Paste 2023 – GW Wilson, NA Beier, DC Sego, AB Fourie & D Reid (eds)

doi:10.36487/ACG_repo/2355_36

Consolidation and unsaturated properties of in-line flocculated fluid fine tailings and centrifuged tailings from oil sands mines

LK Kabwe *University of Alberta, Canada*

GW Wilson *University of Alberta, Canada*

D Barsi *University of Alberta, Canada*

NA Beier *University of Alberta, Canada*

Abstract

Canadian government regulatory and closure commitments for oil sands mines and tailings ponds compel oil sands companies to dewater and reclaim the fluid fine tailings (FFT) in the tailings ponds. As a result, extensive research is underway by several organisations to develop methods to understand the reasons for the slow consolidation of FFT and to design treatment methods for mine closure. The most promising technologies for oil sands tailings dewatering are thickening and centrifugation. In this research, large strain consolidation (LSC) and modified Tempe cell, using axis translation technique with shear strength tests, were conducted on in-line flocculated fluid fine tailings and centrifuged cake tailings samples. These tests determine the treated tailings' consolidation, geotechnical properties, unsaturated characteristics and shear strength. The results of the tests provided several useful engineering functions relating matric suction and effective stress to shear strength, solids contents, and water contents. The modified Tempe cell technique, however, yielded results four times faster than the LSC test technique. The methods and evaluations of the engineering functions are discussed.

Keywords: *consolidation, in-line flocculation, centrifugation, Tempe cell, matric suction*

1 Introduction

In Alberta, the volume of fluid fine tailings (FFT) stored in tailings ponds was approaching 1.3 billion cubic metres (AER Report 2019). Motivated by concern over the growing volume of FFT, the Alberta Government (AER 2017) introduced Directive 085, a new policy document known as the *Tailings Management Framework* (TMF). The TMF seeks to minimise fluid tailings accumulation by ensuring they are treated and reclaimed progressively during a project's life and that all fluid tailings associated with a project are ready to reclaim 10 years after the end of mine life of that project. Reduction of the volume of FFT is achieved by capturing fines from fluid tailings and depositing them in a dedicated disposal area (DDA) in a manner that facilitates subsequent reclamation of the DDA into a trafficable deposit. Several organisations are undertaking extensive research to design treatment methods for mine closure. A promising technology for the disposal of FFT is adding flocculants and using thickeners, in-line flocculation and/or centrifuges to increase the solids content. One could then further dewater the tailings by atmospheric drying.

The objective of the research reported in this paper was to determine the geotechnical properties of the in-line flocculated FFT (ILF-FFT) and flocculated centrifuged cake (C-Cake) tailings samples, including consolidation, unsaturated characteristics, and shear strength, using large strain consolidation (LSC) and Tempe cell techniques. The properties of the ILF-FFT and C-Cake samples, tested by LSC, are compared with those using the Tempe cell technique to assess the effects of the treatments. The LSC technique is tedious and time-consuming and takes several months to one year to complete an oil sands tailings test (Amoako et al. 2020; Abdulnabi et al. 2021). Such lengthy laboratory tests affect practical engineering design as rigorous

timelines drive the engineering industry. Determining the soil water characteristic curve (SWCC) for fine-grained soils and oil sands tailings samples using the conventional Tempe cell method requires a longer duration than that for coarse-grained soils. Therefore, fast and effective methods for determining geotechnical and unsaturated properties are needed. The modified Tempe cell technique used in this study takes one to three weeks to generate unsaturated soil properties and other useful geotechnical properties. The methods and evaluations of the engineering functions are discussed.

2 Material and methods

This section presents material and procedures used to characterise the ILF-FFT and C-Cake tailings samples. LSC and Tempe cell treatments were conducted on ILF-FTT and C-Cake to determine the consolidation and unsaturated properties of the treated samples.

2.1 Sample characterisation

Two tailings samples have been tested in this research: an old (or aged) ILF-FFT that had been in storage for some time (more than 10 years) and an old (seven years) C-Cake. Table 1 and Figure 1 show the samples' initial properties and particle size distributions (PSDs), respectively. The properties of the ILF-FFT and C-Cake samples are after treatment by flocculation and centrifugation. The tailings samples underwent hydrometer tests following the procedure outlined in ASTM D 4221-99R05 (ASTM International 2005) to determine the dispersive characteristics of clay soil by hydrometer in conjunction with the ASTM D 0422-63R07 procedure for the standard particle size analysis of soils (ASTM International 2007). The dispersed PSD is used to define the fines content (<45 µm) and the clay size content (<2 µm). The results are shown in Table 1. The dispersed hydrometer or D-hydrometer involves mechanical agitation and the addition of dispersing agent. The Methylene Blue Index (MBI) measurements of the clay size content for the samples are also shown in Table 1 (provided by AGAT Laboratories). The MBI test disperses the clay aggregates and flocs (ASTM International 1999).

Table 1 Initial properties of the ILF-FFT and C-Cake samples

ID	Treatment	Solids content (%)	Fine (%)	Void ratio	Clay* (%)	MBI (%)
ILF-FFT	Flocculation	46.1	78	2.85	44	Not determined
C-Cake	Flocculation and centrifugation	55.5	82	2.08	52	48

*Clay size dispersed (D)

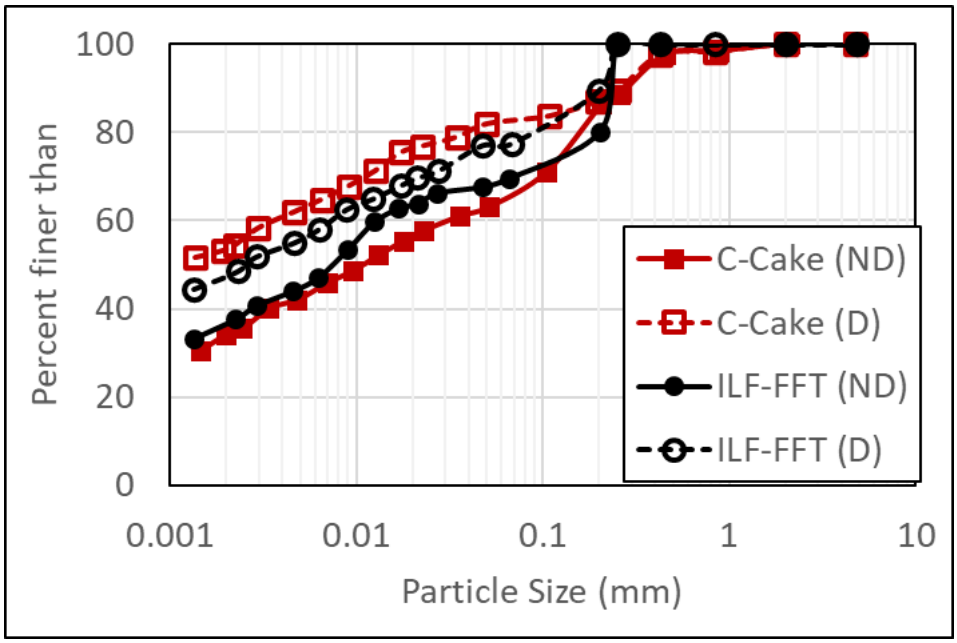

Figure 1 Particle size distributions of ILF-FFT and C-Cake, dispersed (D) and non-dispersed (ND)

The initial solids content of the ILF-FFT is 46%, while the solids content of the C-Cake is 55.5%. The D-hydrometer and ND-hydrometer PSDs (Figure 1) indicate that C-Cake has 82% and 63% fine contents, respectively. Similarly, ILF-FFT has 77% and 68% fine contents for the dispersed and non-dispersed hydrometers, respectively. The ILF-FFT and C-Cake samples have 44% and 52% clay size contents (D-Hydrometer), respectively. The oil sands industry commonly measures clay size amounts using the MBI test (Kaminsky 2014; Omotoso & Melanson 2014). The MBI test detects all the exposed clay surfaces and is therefore an effective method to determine the total amount of clay material present in the tailings. The quantity of exposed clay mineral in the samples can be calculated using an empirical relationship developed for oil sand tailings (Sethi 1995) given below:

$$\text{Clay mineral fraction (\%)} = [(0.006)(\text{MB value}) + 0.04]/0.14 \quad (1)$$

The MBI of the clay size content for C-Cake is 48%. The MBI for ILF-FFT was not measured. The MBI measurements of the clay content are larger than the ND-hydrometer measurements because the MBI test disperses the clay aggregates and flocs.

