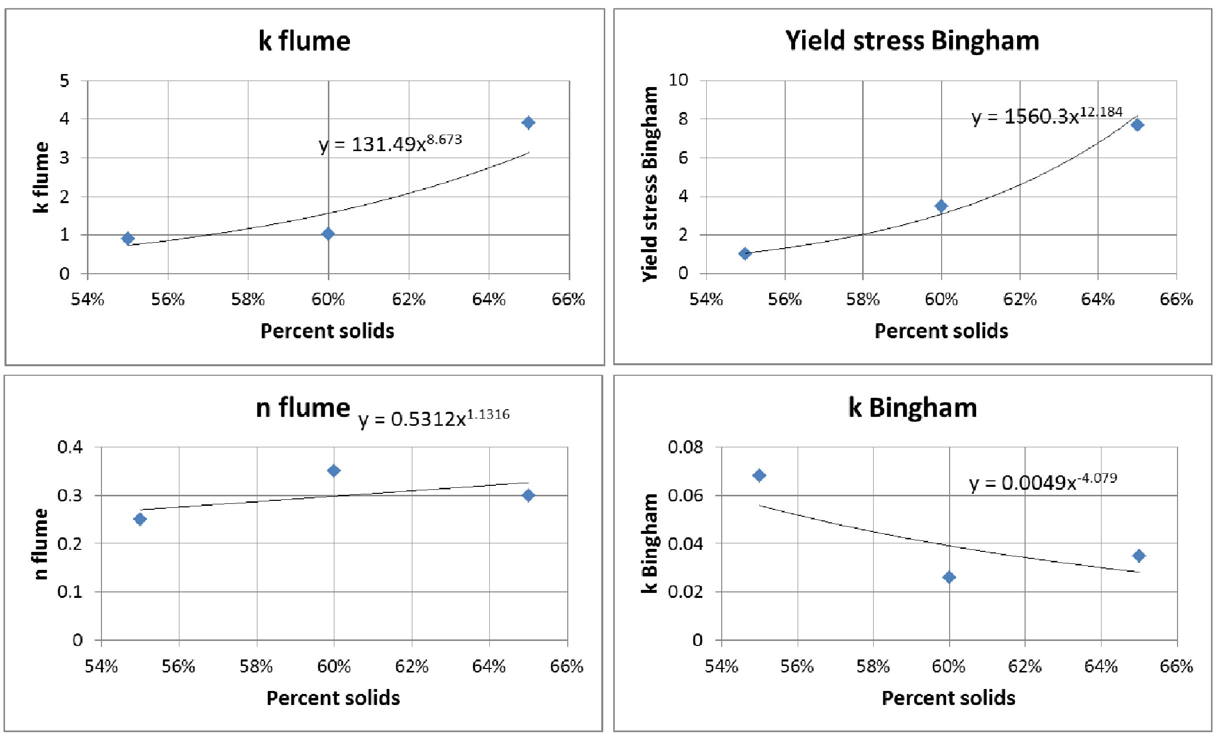


Figure 6 Rheological parameters correlated with percent solids: Bottom – stream power =2.3watts

