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Assessment on consolidation behaviours of treated fluid fine tailings using applied suction method

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Abstract

Large volumes of fluid tailings have been produced by the oil sands mining operations in Northern Alberta using bitumen extraction processes. The produced tailings pose a challenge to the operators due to low compressibility behaviour of materials in the tailing pond as a result of the low hydraulic conductivity and high thixotropic strength. Deposited tailings that are ready to be reclaimed require being consolidated and have adequate strength. Consolidated and developed strength of the deposited tailings need to provide adequate bearing capacity, which is pivotal in establishing the basis for reclamation work such as the capacity to carry the machinery that carry out the reclamation work. Field trials display formation of both unsaturated and saturated zones within the deposited tailings following the deposition of fully saturated tailings. The development of the unsaturated zone requires the removal of moisture from freshly deposited slurry materials. The unsaturated zone development can be attained during design stage by using various dewatering technologies. The presence of the unsaturated zone significantly enhances consolidation properties of the deposited tailings due to dewatering of tailings using the applied suction method. This paper will present results of laboratory experiments carried out to assess consolidation behaviours of freshly deposited treated fluid fine tailings using the applied suction method. The laboratory experiment was conducted using a meso-scale column made of Plexiglas and a PVC base with a high air-entry value ceramic disc with dimensions of 300 mm diameter and 500 mm height. Consolidation of fluid fine tailings obtained using column tests were assessed using standard large-strain compressibility curves and predicted using unsaturated engineering properties. Results were checked and consistent with fundamental principles of unsaturated soil mechanics. Experimental test results from the meso-scale test were compared with standard engineering property testing methods and discussed.

Keywords: *consolidation of tailings, applied suction, unsaturated properties of tailings*

1 Introduction

The mining industry around the world faces massive challenges in managing generated mine wastes due to mining activities. Tailings are one of the mine waste by-products of mining and mineral processing. Tailings are composed of sand, fines (silt and clay size materials) and bitumen, in the case of oil sand tailings. These tailings have slow settling rates and low hydraulic conductivity due to their composition dominated by fines. These high fines contents increase in significance during extraction processes due to additives such as dispersing agents (Beier et al. 2009). Upon deposition, the tailings exhibit segregation behaviours with the coarser particles forming beaches and dykes, and the fine particles being stored in ponds. In the case of oil sand tailings, fine tailings in the pond is known as fluid fine tailings (FFT). Sedimentation of tailings occurs in the ponds based on composition of fines particles for base metals and for FFT's sedimentation. Within two to three years, the solids content reaches 30–35%. In general, these deposits have properties that are slow to consolidate. Once the process of sedimentation ceases, the process of self-weight compression governs the specified solids content. Normally, mine operators used containments to store FFTs. The containments create a large surficial footprint and, to date, have proven to present an engineering challenge to reclaim.

Multiple research initiatives are being undertaken by several operators in order to increase dewaterability of tailings and subsequently accelerate trafficability of tailings following its deposition. Some of the techniques include composite tailings, conventional thickening, centrifugation, inline flocculation and thickening along, and various combinations of the mentioned techniques. Thin-lift deposition or rim-ditching have also been given consideration. These research initiatives increase dewatering of deposited tailings through desiccation (i.e. evaporation, drainage and/or freeze-thaw) and consolidation (Morgenstern & Scott 1995).

It has been well understood and established that geotechnical engineering problems, such as high-volume change deposits (consolidation), stability of earthfill structures, and reclamation of tailings impoundments, can best be analysed using fundamental principles of saturated and unsaturated soil mechanics. For example, unsaturated flow behaviour has been used to predict the dewaterability of thin and/or multilayer tailings deposits of high-density hard rock tailings as well as evaporation and drainage of tailings (Fisseha et al. 2010; Simms et al. 2007, 2010; Sulfate et al. 2010).

Consolidation properties of tailings has been researched and is well understood. However, a necessary secondary objective is to characterise the undrained shear strength developed in deposited ultra-soft tailings and/or FFTs in relation to the total and effective stress as the consolidation process advances. The characterisation of the shear strength in conjunction with the consolidation is carried out through laboratory experimental testing and the findings will assist in validating the use of soil mechanic principles during the handling, analysis, and design phases of engineering structures, such as containment for the FFT.

Experimental study on the consolidation behaviours of FFT were carried out using a meso-scale column apparatus and applying a negative porewater pressure (i.e. suction) technique (Fisseha et al. 2017b). The study emphasised the importance of negative porewater pressure (suction), an application of unsaturated soil principle towards consolidation, drying and desiccation of deposited tailings in the areas where high rates of atmospheric fluxes such as arid and semi-arid environments. Furthermore, shear strengths of the consolidated tailings were measured and evaluated using vane shear devices (Fisseha 2020).

This paper presents experimental results on the self-weight consolidation and consolidation using the applied suction method of treated FFT and evaluate if consolidation properties from the applied suction method can be predicted from standard engineering characterisation tests and self-weight consolidation method with standard settling test results.

2 Methodology of experimental testing

This section will briefly review objectives of the experimental study mainly the need for the consolidation process using the applied negative porewater pressure (i.e. suction) technique and corresponding relationship with the saturated, transition and unsaturated zones. In addition, it describes the equipment used to measure shear strength of tailings during the experimental work.

The applied suction technique for consolidating soft tailings was designed to understand and characterise tailings in relation to saturated/unsaturated zones, under a controlled stress environment in the laboratory using a column apparatus. Fundamentals and advantages of consolidating tailings using the applied suction method are illustrated in Fisseha et al. (2017b, 2022) and Fisseha (2020).

In the field, the process of desaturation, drying, and desiccation from the surface of fully saturated tailings occurs due to atmospheric flux boundary conditions such as evaporation and evapotranspiration between the ground surface and the surrounding atmosphere. A transition/interlayer zone forms as a result of the change in the watertable within the soil profile as the saturation and desaturation processes alternate on the deposited tailings from rainfall or evaporation, respectively.

Figure 1 presents a generic transition/interlayer zone between the unsaturated and saturated conditions. Fully saturated tailings were deposited in the column and water was withdrawn from the tailings regularly using an incremental applied suction method at the bottom boundary. The column apparatus enables the investigation and characterisation of materials in the transition/interlayer zone using controlled suction increments through the base compared to the actual process of evaporation and rainfall. The column mimics the existing field conditions of drying and desiccating in a transition/interlayer zone. The drying/desiccation process that occurred during conceptual field trials and column testing in the lab showed comparable development of the transition zone, except for the change in the direction of flux. The process of consolidation and drying/desiccation progressed irrespective of the flux direction either using applied suction at the bottom boundary or through evaporation and rainfall on the surface for actual field condition. The column apparatus embedded within Figure 1 is to illustrate and visualise the formation of transition zone.

