Independent Expert Engineering Investigation and Review Panel

Report on Mount Polley Tailings Storage Facility Breach

Appendix E: Laboratory Testing and Results

January 30, 2015

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APPENDIX E: LABORATORY TESTING AND RESULTS

1.0 OVERVIEW

Appendix E presents the results of the advanced laboratory testing program completed by the Panel, which included CT scanning of thin-walled tube samples and oedometer, direct shear, triaxial and direct simple shear testing.

2.0 CT SCANNING

All undisturbed thin-walled samples collected by Thurber were subject to scanning at FP Innovations at the University of British Columbia, a facility that is capable of completing X-rays and CT scanning on large items. A prototyping scanning exercise was completed on the set of samples received in the first shipment from site to determine which sample scanning technique / orientation provided the best information for the soil conditions sampled. Digital radiography and CT scanning of samples was completed. CT scanning was completed both parallel and perpendicular to the long axis of the tubes. CT scanning oriented parallel to the tube axis was determined to provide the best results. The CT scanning method utilized does produce some 'noise' in the images due to wave interference, typically manifesting in linear features parallel to the long axis of the tube and concentrated at the center of the tube. During each round of CT scanning, the scan parameters were adjusted to reduce noise. Accordingly, the more recent scan images have less noise than scan images collected earlier in the program.

The horizontal CT scanning method ultimately utilized is able to pick up complex interlayering with samples (see MR14-103 Sa 5) and voids (see MR14-104 Sa 8 for typical example). One sample (MR14-109 Sa 1) was extracted and split for direct visual comparison to the CT scan results. The CT scan results were utilized to select samples for advanced lab testing.

The CT scanning results are presented in Attachment E1. The sheets contain notes on the inferred soil unit sampled and sample elevation along with annotations related to advanced lab testing.

3.0 OEDOMETER TESTING

Following CT scanning, samples for testing in the oedometer were generally selected to coincide with triaxial and direct simple shear samples where possible.

Nineteen oedometer tests were conducted by Thurber. Four tests were conducted on samples from the Upper Till, eleven tests were conducted on samples of the Upper GLU and four tests were conducted on samples of the Lower Tills (two on the basal till and two on the Lower GLU). The results are provided in Attachment E2.

Due to the shape of the compression curves, estimation of preconsolidation pressures is subject to uncertainty. Preconsolidation pressures (σ'_p) were estimated using three methods: Casagrande Method (Casagrande, 1936), Bi-logarithmic Method (Butterfield, 1979), and the Work Method (Becker et al., 1987).

Casagrande (1936) developed a graphical method for the determination of σ'_p. The point of maximum curvature on the e log s'_v oedometer plot is located. Horizontal and tangent lines are then drawn at this point. The bisector to the horizontal and tangents lines is then drawn. The straight line of the normal compression line extends back to the bisector. The intersection of these two lines is the preconsolidation pressure.

Butterfield (1979) developed a method (bi-logarithmic) in which the consolidation data is plotted in ln(1+e) versus ln (s'_v) instead of the traditional e versus log s'_v plot. In this method σ'_p is defined as the point of intersection of two straight lines that extend from the linear section of each end of the compress curve.

Becker et al. (1987) developed a strain energy method (work per unit volume) for determination of preconsolidation pressures. In this method, work is plotted against vertical effective stress on a natural scale. Two lines are then drawn, one through the linear low stress portion of the curve and the second through the linear high stress portion of the curve. The preconsolidation pressure is determined as the intersection between these two straight lines

Estimates of preconsolidation pressure provided in the summary table in Attachment E2 were determined as the average of the three methods described above. Summary plots comparing the shape of the e log s'_v curves grouped by soil unit are also provided.

Attachment E2 also includes a summary plot showing the variation in σ'_p with elevation. The plot includes simplified vertical stress profiles below the crest of the dam at various stages for comparison to the preconsolidation pressure.

Estimates of c_v are also included in a summary table in Attachment E2 along with summary plots comparing the variation in c_v with log s'_v grouped by soil unit. The summary table also includes c_v values obtained from the consolidation phases of the triaxial tests discussed below. A comparison between c_v values obtained from lab testing and ch values obtained from CPT dissipation testing is contained in Appendix H.

4.0 DIRECT SHEAR TESTING

One direct shear test was completed by Thurber on a sample of Upper GLU material (MR14-106H, Sa 1B).

The test specimen was manually trimmed from the Shelby tube sample. Prior to testing, a shear plane was pre-cut with a knife prior to placement in the shear box. The specimen was consolidated in two stages to the required normal stress of 300 kPa. The specimen was tested at three normal stresses, 300 kPa, 150 kPa and 450 kPa. The direct shear results along with a summary are provided in Attachment E3.

5.0 TRIAXIAL TESTING

Following CT scanning, samples for isotropically consolidated undrained (CU) triaxial compression testing were selected to coincide with oedometer and direct simple shear samples where possible.

The triaxial test results, along with a summary, is provided Attachment E4. Four tests were conducted on samples of Upper Till at effective confining pressures of 600 kPa. Nine tests were completed on samples of Upper GLU. Three samples were tested at effective confining pressures of 150 kPa, 300 kPa and 600 kPa (one sample per pressure) to develop the Mohr Coulomb for each sample. Three of the nine tests were conducted at Thurber and the remaining six were conducted at MEG Technical Services.

For the purpose of estimating the peak friction angle within the till, the cohesion was assumed equal to zero; however, the material friction angle should be estimated based on a Mohr-Coulomb envelope with at least three points. The calculated friction angles ranged from 33° to 35°.

Friction angle and cohesion in the glaciolacustrine material were estimated using the Mohr Coulomb envelope developed for each sample. Estimates of friction angle ranged from 19° to 21° and cohesion ranged from 33 to 39 kPa.

Estimates of undrained shear strength within the Upper Till ranged from 224 to 445 kPa and ranged from 85 to 184 kPa with the Upper GLU.

6.0 DIRECT SIMPLE SHEAR TESTING

Following CT scanning, samples for direct simple shear (DSS) testing were selected to coincide with oedometer and triaxial samples where possible

The DSS test results along with a summary are provided in Attachment E5. DSS samples were consolidated under a vertical confining stress of either 300 or 600 kPa. Some samples were further consolidated to non-K_0 conditions, with a shear bias of between 10% and 20% prior to shearing undrained. Consolidation of samples to a shear bias of 30% was attempted but was not possible as the shear bias load exceeded the sample strength.

Ten tests were conducted on samples of the Upper GLU; three test were conducted on samples from the Lower GLU and one test was conducted on a sample from the Upper Till.

Appendix E: Attachments

- **Attachment E1**: CT Scans of Tube Samples
- **Attachment E2**: Oedometer Test Data
- **Attachment E3**: Direct Shear Test Data
- **Attachment E4**: Triaxial Test Data
- **Attachment E5**: Direct Simple Shear Test Data