ACCELERATED OIL SANDS TAILINGS DEWATERING WITH THICKENING AND REFLOCCULATION

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Oil Sands Tailings Treatment and Management Challenges

What are challenges for Oil sands tailings management:

- Need to manage to fluid fine tailings (FFT) and mature fine tailings (MFT) inventory/volume
  - Regulation requirements: e.g. D85
  - Land or footprint requirement
  - Recycle water needs
  - Environmental and operational risks of maintaining a large wet pond

Why is tailings treatment challenging?

- FFT/MFT properties
  - High fines/clay content, smaller particles with charges
  - It will not settle by itself for decades
  - Difficult to treat itself.

- Process design and technology selection
  - Scale requirements compared with traditional mining processes
  - Feed variability: bitumen and clay content
  - Fine treatment effectiveness vs efficient storage volume
Operational Envelope Determination

Concept selection: evaluate the efficiency

• Improve the material properties
• Reduce the storage volume

Governing Phenomenon

• Tailings properties is dominated by feed clay content

• The correlation between feed clay content and deposit solids content was used to evaluate the efficiency of different fine tailings treatment technologies
  • Solids content gain
  • Storage volume

<table>
<thead>
<tr>
<th>Clay content (Lab)</th>
<th>Deposit Solids Content (Field)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>81%</td>
</tr>
<tr>
<td>15%</td>
<td>77%</td>
</tr>
<tr>
<td>20%</td>
<td>73%</td>
</tr>
<tr>
<td>25%</td>
<td>69%</td>
</tr>
<tr>
<td>30%</td>
<td>66%</td>
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<tr>
<td>35%</td>
<td>62%</td>
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<tr>
<td>40%</td>
<td>58%</td>
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<td>45%</td>
<td>54%</td>
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<td>50%</td>
<td>51%</td>
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<td>55%</td>
<td>47%</td>
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<tr>
<td>60%</td>
<td>43%</td>
</tr>
<tr>
<td>65%</td>
<td>39%</td>
</tr>
<tr>
<td>70%</td>
<td>35%</td>
</tr>
</tbody>
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**Treatment Technology Evaluation**

**Case 1: Fresh tailings with SFR of 1.5**

Key observations:
- The solid content of the flocculated tailings increases with SFR,
- The volume of the deposit decreases at lower SFR and increases at high SFR.
- The minimum storage volume is achieved at a preferred SFR range of 0.5 – 0.8.
  - When the mixture of tailings stream SFR is below the preferred range:
    - the higher deposit storage volume: due to water bonding with the higher clay content.
  - When the mixture of tailings stream SFR is above the preferred range:
    - the higher deposit storage volume: due to the sand material in the deposit occupying the storage volume by its grain size.

Case 1 demonstrates that fresh tailings with 1.5 SFR, alone or mixed with FFT/MFT
- Can achieve 65% solids content with a minimum storage volume after flocculation.
- Flotation tailings generally possess SFR in this range.

<table>
<thead>
<tr>
<th>Assumptions</th>
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</thead>
<tbody>
<tr>
<td>Sand Fine Ratio (SFR) of MFT</td>
</tr>
<tr>
<td>MFT clay content [%]</td>
</tr>
<tr>
<td>MFT solids content (%)</td>
</tr>
<tr>
<td>Fresh tailings clay content [%]</td>
</tr>
<tr>
<td>Fresh tailings clay/fines ratio</td>
</tr>
<tr>
<td>Mineral density [Kg/m³]</td>
</tr>
<tr>
<td>Water density [Kg/m³]</td>
</tr>
</tbody>
</table>

| Storage Volume and SC variation for different mixes of MFT and fresh tailings (SFR 1.5) |

<table>
<thead>
<tr>
<th>Deposit SFR</th>
<th>Deposit Volume (Mm³/Mt of Fines)</th>
<th>FFT/MFT Ratio / Solids content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>2.6</td>
<td>100%</td>
</tr>
<tr>
<td>0.5</td>
<td>2.4</td>
<td>90%</td>
</tr>
<tr>
<td>1.0</td>
<td>2.2</td>
<td>80%</td>
</tr>
<tr>
<td>1.5</td>
<td>2.0</td>
<td>70%</td>
</tr>
</tbody>
</table>
Case 2: Fresh tailings SFR between 1 and 2.5

Commercial applications:
- One challenge for commercial scale tailings processing is the varying properties of fresh tailings.
- Flotation tailings with an average SFR of 1.5 can vary between 1 and 2 or 2.5.

The operational envelop for optimum deposit performance:
- Can be determined by considering both deposit composition and further dewatering capability, e.g. both storage volume and solids content gain.
- To achieve 65% solids content, the MFT mix ratio can vary between ~30% and ~ 40%, based on fresh tailings SFR between 1 and 2.5,
- or the optimum deposit (mix) SFR should be between 0.6 and 0.8.

This preferred SFR range could also be expanded to 0.6 - 1.0 for operations flexibility.