Geotechnical properties of Atterberg limits and bitumen content are given in Table 2.

Table 2 Geotechnical characteristics of ILF-FFT and C-Cake

ID	Liquid limit (%)	Plastic limit (%)	Plasticity index	Bitumen** (%)
ILF-FFT	51	24	27	0.45
C-Cake	57	26	31	0.37

**Bitumen content by fine mass

The liquid limits (LL) and plastic limits (PL) of the C-Cake are 57% and 26%, respectively, while the plasticity index (PI) is 31%. Similarly, the LL and PL of the ILF-FFT are 51% and 24%, respectively, while the PI is 27%. The ILF-FFT and C-Cake samples would be classified as high-plasticity clay. A kaolinite-dominated soil should plot as a low to medium plastic soil. However, adding polymer artificially raises the liquid limit, so it plots as a high plastic clay. The bitumen contents of the ILF-FFT and C-Cake (by fines mass) are 0.45% and 0.37%, respectively (Table 2). In all analyses of tests on ILF-FFT and C-Cake, the bitumen is considered part of the fines since it is generally integrated into them.

2.2 Large strain consolidation technique

LSC and shear strength tests were conducted on ILF-FFT and C-Cake samples to determine the consolidation characteristics (compressibility and hydraulic conductivity) and shear strength. The LSC apparatus used in the tests (Figure 2) confined the slurried material in a consolidation cell (15 cm in diameter × 15.5 cm in height). The bottom of the cell is sealed, so drainage during consolidation is only upward. A piston load of about 1 kPa is applied as the first load step. After this, loads are applied by using dead loads and then by an air pressure bellofram. The load increments are doubled for each load step until the maximum vertical stress is reached (about 500 kPa). During consolidation, the sample's height change is continuously monitored with a linear variable differential transducer (LVDT). When no further change in height is observed at each load step, it is assumed that consolidation is complete for that load step. At this stage, the excess pore pressure is also monitored at the base of the sample to ensure that the excess pore pressure is fully dissipated. The hydraulic conductivity is measured at the end of consolidation for each load step (Wilson et al. 2018; Jeeravipoolvarn 2010; Suthaker & Scott 1994). Following the hydraulic conductivity measurement, the sample surface is exposed, and the shear strength is measured using a Brookfield DV3T Rheometer for low strength (up to 6 kPa) and motorised geotechnical vane shear apparatus for testing stiffer consistencies per ASTM D4648/D4648M for low and higher shear strengths, respectively (ASTM International 2016). A subsequent load is then applied after the shear strength measurement. Consolidation of oil sand fine tailings takes considerable time to complete due to the low permeability of the material. For example, with 10 load steps used in the LSC, it can take anywhere from four to nine months to complete the consolidation test (Amoako et al. 2020).

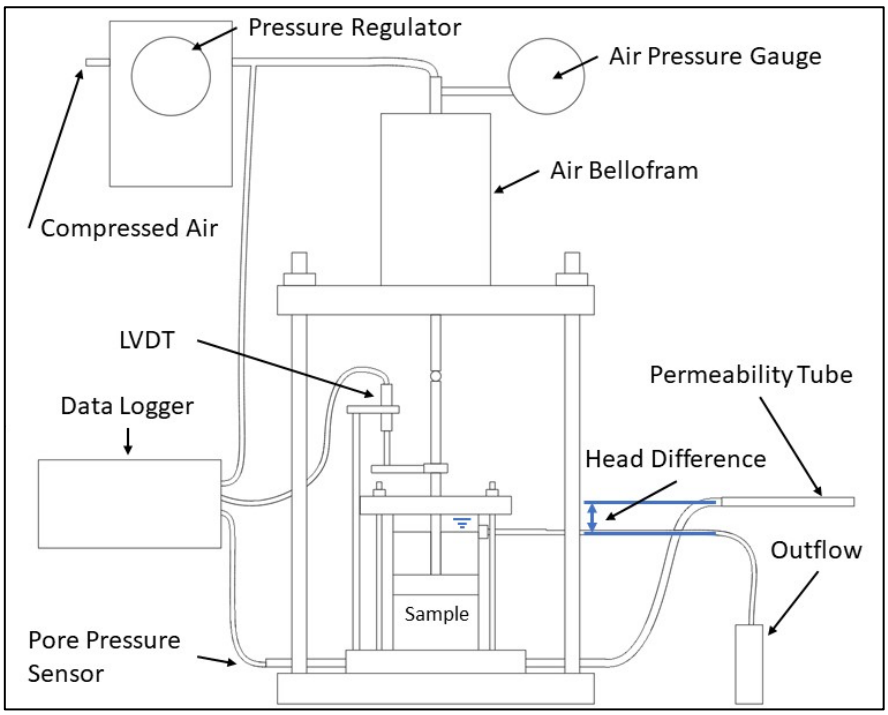

Figure 2 Large strain consolidation apparatus at the Geotechnical Centre of the University of Alberta

2.3 Tempe cell technique

Figure 3 shows the Tempe cell device. The Tempe cell comprises three main parts: the base, plexiglass cell (7 cm in diameter × 7 cm high), and lid. The base is fitted with a high air entry ceramic porous stone with a maximum high air entry value (AEV) of 500 kPa and an outlet for water release. The lid is equipped with an inlet for air pressure supply, and the cell where the sample is confined has a height of 7 cm. In the modified Tempe cell technique used in this research, a series of Tempe cells are used to dewater the ILF-FFT and C-Cake samples at various matric suction ranging from 7 kPa to 400 kPa. The slurried sample is confined in a cell to about three quarters of the cell volume. Air pressure is applied over the sample, and the water released

from the soil is collected at the base of the cell. During the dewatering test, the change in mass of the cell is monitored and plotted against time (see Figure 4). When the mass change stops, it is assumed that a steady state is reached for that matric suction (u_a–u_w) step (u_a = pore air pressure and u_w = porewater pressure). At the end of the test, the lid is removed from the cell, and the sample's shear strength is measured. The water and solids contents are also measured by oven-drying over a 24-hour period at 105 °C (ASTM D2216, ASTM International 2010).