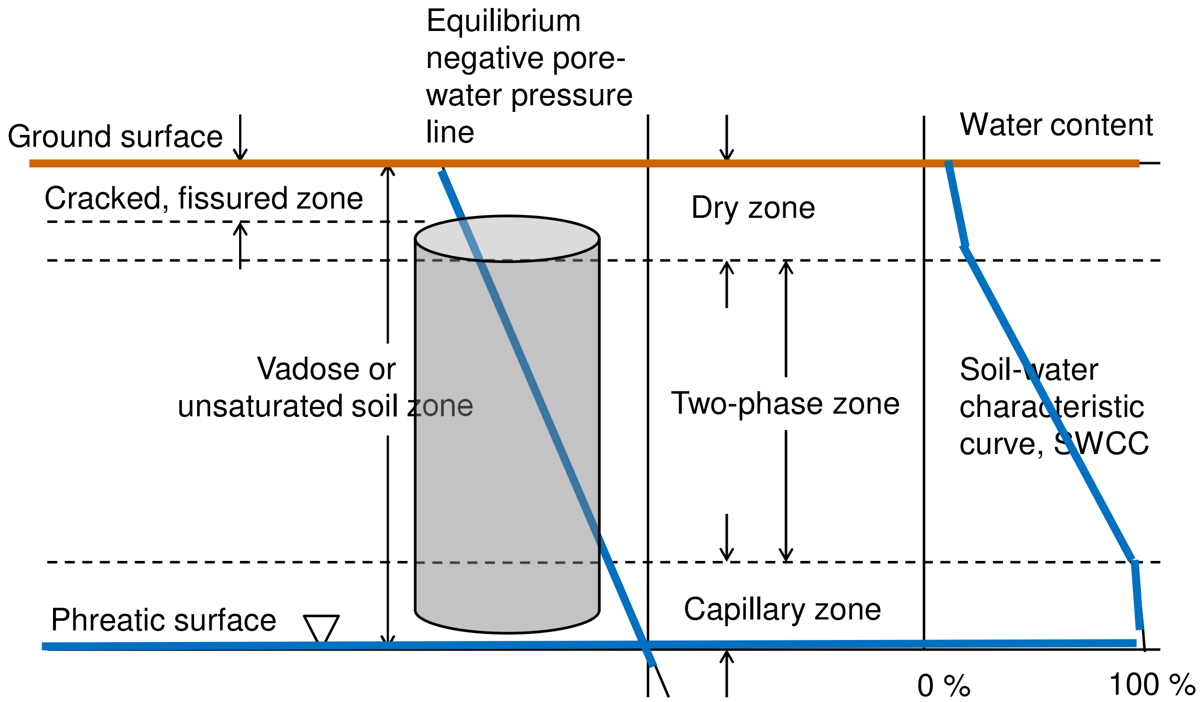

Figure 1 Column used to characterise the consolidation of tailings using applied suction in relation to conceptual unsaturated zone

3 Materials and methods

3.1 Materials

The materials used during the experimental study are described as flocculated FFT and flocculated centrifuged tailings cake (FCTC). Details on how these materials were prepared are presented herein.

Homogenised FFT at a solids content of 38% and FCTC at a solids content of 52% were prepared and geotechnical index properties testing was conducted. The geotechnical index properties of FFT are summarised in Table 1. The index properties from these tests are compared with the index properties reported by Mizani et al. (2014). An anionic polymer, A3338, was used as the flocculant agent. Details of preparation on flocculated FFT and typical output are as outlined in Mizani et al. (2013) and Fisseha (2020). The FCTC materials were fully prepared and shipped to the laboratory and are not part of this paper.

Table 1 Summary of geotechnical index properties of fluid fine tailings (FFT) and flocculated centrifuged tailings cake (FCTC)

Properties	Flocculated FFT	FCTC
MBI (meq/100 g)	3.75	-
Bitumen content (%)**	2.57	0.37
D50, D60 (µm)	3.2, 6.3	1.4, 2.4
Specific gravity, Gs	2.2	2.48
Liquid limit (%)	42	57
Plastic limit (%)	30	26
Fines content (< 44 µm) (%)	81	87
clay size particle (%)	40.5	53
SFR	0.24	0.15

Note: MBI = methyl blue index; SFR = sand to fine ratio; ** Bitumen content – calculated using total bitumen divided by dry tailings. Major ions in pore fluid were not measured.

3.2 Design of meso-scale consolidation and standard characterisation testing

This section presents an overview of the column apparatus design, which was used to carry out the laboratory study. The column apparatus facilitates the use of controlled physical processes such as an applied suction and the measurement and analysis of the changes observed in the freshly deposited tailings. The experiments were conducted in two stages defined by different boundary conditions.

In addition, a number of standard laboratory tests were carried out to characterise and obtain engineering properties of materials used during the experimental testing. Detail descriptions of testing procedure for settling test, soil-water characteristic curve (SWCC), shrinkage curve (SC), large-strain consolidation tests (LSC) to obtain compressibility and hydraulic conductivity curves are presented in Fisseha et al. (2017a) and Fisseha (2020). A brief description on the methodology for consolidation using the applied suction technique (Fisseha et al. 2017b) during the experimental study are presented herein.

3.2.1 Column apparatus design

The column apparatus is composed of two main components: an acrylic column and a polyvinyl (PVC) base plate. The base plate includes a high air-entry value ceramic disk. A drainage path was made within the base plate using grooves to facilitate movement of water during the consolidation process. The porous ceramic disk can withstand a pressure difference up to 100 kPa and is suitable for the application of negative porewater pressures (Fredlund et al. 2012). The negative pressure (i.e. suction relative to atmospheric air pressure) applied to the column apparatus was used as the driving force for the consolidation of the tailings. Details of the column apparatus design are presented in Fisseha et al. (2017a).

Experiments were conducted in two stages:

1. Stage 1: the sedimentation and self-weight consolidation
2. Stage 2: the consolidation using an applied negative water pressure (suction).

During the consolidation using suction stage, the watertable line (i.e. zero pressure line) moves to a lower level along the deposited slurry tailings thickness. The continuous withdrawal of water may generate an unsaturated zone near the surface of the deposited tailings. A consolidated zone develops near the surface, and the unsaturated region is expected to continue to establish negative porewater pressures. Subsequently, the desaturated tailings may start to pull away from the walls of the column boundary. Consequently, cracks may form and propagate downward from the surface of the deposited tailings. It is anticipated that the column testing will mimic the saturated-unsaturated behaviour of deposited tailings under field conditions.

3.2.2 Sedimentation/self-weight consolidation: Stage 1

The first stage of experiments investigated sedimentation/self-weight consolidation, immediately after the tailings were deposited. The drainage boundary was at the top surface of the deposited tailings during this stage, which progressed until the excess pore pressure was fully dissipated and no vertical strain was registered. Figure 2 presents schematic representations of the process of sedimentation and self-weight consolidation during Stage 1 over time.

Figure 2 shows the profile of the tailings immediately following deposition of the slurry. Figure 2 provides a conceptual illustration of the tailings with a uniformly distributed solids content at the initial stage, followed by separation of solids from the fluid as self-weight consolidation progressed with time. The drainage flow during the self-weight consolidation process was in an upward direction as shown using the arrows.

