A Shell Tailings Consolidation Casing Experimental Pilot Project

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Presented at International Oil Sands Tailings Conference
Lake Louise, Alberta. Dec 7, 2016
INTRODUCTION: Casing Consolidation Project

- design, construction, pouring of tailings and monitoring performance of tailings in eight steel casings
- Executed in 2015
- Located at Shell Albian Sands, Sharkbite
- 6 casings, various treated fluid fine tails
- 1 casing, untreated fluid fine tailings
CONTRIBUTORS: ORDER OF INVOLVEMENT

- Barr
- BGC
- OKC: O’Kane
- Golder
- Ledcor
- Coanda
- Worley & Conetech
- Shell: Tailings Ops, Site Earthworks, Technology Development
OBJECTIVES:

- Measure and analyze sedimentation and self-weight consolidation behavior of various tailings treatments
- Evaluation of self-weight consolidation, without freeze-thaw or other atmospheric effects
- Use measured casing data, in combination with numerical modelling, for selection of an improved tailings management technology, as well as scale evaluation of LSCs, geocolumn and beam centrifuge
CONSTRUCTION: CIVIL PROJECT FOLLOWED BY SOME TAILINGS

Leveraged COSIA with Syncrude specific experience from Syncrude 2014 program; allowed execution with lower risk in 2015.

Drilling to total depth inside temporary casing.

Placing permanent casing inside temporary casing.
Annulus grout between permanent casing and temporary casing.

Removing temporary casing after grout poured in annulus.
INSTRUMENTATION AND MONITORING: DUPLICATION

Wireline casing

DGSI Multi-point VWP

Total Pressure Cells

RST Multi-point VWP

Thermistor
**Block Diagram: Mini Rig with Mixer at ~2.3 Cubic Meters/Min**

- **Raw FFT Tanks (159 m³)**
- **Flow Loop**
- **Flocculant Solution Tote**
- **Header**
- **Casing**
- **Release Water Tote**
- **Casing Release Water**
- **Waste Tote**

Legend:
- ▼ = Valve
- ▉ = Sampling Point

*Source: Shell Tailings Consolidation Casings Pilot IOSTC December, 2016*
### POUR SUMMARY: 3 TYPES OF FFT

<table>
<thead>
<tr>
<th>Casing #</th>
<th>MFT Source</th>
<th>Flocculent</th>
<th>MBI (meq/100g)</th>
<th>Start Pour Date &amp; Time</th>
<th>End Pour Date &amp; Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shell-MRM</td>
<td>MFT</td>
<td>9.0</td>
<td>30-Aug-15 9:45</td>
<td>30-Aug-15 16:06</td>
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<tr>
<td>2</td>
<td>Shell-MRM</td>
<td>HPAM</td>
<td>8.6</td>
<td>3-Sep-15 11:06</td>
<td>15-Sep-15 15:54</td>
</tr>
<tr>
<td>3</td>
<td>Shell-MRM</td>
<td>XUR</td>
<td>8.8</td>
<td>9-Sep-15 11:26</td>
<td>17-Sep-15 17:01</td>
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<tr>
<td>4</td>
<td>Shell-MRM</td>
<td>XUR-4A</td>
<td>8.4</td>
<td>4-Sep-15 10:26</td>
<td>16-Sep-15 17:00</td>
</tr>
<tr>
<td>5</td>
<td>Other</td>
<td>HPAM-Ca</td>
<td>11.4</td>
<td>24-Sep-15 13:41</td>
<td>2-Oct-15 17:30</td>
</tr>
<tr>
<td>6</td>
<td>Other</td>
<td>HPAM</td>
<td>11.8</td>
<td>25-Sep-15 9:26</td>
<td>1-Oct-15 19:22</td>
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<tr>
<td>7</td>
<td>N/A</td>
<td>Empty</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>8</td>
<td>Shell-JPM</td>
<td>Centrifuge Cake</td>
<td>14.2</td>
<td>24-Sep-15 10:23</td>
<td>26-Sep-15 15:30</td>
</tr>
</tbody>
</table>

Shell Tailings Consolidation Casings Pilot IOSTC December, 2016
POUR SUMMARY CHART

Casing 1-4 MRM

Casing 5-6, others

Casing 8 JPM
SAMPLING AND TESTING

- Rheology/KPIs
- HMA, Oven
- MBI
- Dean Stark
- Specific Gravity
- PSD
- Atterberg Limits
- Water analysis
- Grad. Cylinder
- H₂O sampling
  - LSCs
  - Beam centrifuge