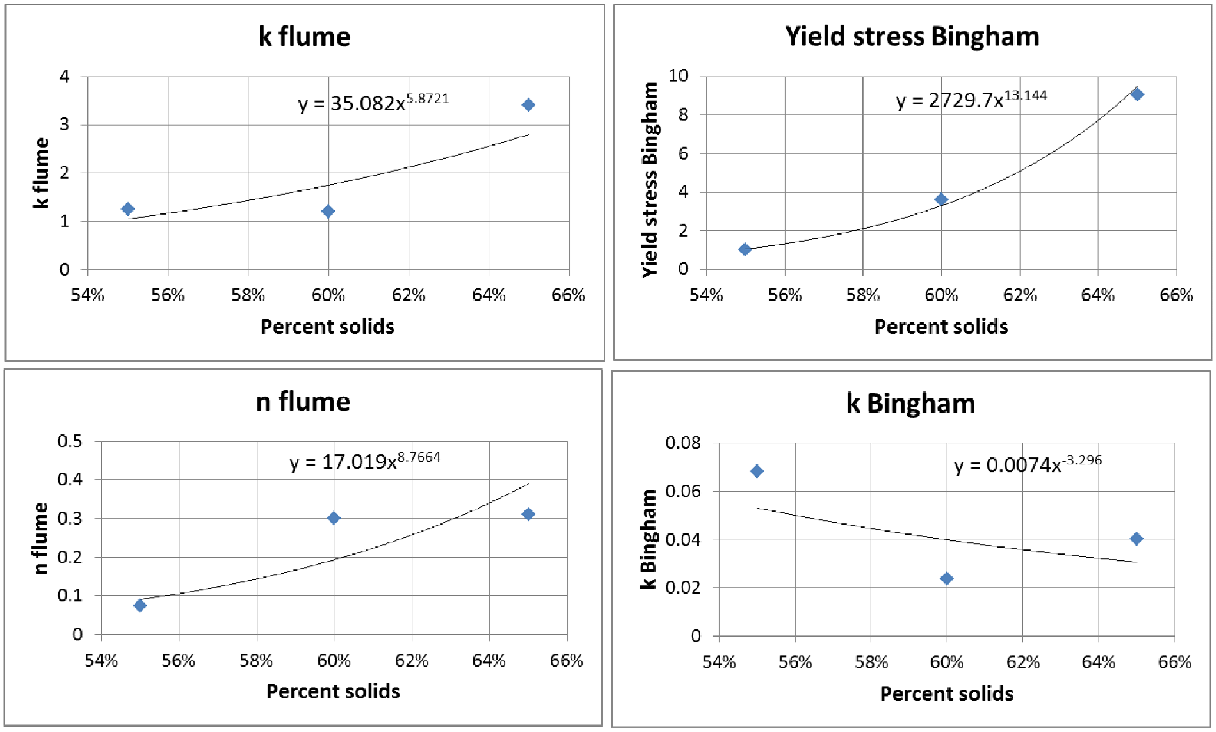


Figure 7 Rheological parameters correlated with percent solids: Middle – stream power = 1 watt

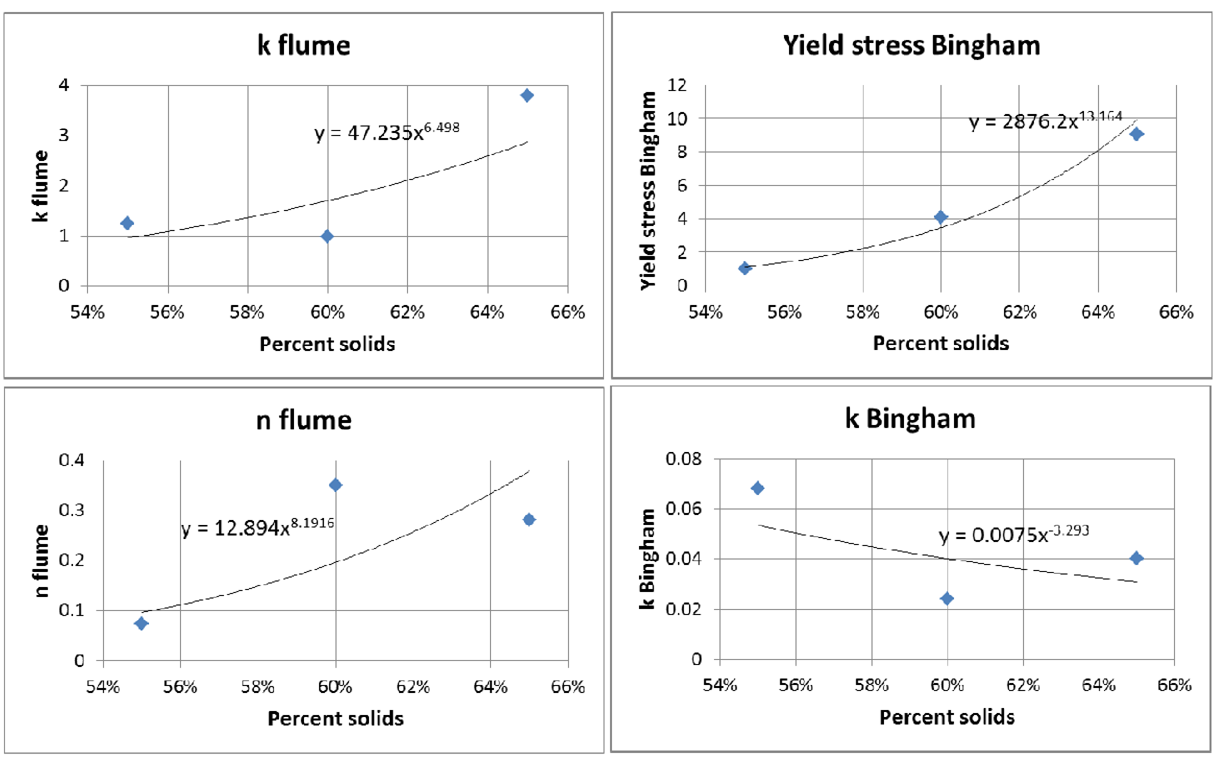
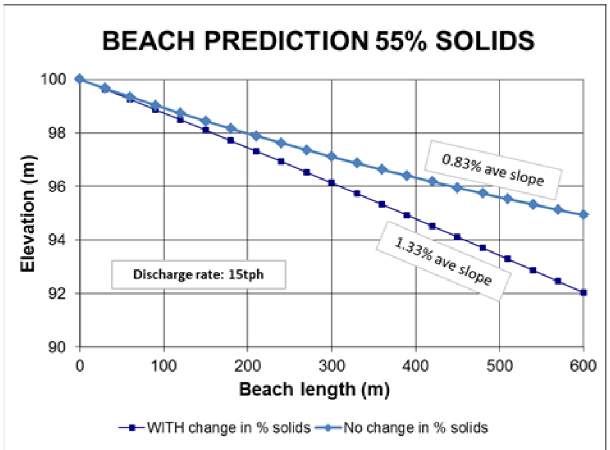