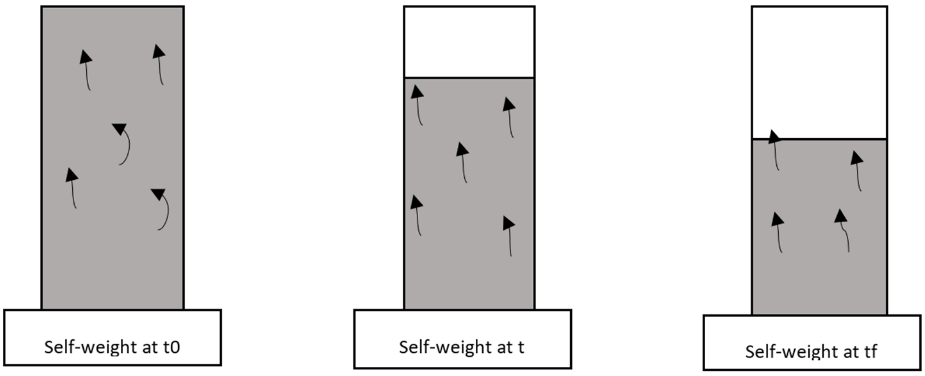

Figure 2 Schematic representation of self-weight consolidation process during Stage 1 over time

3.2.3 Consolidation using applied suction: Stage 2

The process of consolidation using an applied suction, also specified as Stage 2, followed completion of the self-weight consolidation process, Stage 1, is described in this section. The process of consolidation using an applied suction was completed incrementally by applying incremental increases in suction to the bottom boundary. This process uses the bottom boundary as its drainage boundary, as the flow of water is directed in a downward direction due to the exerted suction at the bottom of the column. A schematic representation of the consolidation process using applied suction is given in Figure 3. The progression of consolidation is displayed using change in total height and direction of water flow.

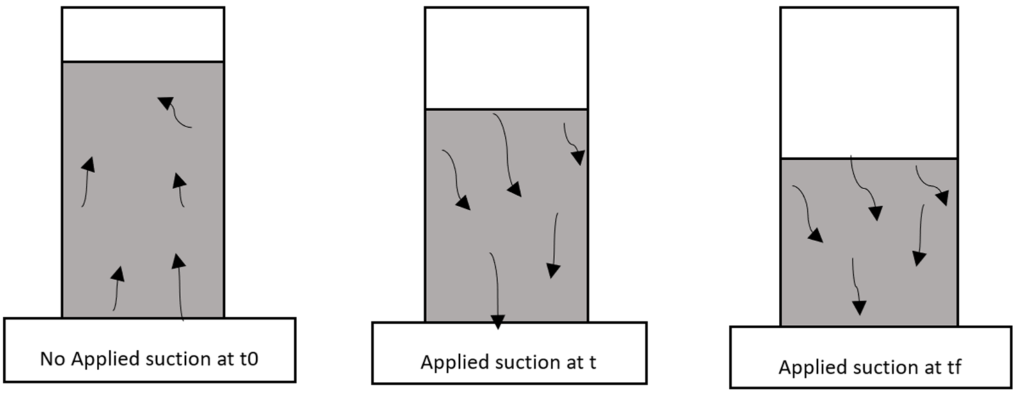

Figure 3 Schematic representation of consolidation using applied suction process during Stage 2 over time

The change in water pressure distribution from hydrostatic at the end of self-weight consolidation (Stage 1 end and prior to Stage 2 start) to an applied suction within the deposited tailings once the applied suction reached an equilibrium condition, is shown in Figure 3.

4 Results and discussion

Laboratory measured engineering properties of flocculated FFT and FCTC are presented in this section. The measured results include standard settling tests and meso-scale self-weight consolidation tests, standard unsaturated properties characterisation tests such as SWCC and SC; standard LSC compressibility and hydraulic conductivity tests; meso-scale consolidation using applied suction test for both materials are presented.

4.1 Settling/self-weight consolidation

Settling test results for the flocculated FFT are presented in Figure 4 based on four separate tests. These four separate settling tests are completed at different period using different batch of samples, however, using similar sample preparation to replicate target solids content. A significant volume change occurred instantaneously following deposition of the tailings due to sedimentation and self-weight consolidation. Overall, slight variations in the measured settling rates were observed between the four tests. The settling column results were used to determine the duration of the self-weight consolidation test, as proposed by Imai (1981). Figure 5 shows the self-weight consolidation time for the flocculated FFT. The results from the settling column tests were extrapolated to complete the curve after day 95 towards infinitesimal settlement. Therefore, the self-weight consolidation process was finalised by day 102 and the next stage of testing commenced. The average hydraulic conductivity from the settling column test was determined to be k = 3.42E -07 m/sec.

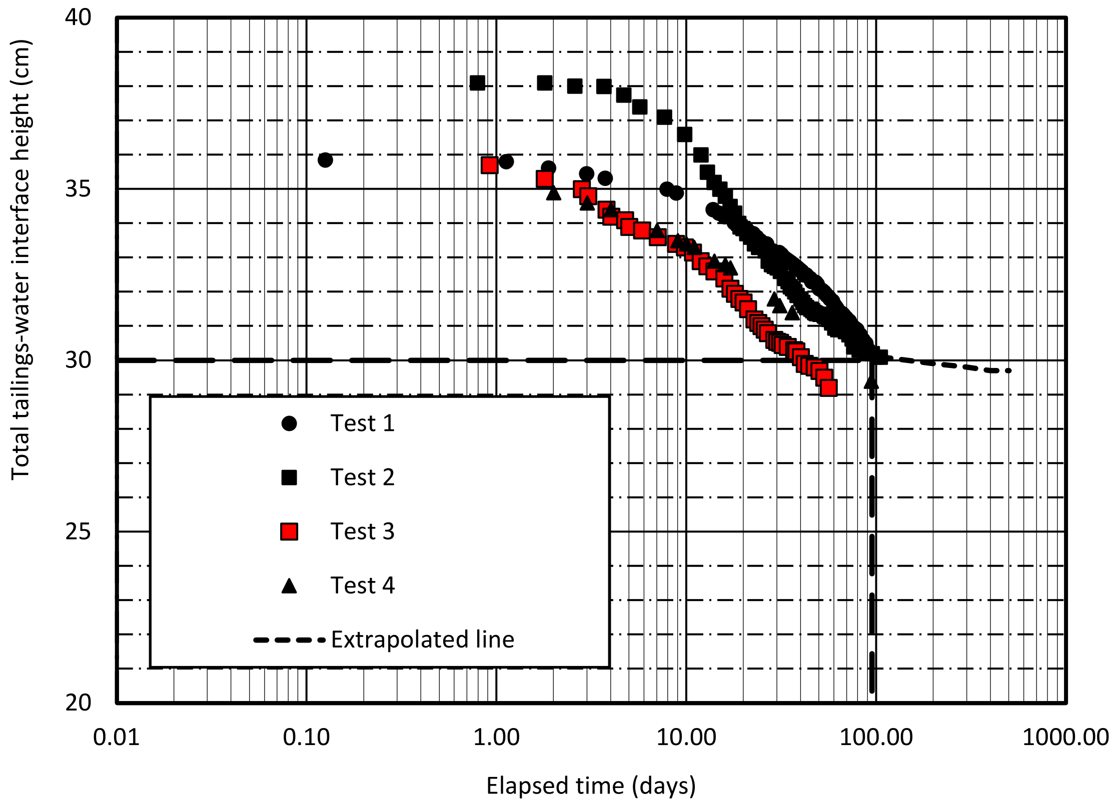

Figure 4 Determination of self-weight completion using the method proposed by Imai (1981)