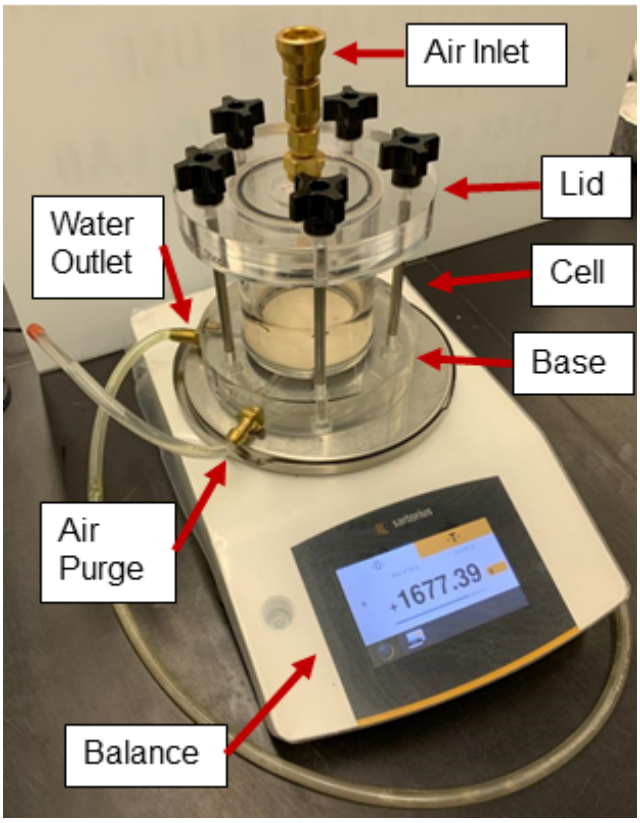

Figure 3 Tempe cell device and a balance used in this study

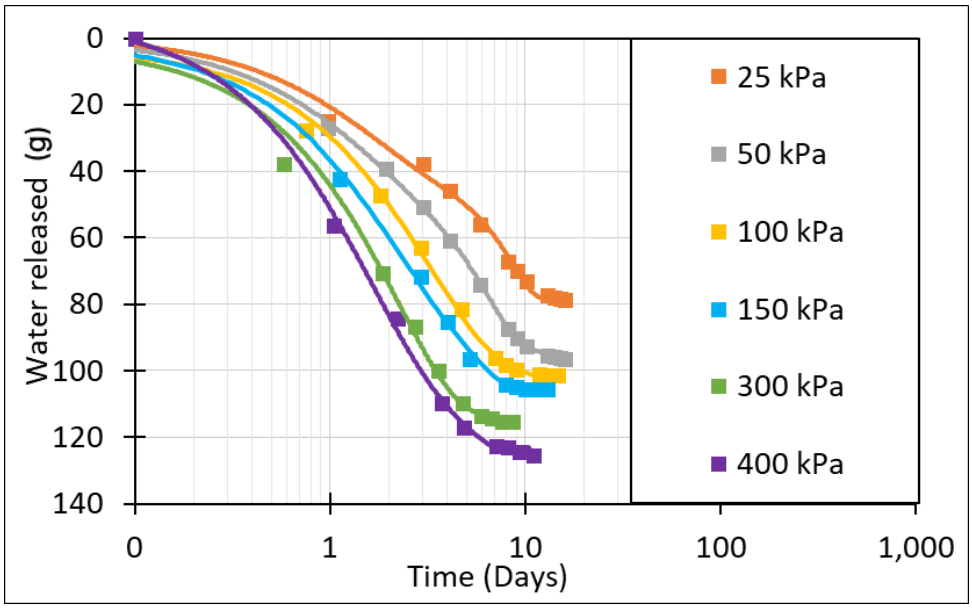

Figure 4 Typical drainage curves of the Tempe cell treatments on the C-Cake sample

3 Results and discussion

Results of the Tempe cell and LSC treatments on ILF-FFT and C-Cake samples are discussed below by comparing the consolidation and unsaturated properties of the treated samples.

3.1 Tempe cell and LSC treatments on ILF-FFT

The properties of the ILF-FFT sample, which was flocculated and treated by Tempe cell, are compared with those of the LSC-treated sample.

3.1.1 Solids and water contents

Figure 5 shows the dewatering of the ILF-FTT sample using the Tempe cell technique extending from 7 kPa to 400 kPa matric suctions. The initial water and solids contents of the ILF-FFT are 115% and 46.4%, respectively. The water content decreases from 115% to 28% as suction increases from 7 kPa to 400 kPa. Similarly, the solids content increases from 46% to 78% with increasing matric suction from 7 kPa to 400 kPa. The solids content increases by 1.7 times and the water content decrease by 4.1 times. When the solids content exceeds 70%, the strength is sufficient to cap a deposit (Fair & Beier 2012).

The water content is plotted as a function of matric suction in a log scale in Figure 6, representing the early part of the SWCC of the ILF-FFT. The AEV of the ILF-FFT is beyond 400 kPa matric suction and cannot be displayed on this curve. The inflection on the curve around 10 kPa does not represent the AEV, determined from the degree of saturation curve (Fredlund et al. 2011). The complete SWCC of the ILF-FFT can be determined in combination with a second apparatus for high suction measurements. This process falls outside the main scope of this research; however, a description of this process can be found in Fredlund et al. (2011).

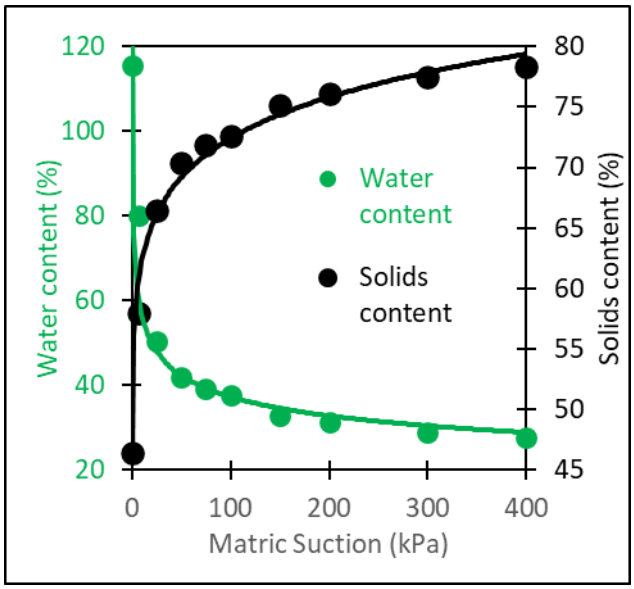

Figure 5 Water and solids content of C-Cake measured with the Tempe cell technique

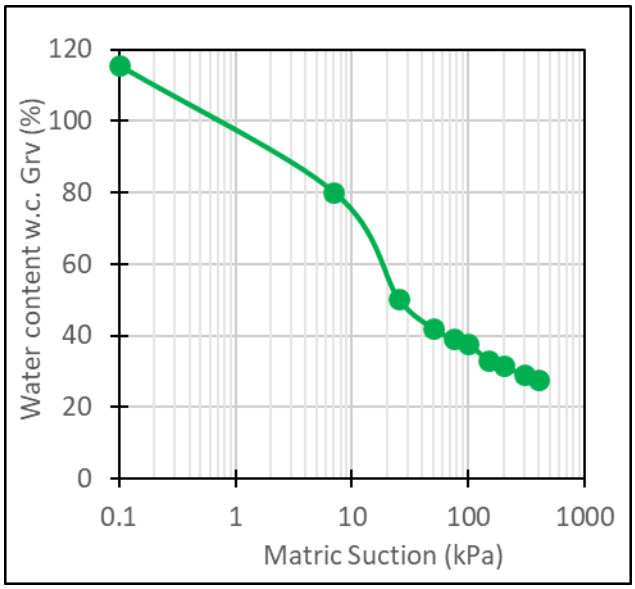

Figure 6 Water content versus matric suction of C-Cake measured with the Tempe cell technique

Figure 7 compares the dewatering rates of ILF-FFT using Tempe cell and LSC treatments. The two techniques display similar dewatering rates, but the LSC plots slightly above the Tempe cell at loads higher than 50 kPa. For example, at 300 kPa load, the Tempe cell and LSC techniques yield solids contents of 77.5% and 80%, respectively.