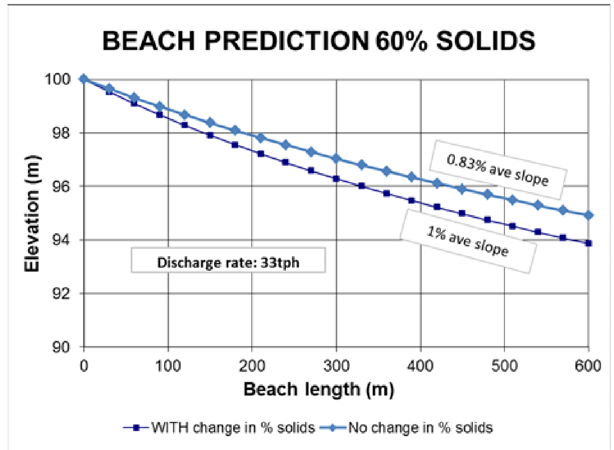
Figure 8 Rheological parameters correlated with percent solids: Top – stream power = 0.3 watts

The trends are similar for each location on the column as evidenced by the best fit equations.

COMAPRISON OF BEACH PROFILES

Beach profile simulations have been carried out with and without the incorporation of the above trends. The beach simulated is 600m long. Flow rates have been varied so as to keep the average beach slopes the same between the three percent solids when no allowance is made for settling out. The resulting beach profiles are shown in Figure 9.





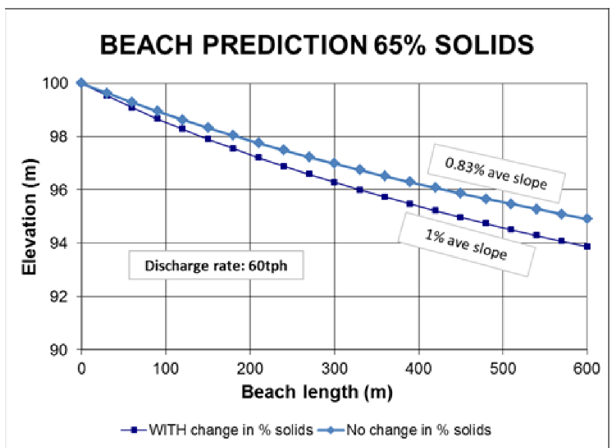


Figure 9 Comparison of beach profiles with and without incorporation of changes in % solids

It is evident from Figure 9 that there is a significant change in the beach profile and average beach slope when changes in the percent solids and rheology down the beach are included.

SUMMARY AND CONCLUSIONS

The authors have developed a fluidised bed column test that enables the correlation of changes in slurry percent solids, particle size distribution and rheology in the flow stream with stream power down a depositing beach. In the test results presented it is evident that, for the sample tested, changes in percent solids are significant, but changes in particle size distribution are relatively insignificant. Changes in rheology are also significant as a result of the changes in percent solids.

Variation in the percent solids and rheology with stream power has been incorporated into a beaching simulation that is based on the stream power entropy approach. It is evident that the impact of the changes on beach slope is significant.

AFTERWORD

The authors would like to note that the fluidised bed column test results are strongly slurry and tailings dependent. Specifically clay minerals in the tailings solids have a significant effect on segregation levels. This has been found in testing oil sands tailings using the same methodology as described in this paper. There are, at this stage, restrictions on publishing this data.

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