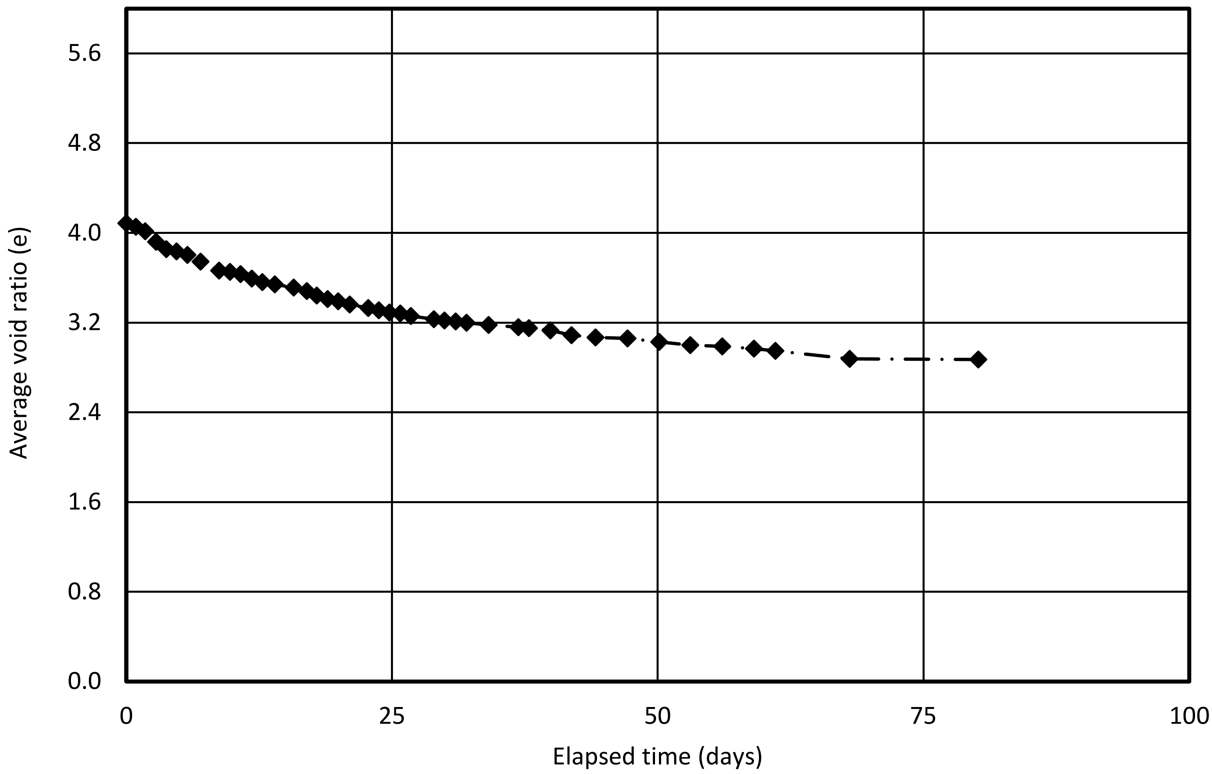

Figure 5 Change in void ratio during the self-weight consolidation for the flocculated FFT

A comparison between the observed settlement from the column settling test (using a 1,000 ml graduated cylinder) and the self-weight consolidation from the meso-scale test indicates the final void ratio of 3.0 (Test 2 and Test 4) for the settling test and 2.9 for the meso-scale test as shown in Figures 4 and 5, respectively. In general, the results obtained from the material characterisation test and the meso-scale test agreed. The measured hydraulic conductivity from the meso-scale self-weight consolidation was 6.64E-07 m/sec compared to the hydraulic conductivity of 3.42E-07 m/sec from the settling column test. The hydraulic conductivity results are within the same order of magnitude as results from a small scale (i.e. the settling column of a 1,000 ml graduated cylinder) and meso-scale apparatus (i.e. 30 cm diameter and 60 cm height) for the flocculated FFT. The repeatable results show that the scale of the testing apparatus did not have a significant effect on the results.

4.2 Unsaturated engineering properties (SWCC and SC)

Figure 6 presents the measured SWCC for both flocculated FFT and FCTC and some values from literature using matric suction and gravimetric moisture content. The SWCC plot using degrees of saturation was generated from the SWCC using gravimetric water content and the SCs. The SWCC air-entry value (AEV) is shown as 200–300 kPa for both flocculated FFT and FCTC compared to 100 kPa and 200 kPa as reported by Yao (2016) and Soliemani et al. (2014), respectively.

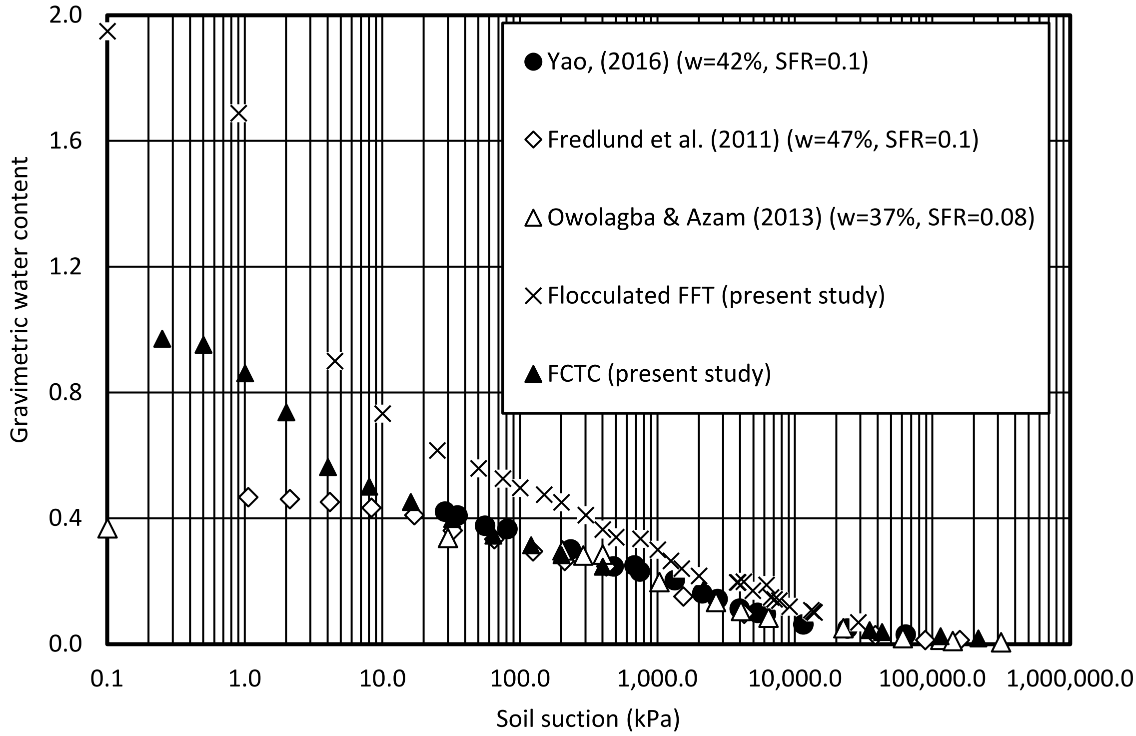

Figure 6 **Comparison of SWCC between TT from the literature (Innocent-Bernard, 2013; Yao 2016) Flocculated FFT, and FCTC (present study)**

Figure 7 presents the shrinkage curve of flocculated FFT and FCTC from the experimental study. Obtained results are consistent with shrinkage results reported by Yao (2016).