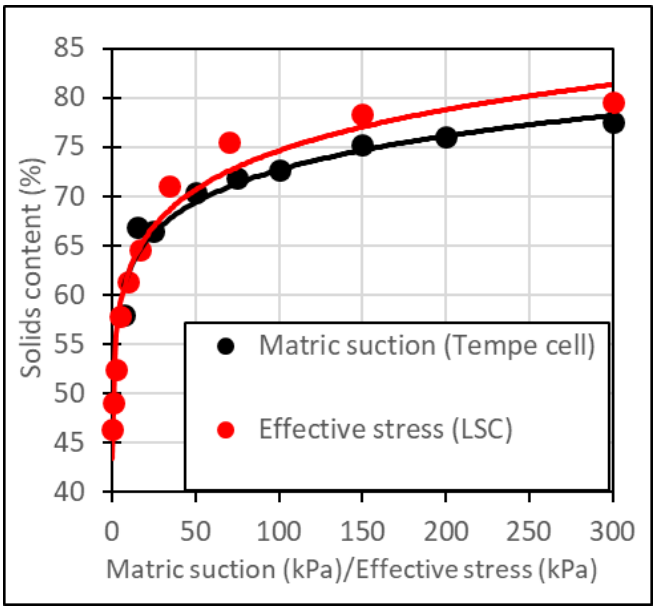

Figure 7 Solids contents curves of ILF-FFT measured with Tempe cell and LSC techniques

3.1.2 Compressibility

Figure 8 compares the compressibility results of the ILF-FTT obtained using the Tempe cell and LSC techniques (fine void ratio: volume of voids/volume of fines). Figure 8 shows that the ILF-FFT samples from LSC and Tempe cell techniques undergo similar compression when subjected to loads (effective stress/matric suction). However, between 2 kPa and 300 kPa, the LSC plots below the Tempe cell, suggesting that the ILF-FFT from LSC releases more water than the ILF-FFT from the Tempe cell for loads between 2 kPa and 300 kPa. It took about four months to complete the LSC tests, yet it took two weeks to complete the Tempe cell tests.

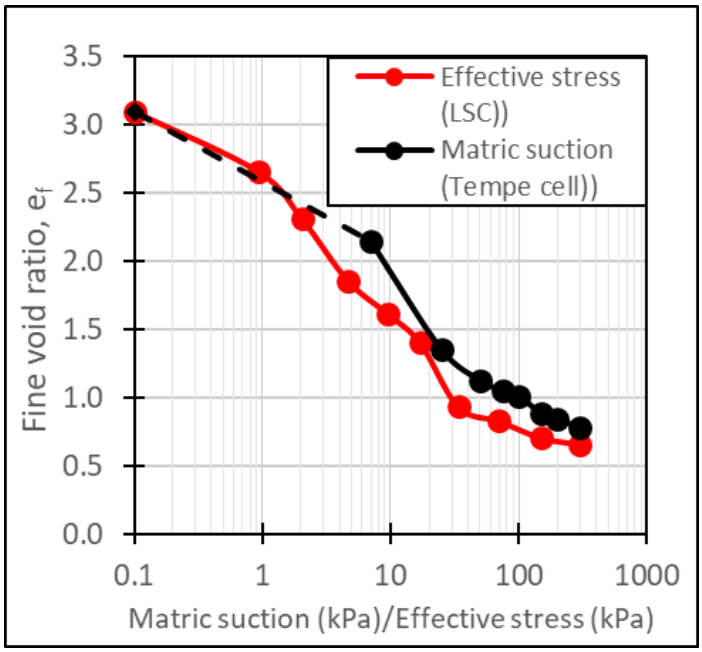

Figure 8 Compressibility curves of ILF-FFT measured with Tempe cell and LSC techniques. No measured data between 0.1 and 7 kPa for Tempe cell

3.1.3 Shear strength

Figures 9 and 10 compare the shear strength plots of ILF-FFT generated using the Tempe cell and LSC techniques. Both figures show that the LSC yields a stronger ILF-FFT than the Tempe cell at fine void ratios lower than 1.6 (Figure 10) and a higher load greater than 60 kPa (Figure 11). As the fine void ratio is reduced to 0.8, the shear strengths of the ILF-FFT derived from the Tempe cell and LSC are 80 kPa and 120 kPa, respectively. These strengths are sufficient to cap a deposit. Figure 11 shows the plots of shear strength as a function of the solids content of ILF-FFT measured with Tempe cell and LSC techniques. The figure shows that the ILF-FFT of the Tempe cell is stronger than that of the LSC. The strength data indicate that when the solids contents are greater than 75%, the strengths are sufficient to cap a deposit.

Figure 12 shows the power function relationship between the effective stress and matric suction of the ILF-FFT derived from the shear strength relationships in Figure 10. This calibration curve of C-Cake is useful and can be used to convert matric suction to effective stress.

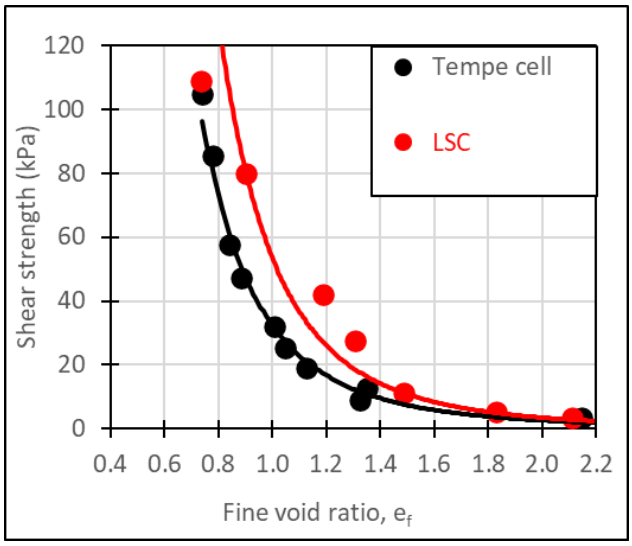

Figure 9 Shear strength versus fine void ratio of ILF-FFT measured with Tempe cell and LSC techniques

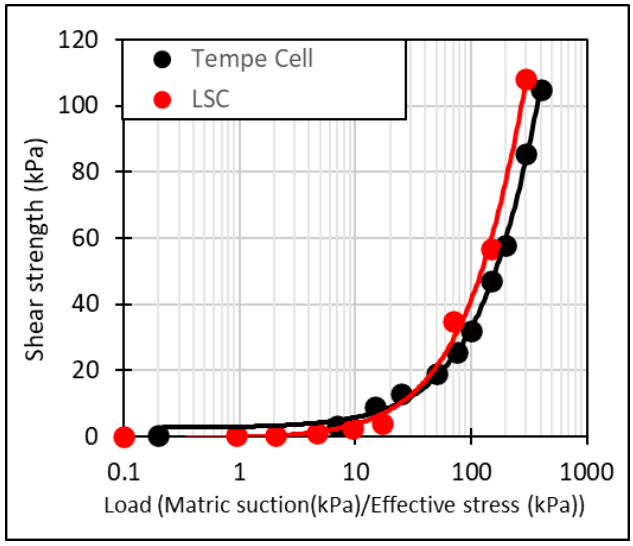

Figure 10 Shear strength versus loads of ILF-FFT measured with Tempe cell and LSC techniques

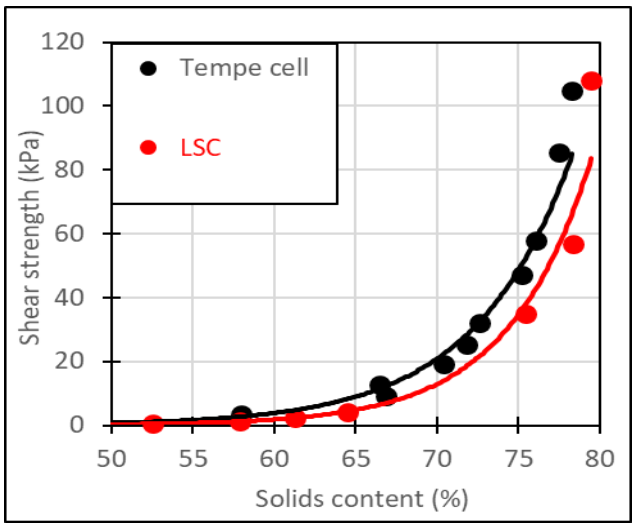

Figure 11 Shear strength versus solids content curves of ILF-FFT measured with Tempe cell and LSC techniques

