

# Paste technology: Success is in the approach

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In North America and throughout the world, surface stacking of mine tailings is becoming an increasingly important method to address many of the environmental problems facing the mining industry. Tailings pond life, improved water recovery, tailings dam safety, and tailings reclamation/re-vegetation are some of the major drivers to investigate the use of paste. Paste disposal is increasingly considered as an alternative to conventional tailings ponds. This state-of-the-art technology requires a different approach integrating the thickening, pumping, and disposal designs. Each segment of the process has critical parameters that must be integrated to provide a successful installation. For example, the selection of the paste thickener type depends not only on the feed stream parameters and underflow paste characteristics, but on site, pumping and deposition demands. For each application, a project team can select from several deposition methods, pump types and thickener configurations to custom fit the individual mine's tailings system.

## INTRODUCTION

In the last few years the use of paste technology in the disposal of mine tailings is increasingly studied as an option to conventional tailings dams. The identified advantages are hard to ignore and interest continues to grow. However, advantages achieved in one step may also be listed as disadvantages for subsequent process steps. The balancing of these advantages and disadvantages has resulted in interesting work for engineers throughout the history of plant process design. This paper addresses how a process is designed to incorporate the advantages of paste thickener in a tailings flowsheet while designing downstream equipment to handle the difficult rheology of paste.

Paste technology is being addressed in several engineering fields such as process metallurgy, geotechnical and transportation. Initially, each investigation was conducted with little communication between the primary stages of thickener, pump and pipeline, and tailings disposal design. This resulted in thickener, pipeline, and deposition designs which may be based on very different paste rheology assumptions. The final process will only perform as allowed by the least restrictive stage. Another example of possible disconnect between process design of the stages of a paste system are the different methods to identify the critical parameters that control the effectiveness of this relatively new technology. An example is measuring the rheological nature of the paste. Methods range from rotary viscometer measurements, to cone slumps, to

pressure drop in pipe lines. Each is an effective measurement method but produce different data values making integration of these data bases difficult.

This paper focuses on the need for an integrated approach to incorporate the production, transport and deposition of paste in the application of paste technology to a mine's tailings disposal project. The success of any paste installation will be greatly improved by an integrated approach that starts from day one. The prescribed approach includes the following;

- Identify mine objectives
- Selection of the project team
  - Review of mine objectives
  - Identify alternative technologies
  - Establish evaluation method
  - Oversee integration of all process steps
- Establish an operation team
  - Commissioning
  - Operator training
  - Manuals
  - Process review and audits

## PASTE FOR DISPOSAL

There have been several articles published about paste and a basic knowledge of characteristics of paste will be needed by the mine to properly implement a paste tailings system. Some of the attributes of paste that relate to tailings disposal are itemized by

Brackebusch & Shillabeer (1998), Jewel (2004). Paste is relatively non-segregating where fine particles are not washed from the paste and collect with water. This prevents a crust forming when the surface is dried, trapping water in the bed. The paste has a yield stress that manifests as the initial pressure needed to start the paste in motion. Paste has a low permeability because the ultra fine particles fill the voids between the larger particles which limits water and air flow through the paste bed. However, the homogeneous nature of the mixture of coarse and fine particles allows the upward migration of moisture to the surface where it is evaporated. Paste can be stacked and will form an angle of repose consistent from head to toe of the stack. The viscosity of paste creates a high pressure gradient and requires more pumping energy than settling slurries.

These attributes can be leveraged to provide significant advantages for tailings disposal.

- The water balance requires less inventory because impoundment of water at the disposal site is not required.
- There is less make up water needed because the losses due to evaporation and water retained in the paste are reduced.
- Stability of tailing stacks eliminates the need for impoundment dikes used in conventional tailings ponds.
- Groundwater pollution is limited due to the low permeability and the capillary actions draws water to the surface limiting drainage to the bottom.
- Concurrent reclamation can be practiced with paste deposition. Areas can be accessed as little as weeks after deposition and reclamation initiated while other areas of the stack are being constructed.
- Reduced land area is needed due to the high angle of repose found in paste stacks.
- The need for liners is greatly reduced with paste. Low permeability restricts water migration from the disposal site.
- Co-disposal of paste and waste rock can be practiced.