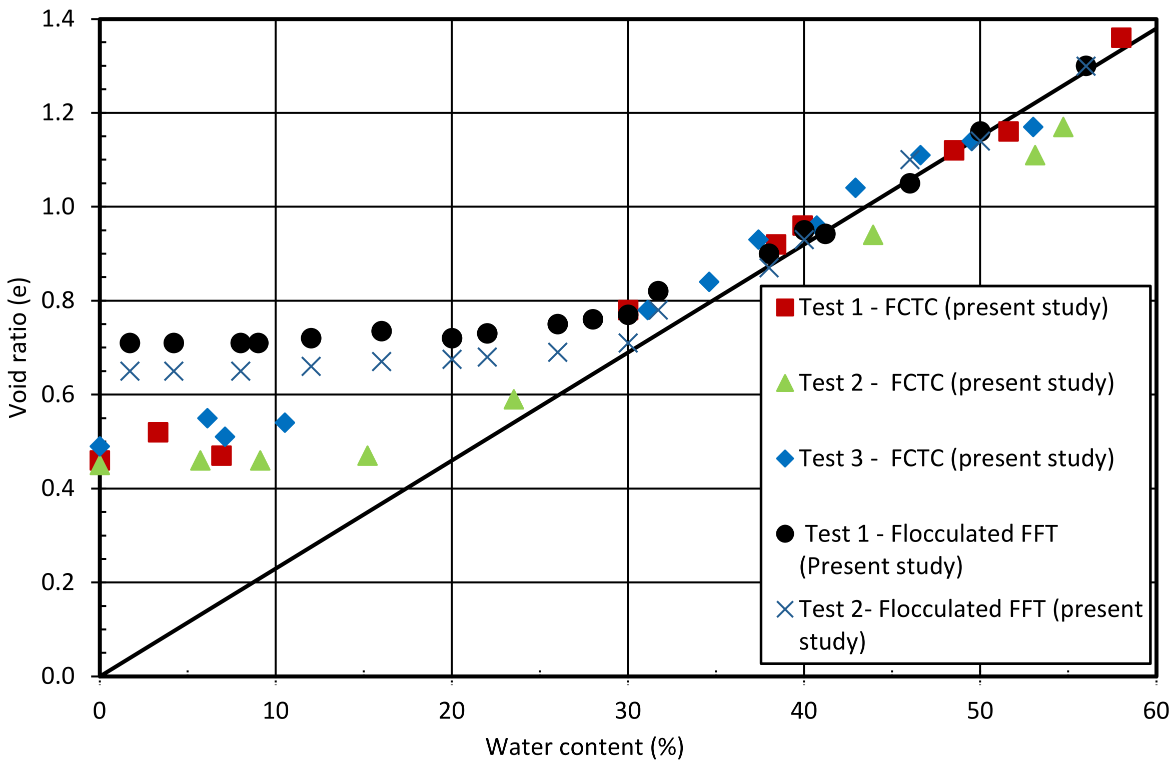

Figure 7 **Comparison of shrinkage curves for flocculated FFT reported in the literature (modified from Yao 2016)**

4.3 Large-strain consolidation properties (compressibility and hydraulic conductivity curves)

Figure 8 presents the relationship between effective stress and void ratio from LSC testing using the step loading method for the flocculated FFT, FCTC and various types of tailings from literature. The tailings exhibited a decreasing trend in void ratio as a function of effective stress. Power law equations were found to best describe the volume compressibility behaviour of the investigated flocculated FFT and FCTC. Figure 9 presents the void ratio versus hydraulic conductivity results for the flocculated FFT, FCTC and various tailings from literature. An increasing power law function is exhibited and about four orders of magnitude difference in hydraulic conductivity is shown between the highest and lowest void ratios.

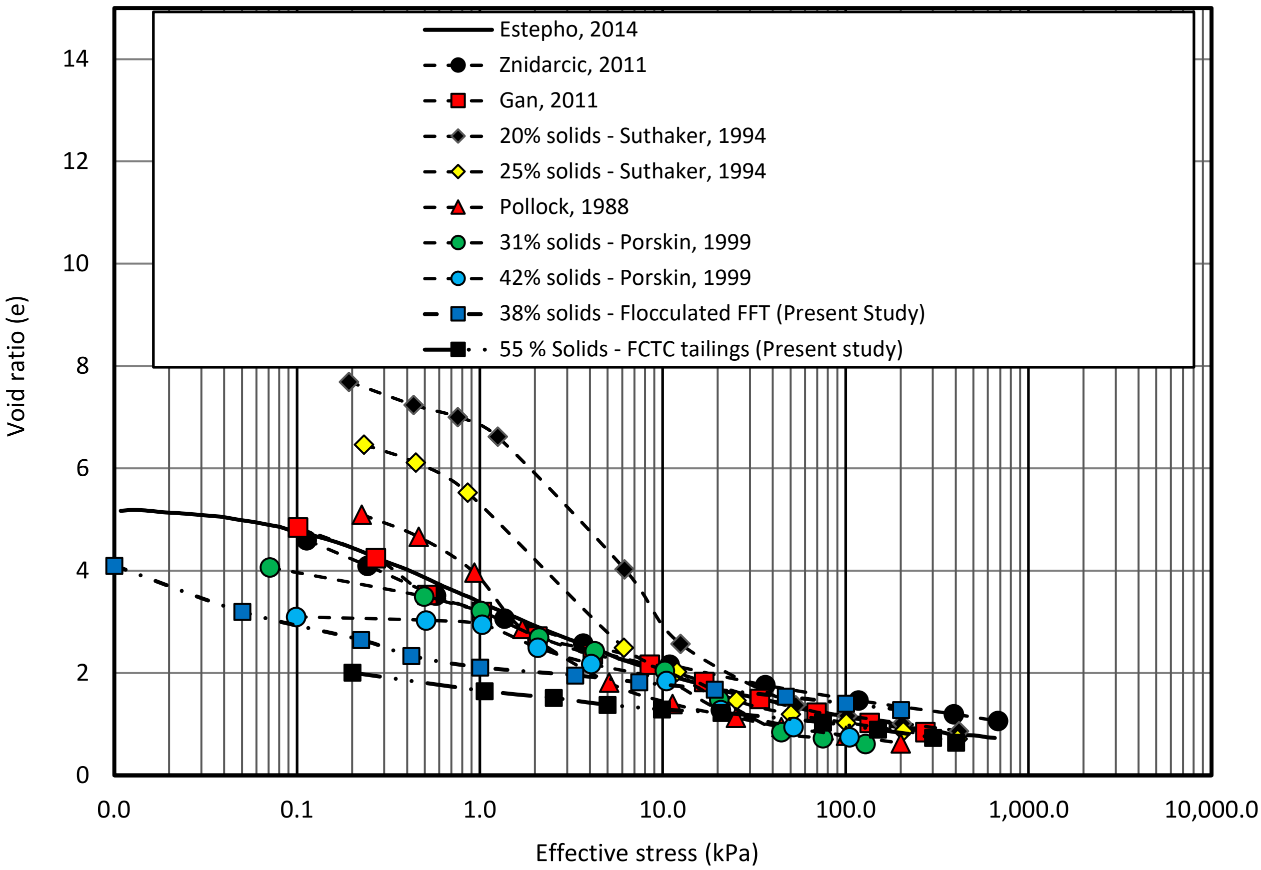

Figure 8 Compressibility curves for different samples of fluid fine tailings reported in the literature compared with the flocculated FFT and FCTC of the present study (after Yao 2016)