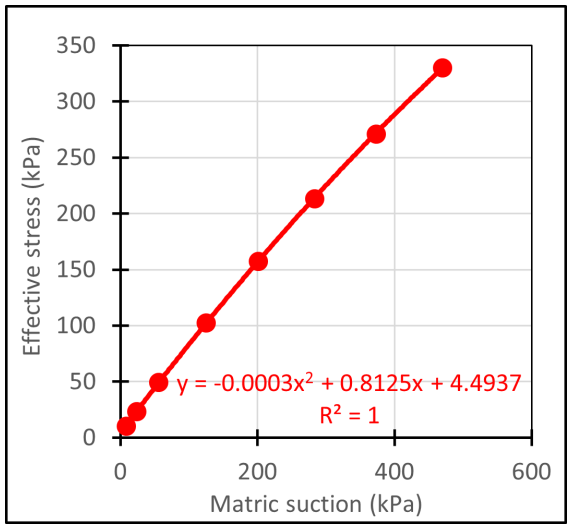

Figure 12 Effective stress versus matric suction plot of ILF-FFT

3.2 Tempe cell and LSC treatments on centrifuge cake C-Cake

3.2.1 Solids and water contents

Figure 13 shows the dewatering of the C-Cake using the Tempe cell technique extending from 7 kPa to 400 kPa matric suctions. The C-Cake's initial water and solids contents are 80.5% and 55.4%, respectively. The final water and solids contents at 400 kPa matric suction are 24.5% and 80.3%, respectively. The water content was reduced by a factor of 3.3, and the solids content was increased by a factor of 1.5. At 400 kPa matric suction, the solids content of the C-Cake is sufficient to cap a deposit. Figure 14 represents the early part of the SWCC of C-Cake. The AEV of the C-Cake is beyond 400 kPa matric suction and cannot be displayed on this curve. Although not the main scope of this research, it is worth noting that the complete SWCC of the C-Cake can be determined with a second apparatus for high suction measurements. Figure 15 compares the dewatering of C-Cake using Tempe cell and LSC treatments. The Tempe cell shows a higher dewatering rate than the LSC at all loads.

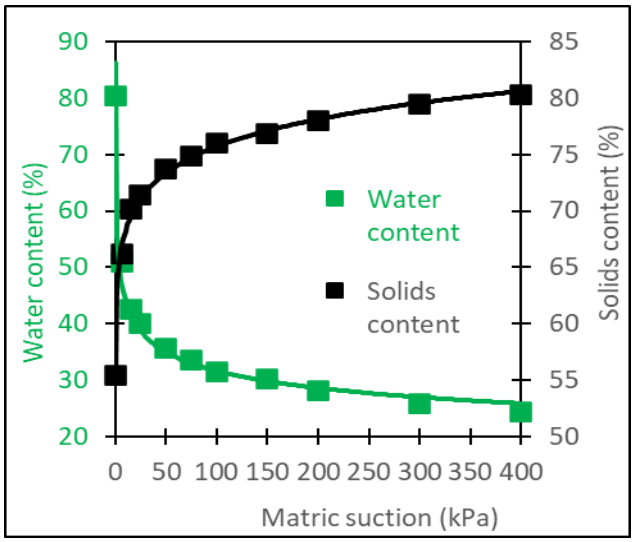

Figure 13 Water and solids contents data versus matric suction of C-Cake measured with Tempe cell technique

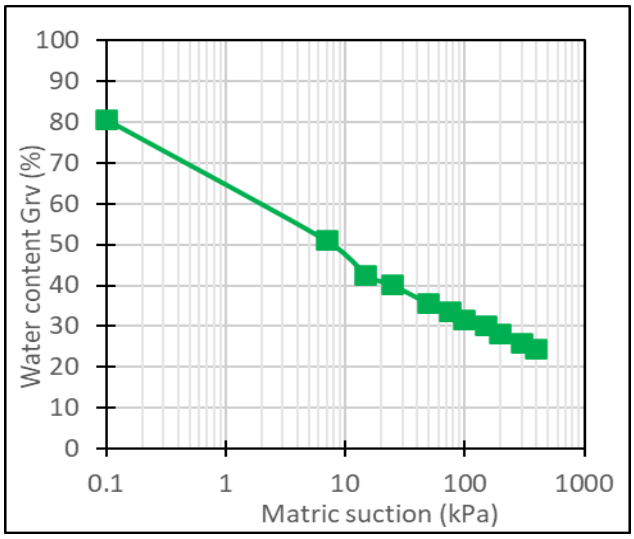

Figure 14 Water content versus matric suction of C-Cake measured with Tempe cell technique

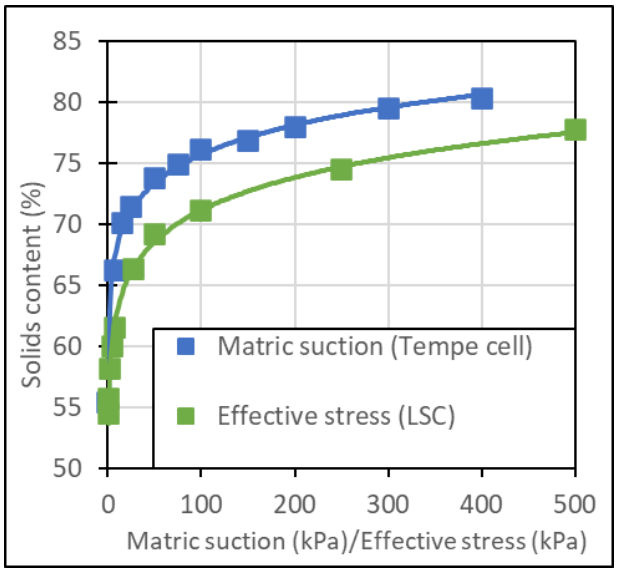

Figure 15 Water content as a function of matric suction of C-Cake, measured with the Tempe cell technique

3.2.2 *Compressibility*

Figure 16 compares the compressibilities of the C-Cake obtained using the Tempe cell and LSC treatments. There were no measurements at matric suctions between 0.1 kPa and 7 kPa. Figure 16 shows that the C-Cake from the Tempe cell releases more water than that from the LSC at loads between 0.1 kPa and 200 kPa.

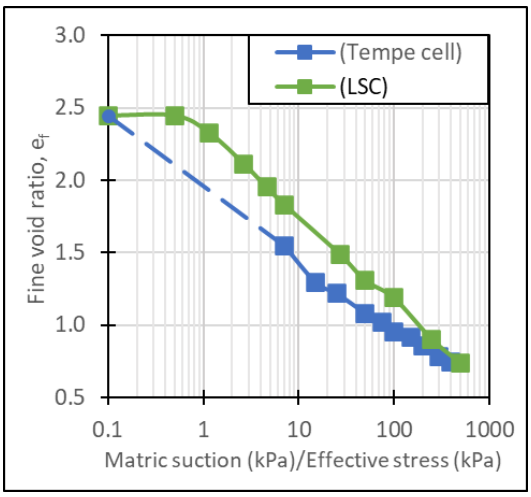

Figure 16 Compressibility curves of C-Cake measured with Tempe cell and LSC techniques

3.2.3 *Shear strength*

Figures 17 and 18 compare the shear strength plots of C-Cake generated using the Tempe cell and LSC techniques. Results in Figure 17 indicate that the LSC generates a stronger C-Cake than the Tempe cell at fine void ratios lower than two. In Figure 18, both LSC and Tempe cell yield the same shear strength at all loads. Results in Figure 19 indicate that LSC yields a stronger C-Cake than the Tempe cell at all solids contents.