Volume and solids content variation for different deposit mixes of MFT and fresh tailings (SFR 1 – 2.5)
**Case 3: Use of coarse tailings or a combination of coarse / fines tailings as fresh tailings**

These deposit mixes demonstrated the operation scenario of adding up to ~45-48% of MFT to get 65% solids content.

However, these mixes consume higher storage volume.

- At SFR of ~1, the treated tailings consumed approximately 15% higher volume (~1.9Mm³) than the optimum volume (~1.7Mm³ at SFR of 0.3).
- At higher SFR (>1), the treated tailings volume increases with SFR.
- The potential of these mixes to achieve higher solids content and increased treatment of MFT is offset by the high deposit volume required.

**Treatment Technology Evaluation**

Volume and solids content variation for different deposit mixes of MFT and fresh tailings (SFR 8 - 13)
Tailings Depositing and Long Term Consolidation

Storage volume and tailings filling:
- To store the same amount of fines, high SFR tailings will take a longer time for treatment and depositing, and additionally requires of high storage volume.
- While material of SFR between 0.5 and 1 demonstrates low storage volume requirement in the short term, and SFR 1 material shows better consolidation the long term.

Long term consolidation:
The deposit performance can be categorized as three regions:
- High SFR and sand dominated material (e.g. SFR > 2)
- Low SFR and fine/clay dominated material (e.g. SFR < 0.5)
- Medium SFR and sand/fines balanced material (e.g. SFR ~1).

Performance after consolidation:
- Material with high SFR gains higher strength rapidly, but with little or no post deposition consolidation, and will be ready for capping material at end of deposition.
- Materials with medium SFR will gain a good strength, deposition settlement and consolidation, and will be ready to be capped on time
- Material with lower SFR will take a much longer time to gain strength.

The modelled deposit was presumed to be capped with 5m coarse sand tailings after a 20/30 year
Kearl Fine Tailings Treatment (KFTT) Process: Thickening and Reflocculation

Mine Feed

Crusher

Bitumen

Separation Cell(s)

Floatation Cell

Froth

Product

Flotation Tailings

Fluid Fine Tailings

Mixer

Thickener(s)

2nd Chem. Injection

Tailings Deposit Area

Coarse Sand Tailings

Thickened Tailings

Tailings Deposit Area
Kearl Fine Tailing Treatment (KFTT): Why Thickening and Reflocculation?

Why Thickening and Reflocculation?
- Reduce the land footprint
- Recover more water: two stages water recovery
- Accelerate water release at deposition area
- Enhance strength gain after deposition

Lab tests
- Thickened Tailings
- 7 Days
- Lab, 2011-2012

Field sample & tests
- After 7 days
- Kearl Site lab, 2016-2017

Comparison of TT and Reflocculated TT

Lab tests
- Field sample & tests

Kearl Fine Tailing Treatment (KFTT): Why Thickening and Reflocculation?
Flow Characteristics of Treated Fines Deposit at Commercial Scale

- The slope of first 500 meters is ~ 2.5% to 1%
- Slope flattened towards 0.5% beyond 0.5 km
- Polymer treated fines with ~ 1 SFR tend to flow 0.75 to 1 km
- Atmospheric drying helps low SFR treated fines to gain high solids content compared to similar material placed below water.
KFTT: Convent Fluid Fine Tailings to Reclaimable Land

Overflow Water

Recovered O/F Water

Thickened Tailings (TT)

Reflocculated TT

Layered TT

Layered TT

Reclaimable TT
Conclusions

Oil sands tailings treatment has engineering challenges. Selected tailings treatment technologies should be able to treat fines tailings at an acceptable rate while maintaining short term and long term dewatering capabilities.

- Reduction of clay or FFT/MFT mixing ratio can improve short and long term dewatering capability, but will also reduce fines treatment efficiency.
- Optimal mixes of fresh tailings and FFT/MFT can enhance dewatering while maintaining efficient fines storage volume.

This work introduces a methodology of identifying optimum operation envelope to determine the process scheme design.

- Identification of the correct recipe should consider both efficient fines treatment and creating reclaimable deposit in a relatively short time.
- Tailings mixtures of medium SFR (preferred~1), with approximately 30-40% MFT, was identified as the optimum composition for short term dewatering and long term consolidation.
- An application of selected treatment envelope, with thickening and re-flocculation process, can produce favorable deposit properties for timely reclamation.

![Image of oil sands tailings treatment site]
Thickening and In-Line Flocculation Process

Thickener Feed
- Blend flotation tailings from extraction plant and fluid fine tailings from barge at gravity distributor
- Target flotation tailings and FFT ratio as 70% : 30%

Primary Treatment: Thickened Tailings
- Remove 60-80% of water from feed streams
- Produce thickened tailings at 40-50% solids content
- Sheared down for transportation

Secondary Treatment: In-line Flocculation
- Injection of polymer prior to deposition
- Deposited at >40% solids content
- Continued dewatering removes additional 25-40% water from TT; water pumped to WETA via East ETA sump
- Expect to achieve 50-65% solids content after deposition