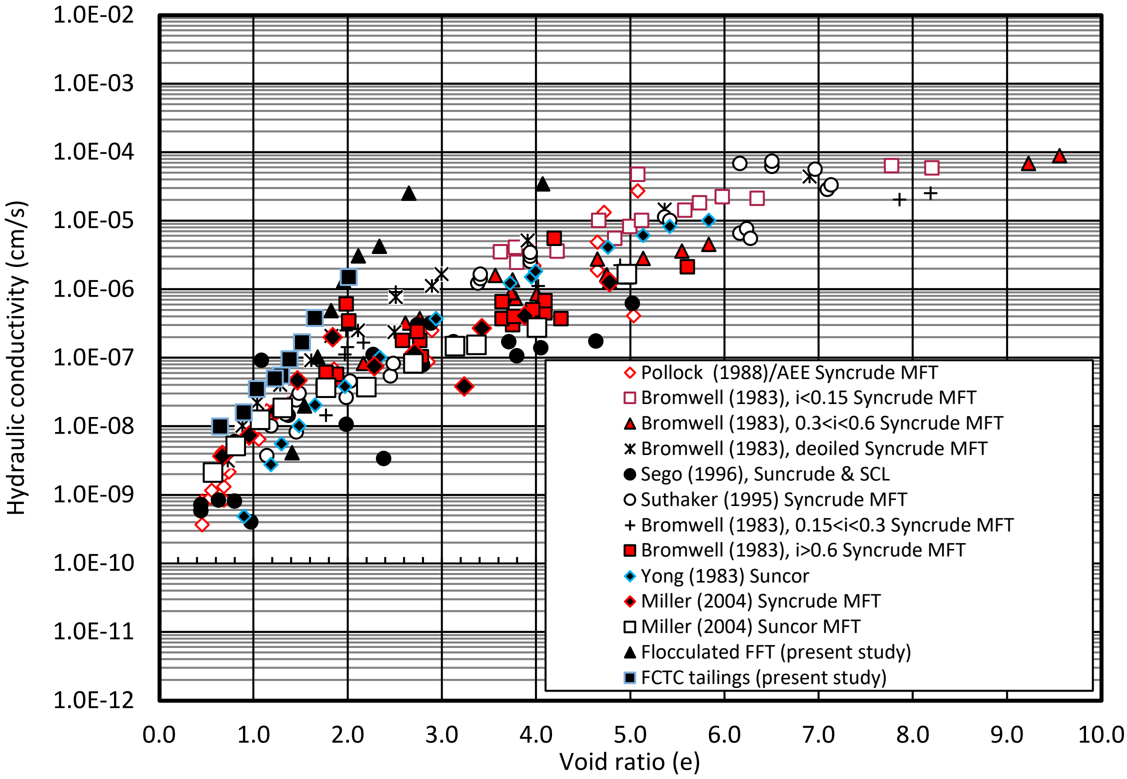

Figure 9 Hydraulic conductivity of fluid fine tailings reported in the literature (after Jeeravipoolvarn 2015; Yao 2016)

4.4 Consolidation using applied suction test

Results of consolidation using the applied suction technique with a meso-scale column are presented in this section.

4.4.1 Stress-strain relationships

The combined results of incremental applied suction in relation to the void ratios for both flocculated FFT and FCTC are presented in Figure 10. Figure 10 presents that the flocculated FFT achieved a 60% change in total volumetric strain due to an applied suction of 60 kPa, compared to 29% for the FCTC.

The self-weight consolidation process provided a 24% total strain reduction of deposited tailings. Large volumetric changes were observed during an applied suction of 30 kPa compared to the subsequent incremental loads. The large volume changes for flocculated FFT were observed during both the material characterisation and meso-scale test periods. The FCTC exhibited less volumetric strain compared to flocculated FFT; however, similar changes were observed for the applied suction up to 30 kPa compared to the higher incremental suction values.

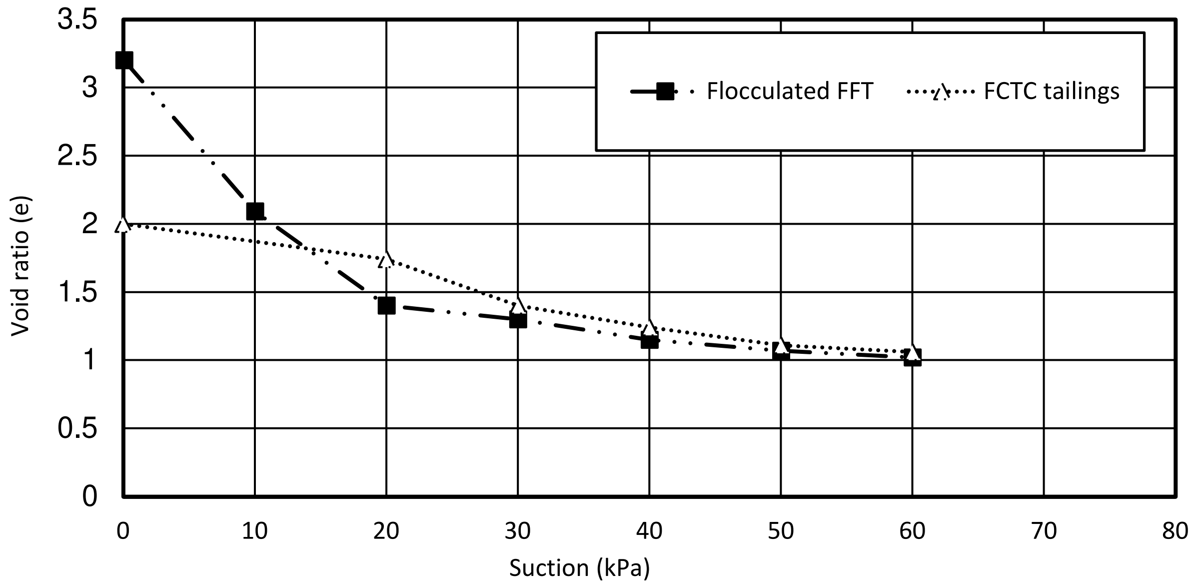

Figure 10 Final volumetric strain measured during consolidation using applied suction technique for both flocculated FFT and FCT

Figure 11 presents the measured and predicted results for the increments of suction of the flocculated FFT. Overall, bigger differences were observed between the measured and predicted results during the initial stage (i.e. from 10 to 30 kPa). The differences decreased with additional increments as expected. The results give reasonable agreement for the increments of suction of 40 to 60 kPa. The discrepancy at the initial stage can be attributed to not reaching equilibrium prior to the subsequent incremental suction increase (i.e. from 10 to 30 kPa). The pore pressure values were not available for those specified increments to confirm when equilibrium was reached. However, the measured and predicted results agreed for the later consolidation stage (i.e. 40 to 60 kPa suction), when pore pressure measurements were available to confirm that equilibrium had been reached.