Figure 20 shows the power function relationship between the effective stress and matric suction for C-Cake derived from the shear strength relationships in Figure 18 and plotted along with that of the ILF-FFT from Figure 12. These valuable functions of C-Cake and ILF can be employed to convert matric suction to effective stress. The slope of the C-Cake is four times greater than that of the ILF-FFT.

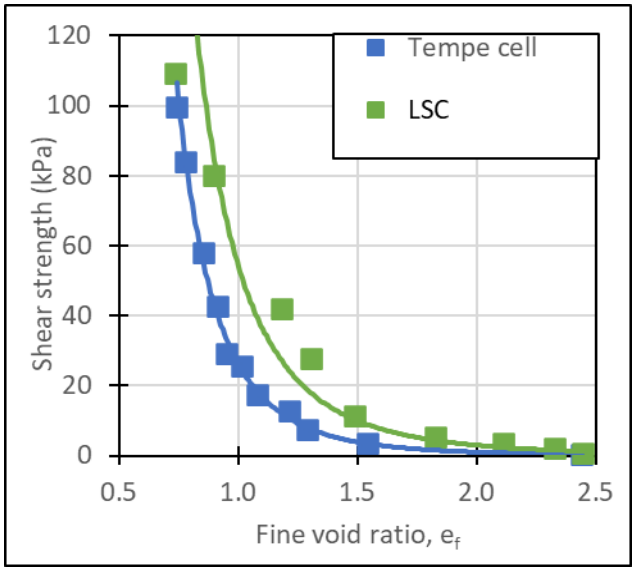

Figure 17 Shear strength versus fine void ratio curves of C-Cake measured with Tempe cell and LSC techniques

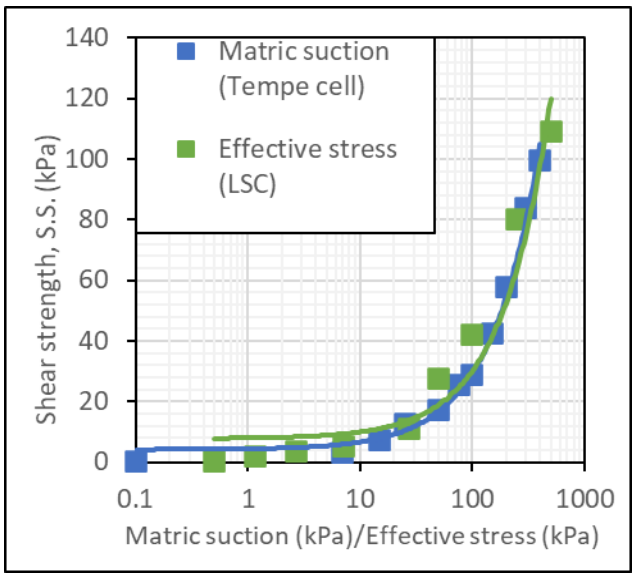

Figure 18 Shear strength versus loads curves of C-Cake measured with Tempe cell and LSC techniques

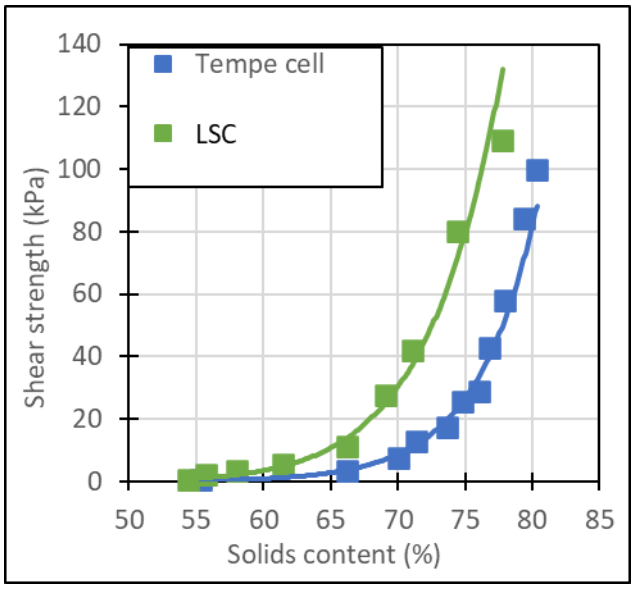

Figure 19 Shear strength as a function of solids content curves of C-Cake measured with Tempe cell and LSC techniques

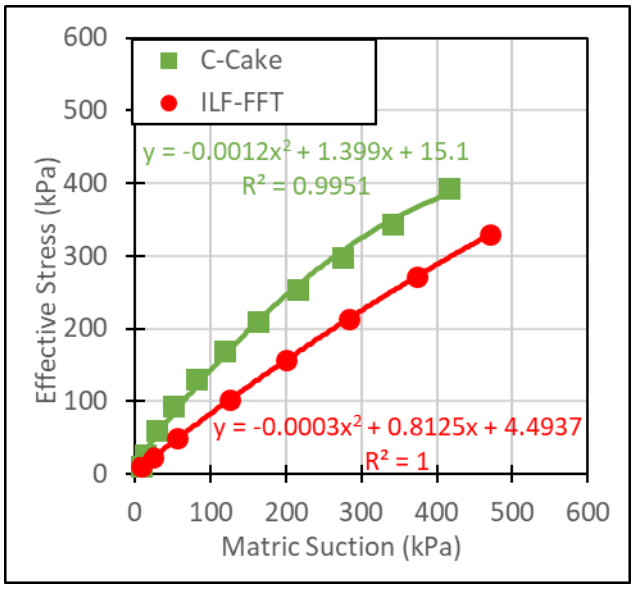

Figure 20 Effective stress versus matric suction plot of C-Cake

3.3 Effects of Tempe cell and LSC treatments on the properties of ILF-FFT and C-Cake

In this section, the performances of the two techniques are evaluated by comparing the results of the Tempe cell and LSC treatments on ILF-FFT and C-Cake.

Figure 21 shows the results of the LSC treatments on ILF-FFT and C-Cake samples. The figure shows that the ILF-FFT compressibility curve crosses that of the C-Cake curve at 2 kPa and remains below the C-Cake curve thereafter, up to 300 kPa matric suction. This result indicates that the ILF-FFT is more compressible than the C-Cake.

Figure 22 shows the data of the Tempe cell treatments on ILF-FFT and C-Cake. Results show that the ILF-FFT curve meets that of the C-Cake at 25 kPa matric suction, and they both remain the same thereafter. This result indicates that centrifugation does not affect the treated tailings sample at matric suction greater than 25 kPa.