## INTEGRATED APPROACH

A paste disposal system includes the production, transport and deposition of the paste. Each of these fields has critical information and data to be considered to design a working paste disposal system for the

customer. However, there are interconnected decisions between these three fields that must be made together. In non-paste systems, which do not involve unusual (non-Newtonian) rheology these decisions can often be made independently with some success. This has led to the common practice of the customer developing a specification and each, the thickener, pipeline designer and geotechnical vendors bidding only to their sections of the RFQ. In several of the installed paste systems this approach has limited the success of the operation. Each process stage might be operating in the designed parameters but significant problems have been identified between stages. Examples of the results of the old individual stage approach are discussed by Jewell (2004), Slottee (2004).

The problem of integrating each of these process stages can be solved by the method being proposed in this paper. The establishment of a paste team at the start of any paste investigation will allow the identification of critical design elements between all of the three stages. The deposition of the paste must be decided first. From the deposition site the pumping requirements can be defined and then the paste production can be evaluated to meet the rheological requirements at the “end of the pipe.” This design strategy is depicted in the Figure 1. By starting at the deposition site and working upstream, problems of over-design or under-design of the transport system and the paste production system can be avoided. The upstream processes will be designed to achieve the goal set by the deposition method.

This approach is iterative in reality. If the rheology required for the deposition site design slope cannot be produced by the thickener, then the site design must be reconsidered. Similarly, if the paste thickener underflow is significantly sheared in the pipe line such that the design slope is not achieved, the thickener may have to be re-designed to produce a higher underflow density. Each of the paste system stages have several options to select from and by creating the paste team the selection is made with common objectives.

A brief description of deposition, transport, and production options are provided below to show how the integration process can be used to provide a unified solution.