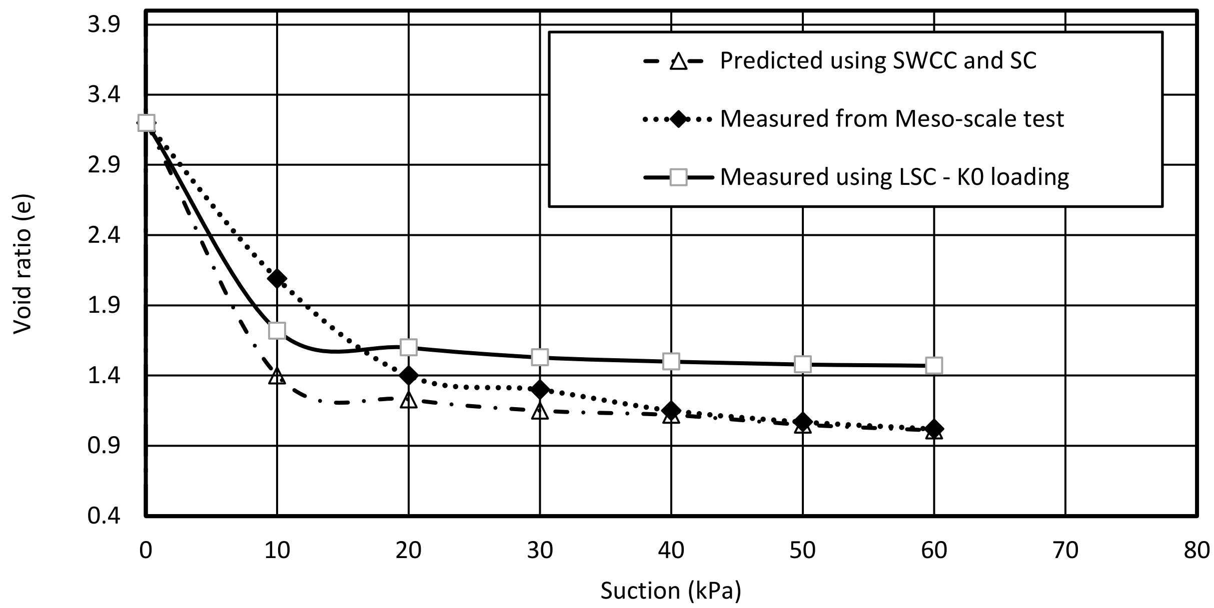

Figure 11 Comparison of measured and predicted final void ratios in relation to the applied suction for the flocculated FFT

Similarly, Figure 12 presents measured and predicted results for the FCTC. Similar to the results observed in flocculated FFT (Figure 11), a larger difference was observed between the predicted and measured void ratio for the initial stage (i.e. 20 to 30 kPa). The possible reason for the discrepancy was that the tailings may not have reached equilibrium at the time of the experiment completion.

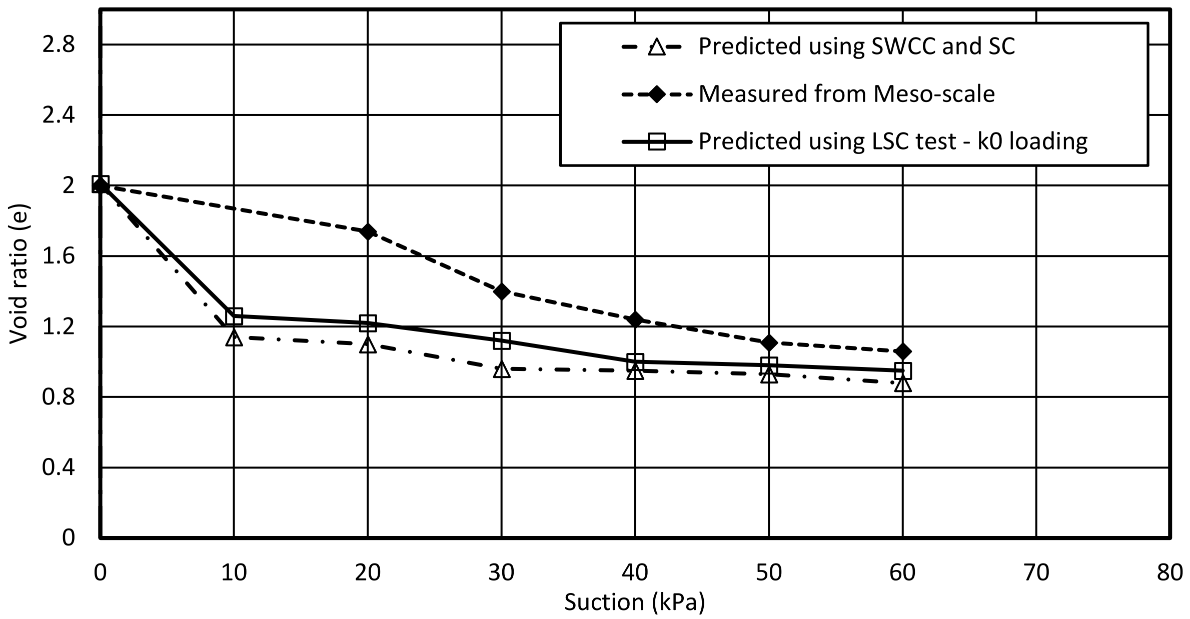

Figure 12 Comparison of measured and predicted final void ratios in relation to the applied suction for the FCTC

In addition, the lower hydraulic conductivity property for FCTC required a longer time to reach an equilibrium state compared to the flocculated FFT, since both columns were connected to a single vacuum pump and desiccator. The higher suction increments showed better agreement for both prediction methods (unsaturated soil properties and LSC testing). The minor differences in values observed are errors from estimating the volumetric strain for the meso-scale testing since the change in height measurements were monitored using a rough estimation technique. Overall, the predicted values were acceptable and within the margins of error.

In general, acceptable results were achieved from the meso-scale testing, which asserts the use of the unsaturated soil property functions to predict expected volumetric strain and change in void ratio due to applied suction conditions either for laboratory or field conditions.

The relationships used to predict the void ratio are best represented using a power function for both methods (i.e. using unsaturated soil property and standard LSC test). The correlations are summarised in Table 2. These correlations can be used to predict the material properties from available data. Generic formulae can be developed by conducting significant characterisation tests for FFT.

Parameters listed in Table 2 are void ratio (e), matric suction (ψ), and effective stress (σ').

Table 2 Void ratio versus suction from column test compared with predicted using unsaturated soil properties and LSC properties

Materials used	From unsaturated soil property results	LSC results
Flocculated FFT	$e = 2.0949(\psi)^{-0.176}$	$e = 2.0031(\sigma')^{-0.077}$
FCTC	$e = 2.8424(\psi)^{-0.312}$	$e = 2.6798(\sigma')^{-0.259}$

The compressibility results obtained under k_0 – loading conditions (i.e. standard LSC testing) were compared to the meso-scale results, which were conducted under isotropic loading conditions and ideal in representing the field trails. Theoretical formulations for both isotropic and k0–loading conditions were used to carry out the calculation assuming Poisson's ratio of 0.3. Difference in the final void ratio is observed between the two methods and considerations to account for this difference are recommended.

4.4.2 Solids content

The initial and final solids content changes along the profile of the consolidating tailings are presented in Figure 13 for both flocculated FFT and FCTC. The solids contents were measured following completion of the test and a few months after the completion of the consolidation test for the flocculated FFT. The columns apparatus were loosely covered on the top surface using a plastic lid but not entirely sealed to control potential loss due to evaporation. The cover lid had been continuously removed to perform tests during the testing stage. The results were used to check if evaporation was occurring near the surface of the deposited tailings and along the profile.

The solids content for the flocculated FFT showed a slight increase near the base of the column but was within the margin of error. The predicted solids content through the profile shows good correlation compared to the measured solids content for both flocculated FFT and FCTC. However, a 15% increase in solids content was observed for the test completed three months after the completion of the consolidation test. It is evident that an increase in solids content in the measured results could be attributed to an additional loss of moisture from the effect of evaporation over time. A further assessment is required to verify the measured and predicted results to include the effect of evaporation as part of future work.