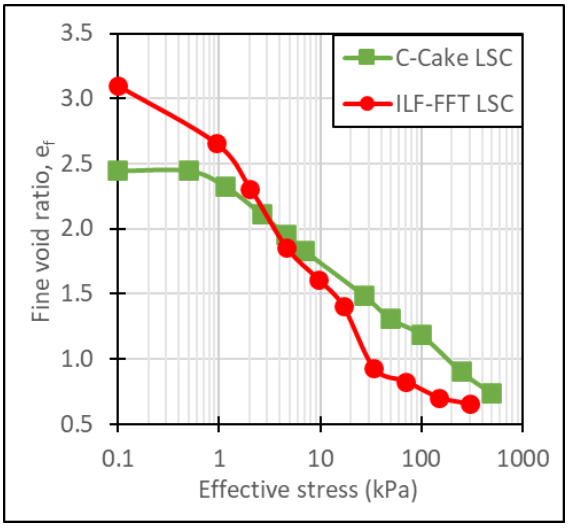

Figure 21 Compressibility curves of ILF-FFT and C-Cake measured with LSC technique

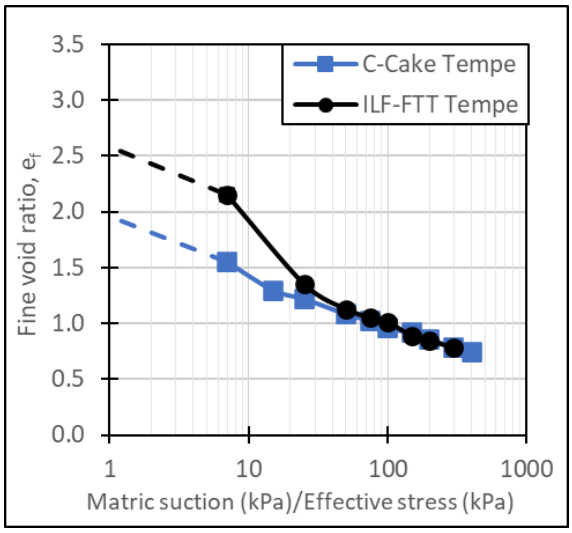

Figure 22 Compressibility curves of ILF-FFT and C-Cake measured with Tempe cell

Figures 23 and 24 present the results of the shear strength of ILF-FFT and C-Cake samples measured using LSC and Tempe cell techniques, respectively. The data of the LSC treatment in Figure 23 indicates that the C-Cake is stronger than the ILF-FTT at all fine void ratios. The Tempe cell treatment results in Figure 24 indicate that both the ILF-FFT and C-Cake have the same shear strengths at all fine void ratios.

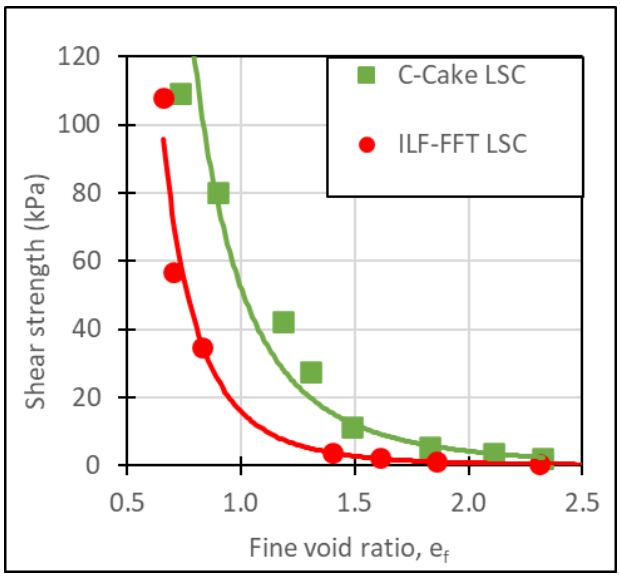

Figure 23 Shear strength versus fine void ratio curves of ILF-FFT and C-Cake measured with LSC technique

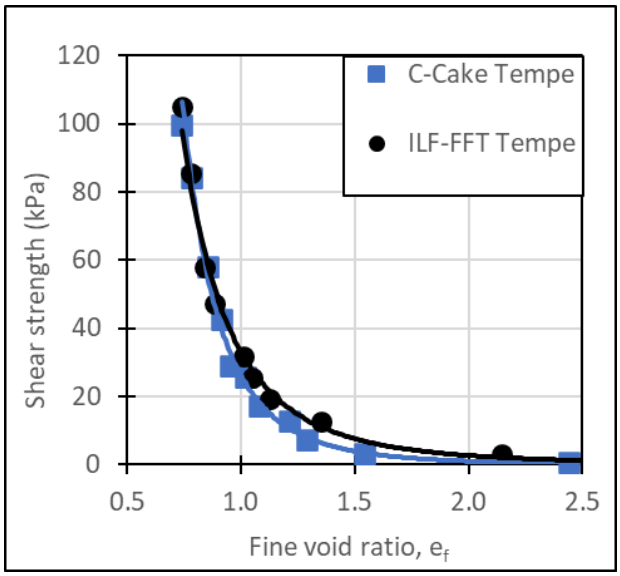

Figure 24 Shear strength versus fine void ratio curves of ILF-FFT and C-Cake measured with Tempe cell technique

A better comparison is in Figures 25 and 26, where the shear strength is plotted as a function of solids content. Results of both the LSC and Tempe cell indicate that the C-Cake is stronger than the ILF-FFT at all solids contents. They suggest that flocculation and centrifugation increase the shear strength of the samples. Other researchers have reported this result (Abdulnabi et al. 2021; Wilson et al. 2018).

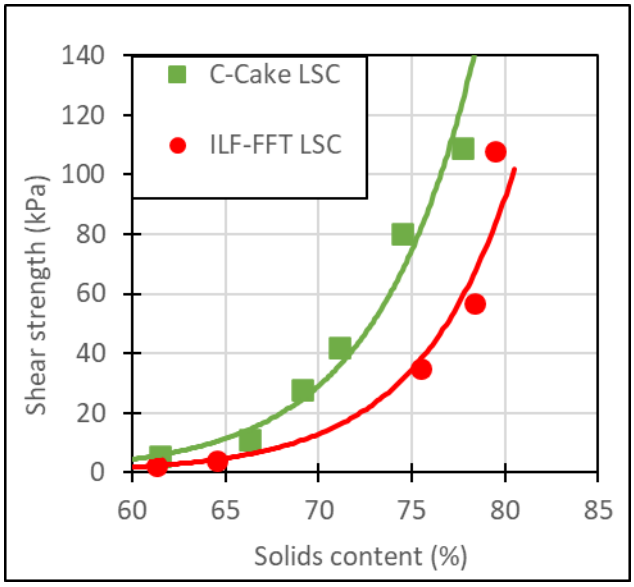

Figure 25 Shear strength versus content curves of ILF-FFT and C-Cake samples measured with LSC technique

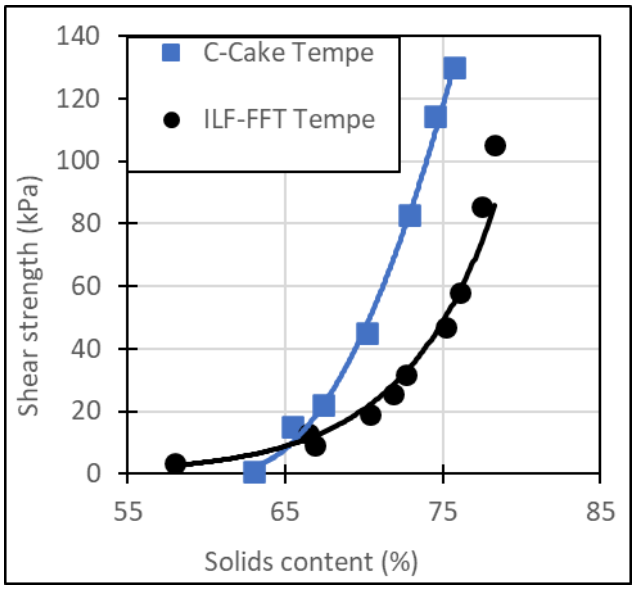

Figure 26 Shear strength versus of solids content curves of ILF-FFT and C-Cake measured with Tempe cell technique

3.4 Hydraulic conductivity

The Tempe cell technique does not involve the determination of the hydraulic conductivity (K) and is not discussed in this section. The K of the C-Cake sample, which was flocculated and centrifuged, is compared with that of the ILF-FFT to evaluate the effect of flocculation and centrifugation in Figure 27. The data show that C-Cake has greater K for void ratios between 1.6 and 2.1. The C-Cake shows significantly higher K at void ratios lower than 1.8. For example, the C-Cake is greater than the ILF-FFT by 2.5 orders of magnitude at the void ratio of 2.1. The important conclusion is that the C-Cake will consolidate much faster at lower void ratios than 1.6. The speed of consolidation is the benefit of centrifugation (Wilson et al. 2018; Abdulnabi et al. 2021).