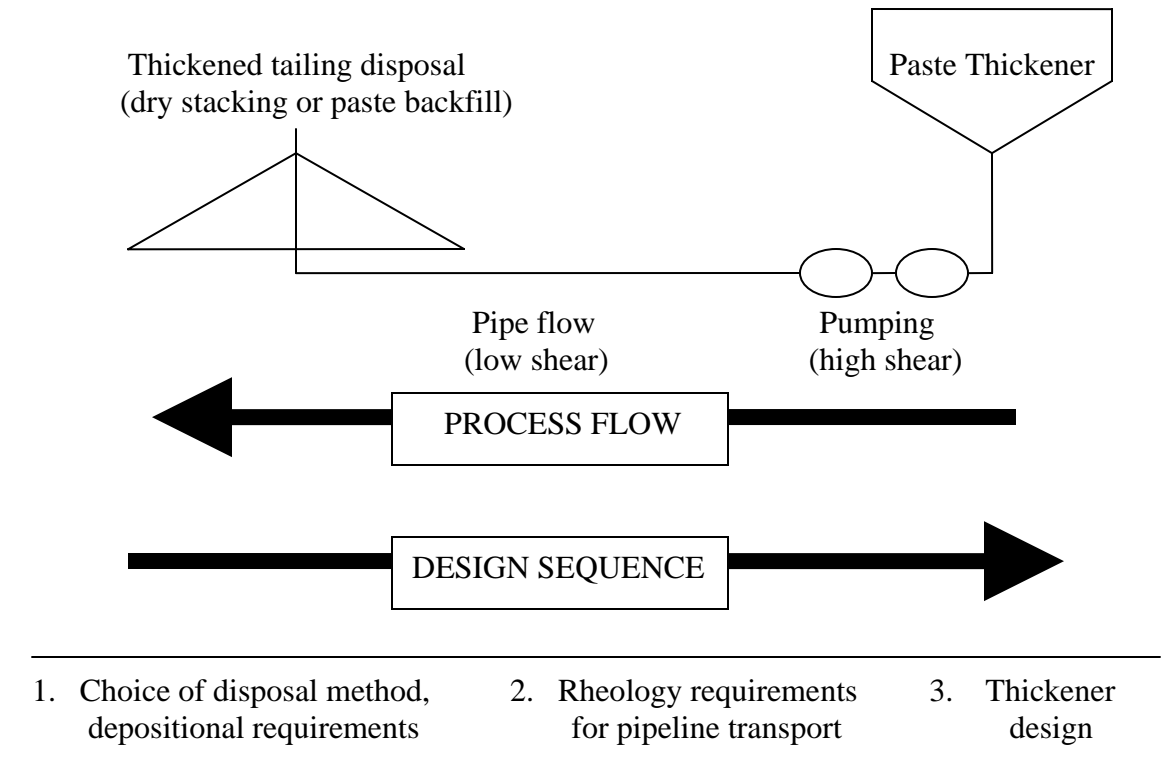


Figure 1. Paste System Design Method

### Deposition Option

A critical question to answer is “What is the mine going to do with the paste once it has been produced?” This question must be addressed first before any other. The answer is site dependent. The impoundment site and deposition method must be investigated and the optimum combination selected. Selection of the disposal site must include consideration of any transport and production limits. Distance to the site and the desired angle of repose (slope) are factors that are inseparable from the transportation and paste production stages.

Several deposition methods have been used and each has its place in the industry. A description and a cost comparison of some of the methods was discussed by Williams (2000) who studied the following surface stacking methods;

- Paddock impoundment
- Gully impoundment

- Waste rock dump impoundment, WRD
- Central thickened discharge (paste), CTD
- In-pit disposal

The selection of the optimum method will involve balancing several controlling factors such as: available area, the potential impoundment sites terrain, environmental factors, seismic risk, annual rainfall, construction, operating and closure costs, and distance from tailing thickener to the site Brzezinski (2001). For the paste option Williams (2000) concludes that the “best practice” for environmental issues will be different for each site and are best evaluated by fixing costs to the remedial or preventive measures associated with each alternative. However, based on the relative start-up and life-of-mine costs, the surface stacking options would be ranked; in-pit (least), CTD, gully, WRD, then paddock.

## *Transportation*

The transportation of non-segregating paste streams is an important factor that requires a thorough understanding of the rheology of the paste entering the pipeline from the thickener and shear behavior during flow. Proper pipeline and pump sizing require testing and analysis for pipeline operation, stoppage and restart pressures with definition of the operating parameters in terms of flow rate, concentration, pressure etc. Van Dyke (2001)

Pumping distance is always important, but particularly so for paste. Centrifugal pumps can only be used for short distances, measured in meters. Longer distances (up to a few kilometers) require high pressure reciprocating positive displacement pumps which can be very expensive and may determine whether a paste tailings disposal project is economically viable.

## *Paste Production*

Modern flocculants and thickener geometry have been combined to allow paste producing thickeners. The production of paste in thickeners only, without the use of filters, has been an important factor in making surface stacking a viable option in mine tailings disposal.

The modern paste thickener can produce underflows that approach the limit of pumpability. It is for this reason that the integrated rheology based approach to downstream design must be used.

At this time three geometries that characterize paste thickeners. Generally, the bottom slopes ranges from about 15° to 60°, increased sidewall heights and tank diameters from a few meters to 90 m. The three geometries are;

- Steep Cone with or without rakes– With 60° floor slopes and sidewall highest of 3 to 5 meters, these thickeners are generally limited to <12 meters.
- Deep Bed – This type of thickener has a 30° to 45° bottom slope and diameter to sidewall ratios of about 1. The largest installed diameter is 20 meters for this type of thickener.
- Shallow Cone – The third type of paste thickener is characterized by shallow bottom angles of 10° to 15° but have mud depths greater than conventional or high rate thickeners. These shallow bottom thickeners can have diameters up to 90 m with the use a traction drive raking systems.

Each of these paste thickeners types will produce different products but all could produce paste that stacks at 2-5% slopes depending on the feed characteristics.

## PASTE TEAM METHOD

This method prescribes the formation of an active paste team which includes representatives from the mine, paste production, transportation, and deposition experts. This team should be selected after the mine has identified mine objectives that suggest paste is a viable option.

### *Project team*

Generally the paste team should include mine representatives, paste production, transportation, and deposition experts. Team members should have experience in paste technology. Much of the experience in conventional tailing handling does not strictly apply to paste systems. The ability to first obtain the critical data and then evaluate it in behalf of the customer is very important to the success of the venture. Many such experts have worked closely with and have contacts with other experts in these fields and can help the customer assemble their team.