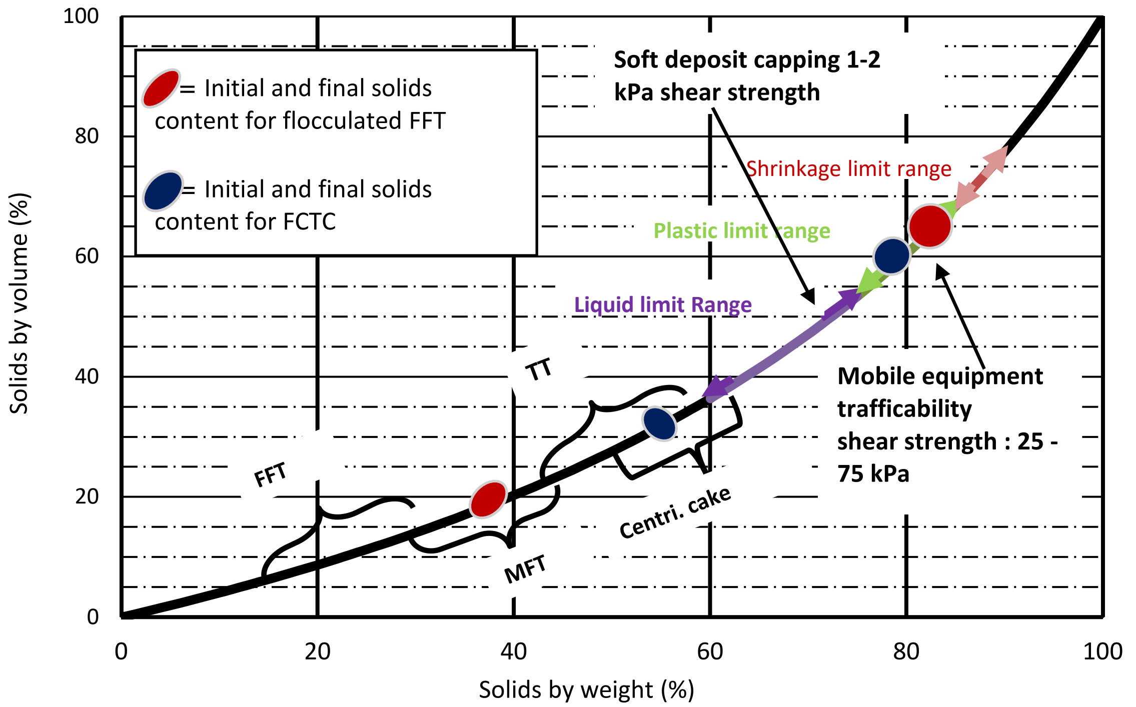

Figure 13 Comparison of the initial and final solids content for both flocculated FFT and FCTC following completion of the experimental test (modified from Fair & Beier 2012)

In general, an increase in solids content was observed between initial deposition and final following the completion of consolidation tests using an incremental applied suction of 60 kPa. The average initial and final solids content for the profile was 38% and 85% (with evaporation), respectively, for the flocculated FFT. Similarly, the average initial and final solids content for the FCTC was 53–55% and 75%, respectively. Development of suction attributed in shifting the tailings property as an increase in solids content progressed as depicted in Figure 13. For instance, the final measured solids content for the flocculated FFT and FCTC falls within the plastic limit range, as shown in Figure 13, compared to its initial condition. The plastic limit range has expected values of undrained shear strength ranging between 25–75 kPa, that is suitable for mobile equipment trafficability (Fair & Beier 2012).

5 Conclusion

The following conclusions were drawn following the experimental study for the process of consolidation using incrementally applied suction for the materials tested:

1. **The functionality of the column apparatus**: the functionality of the column apparatus in mimicking conceptual field drying/desiccation process was confirmed. A transition zone formed near the tailings surface as observed in the field trials for drying/desiccation cases. The consolidation process using increments of suction showed an increase in effective stress with an increase in suction. In addition, an increase in undrained shear strength with time and depth was observed as the increase of effective stress progressed. Moreover, consolidation using increments of suction allowed comparison of the change in volumetric strain between methods using isotropic and k_0-loading conditions. In addition, the results from the meso-scale column test were compared with different predictive techniques such as using the SWCC and SC (i.e. unsaturated soils properties functions (USPF)).

2. **Settling/self-weight consolidation**: in general, the self-weight consolidation process exhibited a comparable pattern and an agreement to the results reported in the literature. The results from the meso-scale column confirmed the settling test results in relation to the total settlement and dissipation time for excess pore pressure. The results provide satisfactory agreement when compared to larger scale testing of similar material (Fisseha et al. 2018).

3. **Volumetric strain**: the measured volumetric strain using the meso-scale column was compared with predictive methods using unsaturated soil properties and compressibility curves. The results show an average initial and final void ratio for the flocculated FFT was 3.2 and 1.01, respectively. The flocculated FFT shows a good agreement with predictive methods using USPF, mainly for the higher suction measurements. The predictions using the compressibility curve underestimated the total volumetric strain values for the flocculated FFT. Similarly, the results for the average initial and final void ratio of the FCTC show 2.01 and 0.95, respectively. The predictive method using both USPF and compressibility curves overestimated the volumetric strain change for the FCTC. However, these methods can still be used to predict the final volumetric strain with reasonable acceptance.

4. **Isotropic and k_0-loading comparison:** the comparison between the isotropic and k_0-loading conditions was completed to verify the technique commonly used by the industry (i.e. compressibility curve from LSC test). The calculation was completed assuming a Poisson's ratio of 0.3 and modulus of elasticity due to applied suction equal to Young's modulus from LSC test. The calculated results using isotropic method shows 9% higher for the flocculated FFT and 4% higher for the FCTC compared to the k_0-loading methods. The isotropic method formulation considers applied suction effect only compared to k_0-loading condition (i.e. LSC testing method). Therefore, the LSC method overpredicts the estimation of final void ratio compared to actual field condition. An appropriate correction factor should be considered as a recommendation during engineering design and modelling stages.

5. **Solids content:** an increase in solids content is attributed to the applied suction during the consolidation test, and these results are observed in the final solids content of the tailings. The increase in the solids content contributed towards changing the tailings property as presented in Figure 13. For instance, the final measured solids content for the flocculated FFT and FCTC falls within the range of plastic limit compared to its initial condition. The plastic limit range has expected values of undrained shear strength ranging between 25–75 kPa, that is suitable for mobile equipment trafficability (Fair & Beier 2012).

The conclusions drawn from the present study focuses on calibrating and using new technique (i.e. applied suction method) to consolidate tailings with large-strain properties, followed by predicting the consolidation properties of materials by using unsaturated soils property functions. Since the column apparatus design and applied technique follow fundamental principles of soil mechanics (mainly unsaturated soils), the author strongly believes repeatable and consistent can be achieved if applied to soft tailing (such as tailings with varies composition other than oil sands).

In the field, use of suction can be utilised through materials which exhibit unsaturated soil behaviours during the tailings management consideration. The following list of tailings management options are some of the methods including unsaturated soil behaviour: dewatered tailings, paste and thickened tailings, filtered tailings, comixed and comingled tailings, dry stack.

Acknowledgement

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