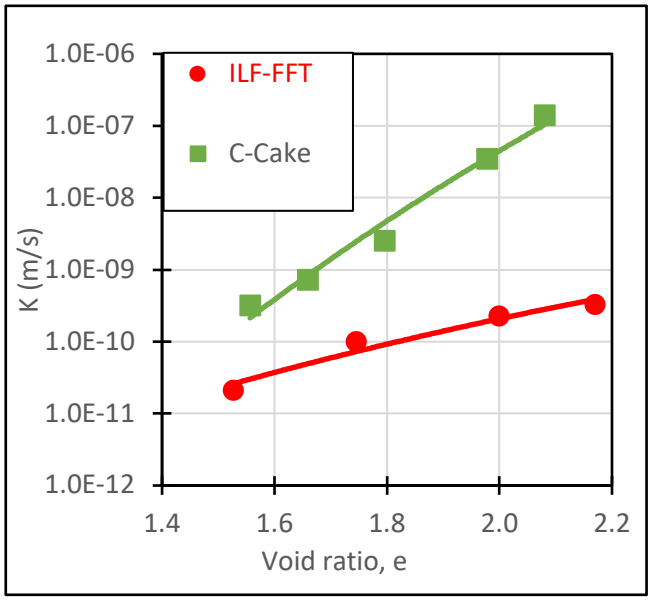

Figure 27 Hydraulic conductivities K of ILF-FFT and C-Cake measured using the LSC

4 Summary and conclusions

LSC and Tempe cell techniques with shear strength tests were conducted on ILF-FFT and C-Cake tailings samples. These tests determine the consolidation and geotechnical properties, unsaturated characteristics, and shear strength of the treated tailings samples. LSC tests with shear strength provide the consolidation properties (compressibility and hydraulic conductivity) and shear strength. The Tempe cell tests provide unsaturated soil properties, including SWCC and other valuable functions relating matric suction and shear strength and solids content. Results show that the LSC and Tempe cell techniques generate similar compressibilities and other geotechnical functions relating effective stress and matric suction to solids content and shear strength of the tested ILF-FF and C-Cake samples. The most important function is the relationship between effective stress and matric suction. This is a valuable engineering function in dewatering oil sands tailings and surface drying the tailings deposits. The slope of the C-Cake function was four times greater than that of the ILF-FFT. The Tempe cell determines the early portions of the SWCC but cannot alone determine the complete SWCCs of ILF-FFT and C-Cake samples with AEVs beyond the maximum 500 kPa suction for the Tempe cell used in this research. This is the limitation of the Tempe cell technique. LSC determines the K of the samples, but Tempe does not include the determination of K. In summary, it took about five months to complete LSC tests, whereas it took about three weeks to complete Tempe cell tests of ILF-FFT and C-Cake. Its main benefit is the rapid yielding of compressibility and strength data gained from the Tempe cell technique used in this research. The Tempe cell technique will be attractive to geotechnical practitioners due to its shorter test time, and it can complement the LSC technique if K is needed for consolidation modelling.

Acknowledgement

This research was funded by Canada's Oil Sands Innovation Alliance (COSIA) and the Natural Sciences and Engineering Research Council of Canada (NSERC).

References

Abdulnabi, A, Amoako, K, Moran, D, Vanadara, K, Aldaeef AA, Esmaelizadeah, A, … & Simms, P 2021, 'Evaluation of candidate polymers to maximise the geotechnical performance of oil sands tailings, *Canadian Geotechnical Journal*, vol. 55, no. 3, pp. 359-371, https://doi.org/10.1139/cgj-2020-0714

Alberta Energy Regulator (AER) 2017, *Directive 085: Fluid Tailings Management for Oil Sands Mining Projects*, viewed 10 April 2020, https://www.aer.ca/documents/ directives/Directive085.pdf

Alberta Energy Regulator (AER) 2019, *State of Fluid Tailings Management for Mineable Oil Sands 2018*, viewed 11 April 2020, https://www.aer.ca/documents/oilsands/2018- State-Fluid-Tailings-Management-MineableOilSands.pdf

Amoako, KA, Abdulnabi, A, Beier, NA, Soares, J & Simms, PH 2020, 'Longterm consolidation of two new polymer treatments of oil sands fluid fine tailings', *GeoVirtual2020, Canadian Geotechnical Conference, The Canadian Geotechnical Society, on-line conference*.

ASTM International 1999, *Standard Test Method for Methylene Blue Index of Clay* (ASTM C837-99), ASTM International, West Conshohocken, https://doi.org/10.1520/C0837-09R19.

ASTM International 2005, *Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer* (ASTM D4221-99R05), ASTM International, West Conshohocken, https://doi.org/10.1520/D4221-99R05

ASTM International 2007, *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D422-63R07), ASTM International, West Conshohocken, https://doi.org/10.1520/D0422-63R07E02

ASTM International 2010, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (ASTM D2216-19), ASTM International, West Conshohocken, https://doi.org/10.1520/D2216-19

ASTM International 2016, *Standard Test Method for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil* (ASTM D4648/D4648M-16), ASTM International, West Conshohocken, https://doi.org/10.1520/D4648_D4648M-16

Fair, AE & Beier, NA 2012, 'Collaboration in Canada's oil sands: fluid fine tailings management', *Proceedings of the Third International Oil Sands Tailings Conference*, University of Alberta Geotechnical Centre, Edmonton.

Fredlund, DG, Stone, J, & Stianson, J & Sedgwick, A 2011, 'Determination of water storage and permeability functions for oil sands tailings', *Proceedings Tailings and Mine Waste 2011*, The University of British Columbia, Vancouver, https://doi.org/10.14288/1.0107734

Jeeravipoolvarn, S 2010, *Geotechnical Behavior of In-Line Thickened Tailings*, PhD thesis, University of Alberta, Edmonton.

Kaminsky, HAW 2014, 'Demystifying the methylene blue index', *Proceedings of the 4th International Oil Sands Tailings Conference*, Geotechnical Centre and the Oil Sands Tailings Research Facility (OSTRF), University of Alberta Geotechnical Centre, Lake Louise.

Omotoso, O & Melanson A 2014, 'Influence of clay minerals on the storage and treatment of oil sands tailings', in R Jewell, A Fourie, PS Wells & D van Zyl (eds), *Proceedings of the 17th International Seminar on Paste and Thickened Tailings*, Australian Centre for Geomechanics, Perth, pp. 269-280.

Sethi, A 1995, 'Methylene blue test for clay activity determination in fine tails', *MRRT Procedures 23*.

Suthaker, NN & Scott, JD 1994, 'Large scale consolidation testing of oil sand fine tails', *Proceedings of the 1st International Congress on Environmental Geotechnics*, BiTech, Vancouver, pp. 557-562.

Wilson, GW, Kabwe, LK, Beier, NA & Scott, JD 2018, 'Effect of various treatments on consolidation of oil sands fluid fine tailings', *Canadian Geotechnical Journal*, vol. 55, no. 8, pp. 1059-1066, https://doi.org/10.1139/cgj-2017-0268@cgj-ec.2018.01.issue-7