Shell Tailings Consolidation Casings Pilot
IOSTC December, 2016
INSTRUMENTATION: NEAR-INFRARED SPECTROSCOPY (NIR) CAN WORK

NIR Clay content (meq/100g) and Lab Raw MFT MBI (meq/100g)

Sample Date (2015 mm/dd)

- Lab: Casing 5 wet raw MFT
- Lab: Casing 6 wet raw MFT
- NIR: 2nd Derivative
- NIR: 1st Derivative and MSC
- NIR: 1st Derivative
- NIR: 1st Derivative and VN

Shell Tailings Consolidation Casings Pilot
IOSTC December, 2016
INSTRUMENTATION AND MONITORING: CONTINUOUS MUDLINE

Casing 2: Mudline Comparison

PLS to measure mudline

Date (MM/DD/YYYY)

- PLS installation time
- Mudline - PLS
- Mudline - Ultrasonic
- TCCEPP mudplate manually 1
- TCCEPP mudplate manually 2
- COSIA mudplate manually
- PLS mudplate manually

Shell Tailings Consolidation Casings Pilot
IOSTC December, 2016
Slimline Wireline geophysical tools offer a proven method of density determination with high resolution data and non-invasive sampling.
- Slimline Wireline: Gamma-gamma or density tool allows determination of changes in density over time, and thus consolidation without sampling

- Plotted around common arbitrary axis, to allow visual focus on change over time
Mudline is calculated from PLS, and Sonic Ranger for top of fluid.

PLS instrumentation results are validated by manual readings.

Mudline (m) since end of last pour for all Casings vs. Elapsed Days

- Casing 1 FFT (untreated)
- Casing 2 HPAM (Shell)
- Casing 3 XUR (Dow)
- Casing 4 XUR -4a (Dow)
- Casing 5 HPAM (Other)
- Casing 6 HPAM (Shell-JPM)
- Casing 8 Cake (Shell-JPM)
PERFORMANCE: AVERAGE SOLIDS CONTENT FOR 3 FFT TYPES IN 7 CASINGS

Average Solids Content(%) since end of last pour for all Casings vs. Elapsed Days

- Solid data points at time-0 are raw entry tailings solids content.
- Empty data points at t-0 are avg. solids content of treated tailings at end of last pour.
- Average solids content curves are calculated from entry (or initial) solids content, entry mudline and mudline from PLS instrumentation readings.
- Updated to Aug. 31, 2016

Casing 1 FFT (untreated)
Casing 2 HPAM (Shell)
Casing 3 XUR (Dow)
Casing 4 XUR -4a (Dow)
Casing 5 HPAM (Other)
Casing 6 HPAM (Other)
Casing 8 Cake (Shell-JPM)
SUMMARY: NUTS ‘N BOLTS LEARNED

- COSIA informal communication allowed Shell to leverage other Operator experience, and formal arrangement allowed for other Operator FFT
- NIR is (very) promising
- remote data by cellular allows data monitoring during periods of inaccessibility (fires, road conditions)
- Slimline wireline can provide high-resolution density data
- PLS mud plate provides real time mudline, with maintenance
- Sacrificial water layer with real-time text-alarms prevented atmospheric effects from influencing results
SUMMARY: LIMITATIONS

- FFT variability was limited
  - compromise acceptable for comparative analysis
- Fill rate
  - \(1/2 \text{ m} \text{ hour}\) is high relative to commercial but required for practicalities
- Transport
  - stability of floccs at commercial scale not addressed
- Deposition
  - tremie deposition was ideal whereas actual deposition is variable
- Scale up concerns limit firm conclusions but do influence subsequent direction
SCALE UP CONSIDERATIONS AROUND CONSOLIDATION

- 150cm LSC cylinder → 3m Geo column → 10m Casing

- Test plan objectives need to be aware of scale up
Results are influencing subsequent evaluations, as well as business decisions re. optimizing current technologies.

Will continue with annual wireline, sampling & CPT work.

Evaluation of other opportunities:
- terminate 1 or more casings, and re-fill with other novel treatments
- sand raining
- sand drains or wick drains
- other

Modeling in progress to evaluate consolidation properties for each casing, that will also allow scale-up evaluation.