### *Review of mine objectives*

The first order of business is to review the plant objectives and confirm that paste is a viable option. Sometimes the mine may have set unrealistic objectives for their own situation. There will be many site specific parameters to be defined. Each member of the team will need to evaluate the mine's objectives based on their field of expertise. This evaluation is preliminary and a general agreement that paste is a potential solution is sought.

### *Identify Alternative Technical Solutions*

The team will, based on their experience, provide a list of alternative technical solutions to meet the mine's set objectives. These solutions will identify deposition, transportation, and paste production issues. Each alternative will have limits that will need to be evaluated.

### *Establish Evaluation Method*

The team will now need to collect the critical data about the particular mine and the tailings stream to be treated. The selection of the evaluation method objectives must keep the mine's

drivers for investigating paste. The mine identified drives (water, cost, time line, etc) must be met by the study. The investigation can include;

- Deposition site(s) characterization
- Data collection
  - Historical, technical data base
  - Bench-scale tests
    - Thickener sizing tests
    - Deposition trials
    - Pumping trials
  - Pilot-scale test
    - Thickener sizing tests
    - Deposition trials
    - Pumping trials

The Geotechnical deposition team member will oversee the site characterization. This will include the climate, topographical and seismic nature of each potential site. An accurate sample that represents the tailing to be processed must be collected and used for any bench-scale tests. The samples used by each team member must be identical. Having a representative sample has consistently been the battle cry for equipment supplier T&D laboratories. However, with paste it is even more critical that the samples used accurately represent the tailing stream. Because the bench-scale tests involve rheological studies, the plant water must be used, Vietti (2004). The sample should be the actual tailing processed through the plant concentrator. Attempts to synthesize a sample from mine samples or core samples will not be accurate. Even the slightest change in PSD can result in a variation of several percentage points in the solids concentration predicted from the rheology studies. This could bias the water recovery predictions significantly.

Bench-scale studies are a requirement. Each mine will produce a different result. It is not recommended to base the paste evaluation on similar commodities studies or only on plant historical data. Pilot-scale testing is the more expensive portion of the investigation. The paste team may or may not feel that pilot tests are necessary. There are methods to obtain the desired test results from the bench-scale tests only. However, the pilot-scale tests do provide the opportunity for larger scale thickening, pumping and deposition tests to confirm the bench-scale tests and increase mine confidence.

#### *Oversee integration of all process steps*

The paste team needs to be an active group with set procedures of assignment and reviews. The data generated by implementing the evaluation

method are to be compiled and reports written. This information should be reviewed by the team and a final recommendation jointly provided by the paste team. As with all process flowsheets there will need to be a balance between stages that will optimize the full system not just a single stage.

#### *Technology Transfer*

The final function of the paste team is to transfer operational ability to the mine. This is accomplished through manuals with technical information not just “what to do”, mine personnel training sessions, and process reviews. The uniqueness of the paste systems requires that a more complete effort in training of the mine personnel be accomplished to shorten the learning curve.

## CONCLUSIONS

Paste disposal systems provide several advantages that make it an excellent alternative to conventional tailing disposal methods. The success of a paste system is greatly improved by establishing a paste team. Integration of all phases of a paste system is critical. Each stage; paste production, transport, and deposition must be married to optimize the full circuit.

The paste system design should begin with the deposition method and work back upstream to the thickeners. This reverse method will allow for the end objective to be met. This method also requires close interaction between the paste thickener, pumping and geotechnical experts. To optimize the full circuit, each stage must consider the limits and strengths of the other system.

To accomplish this integrated design approach it is recommended that a paste team that includes the paste production, transportation and deposition experts should be formed very early in the evaluation process. This team will work together to select options and methods to evaluate each option, providing the customer with holistic approach.

This paste team concept can also apply to commissioning and startup. Paste systems require their own operating procedures which are different in many ways to conventional disposal methods. Typical mine operators and engineers will not have experience in the handling of paste. Operator training and more extensive manuals can be provided by the paste team to complete the transition from conventional disposal to paste disposal.

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