



SOIL SUCTION IN MINE TAILINGS

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THESIS SUMMARY

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The failure of the tailings dam at Merriespruit highlighted the uncertainties concerning the strength and stability of such dams. Owing to the theory, a tailings dam would remain stable at a slope equal to the material's internal angle of friction and is thus designed accordingly. In practice however, it was found that these structures remain stable at slopes greater than this specified angle. It was also found that, irrespective of sufficient freeboard, failures often occur after prolonged rainfall. Negative pore or suction pressures present in the tailings, especially in the upper regions, increases the effective stress and hence the stability of the structure. Currently the friction properties of tailings can be measured with relative accuracy whereas the opposite is true for the suction pressures. Measurement of these pressures would result in the economical design and risk assessment of tailings dams.

The aim of the thesis is therefore to design, calibrate and test an instrument that is able to measure the suction pressures in gold mine tailings.

A literature survey was conducted to assess the advantages and disadvantages of the available suction measurement devices. Attention was paid to the specific characteristics of suction pressures in mine tailings. This study showed that the tailings environment is harsh with varying moisture contents and temperatures as well as high salinity. The instrument required for measuring the suction pressures in gold mine tailings would have to be able to operate under these conditions. The literature survey however, indicated that most of the instruments, with the exception of the Imperial College suction probe, would not comply with these criteria. Limitations such as suction range, long response time and their susceptibility to salinity and other environmental influences made them unsuitable.

A suction probe was designed and built based on the Imperial College suction probe but using a lower air entry ceramic. Laboratory desorption tests were conducted on two samples of gold mine tailing. These tests indicated some design flaws of the instrument but none the less gave an indication of the suction characteristics of the material. The instrument was however discarded after some period of time due these design flaws and a new instrument, namely the mid-plane suction probe, was designed and built. This probe incorporated a Kyowa PS-2KA pressure transducer and the overall size was reduced to the dimensions generally used for a mid-plane triaxial pore pressure sensor (hence the name). Desorption tests were carried out on the same tailings using the mid-plane suction probe. These tests were successful demonstrating that the goals set out in this thesis were met.

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TABLE OF CONTENTS

1	INTRODUCTION	1-1
1.1	Background	1-1
1.2	Objectives	1-2
1.3	Scope	1-2
1.4	Methodology	1-2
1.5	Organisation	1-3
LITERATURE REVIEW: INVESTIGATION OF SUCTION MEASUREMENT 2-1		
2.1	Definition of Suction	2-1
2.1.1.	<i>Matric Suction</i>	2-2
2.1.2.	<i>Osmotic Suction</i>	2-4
2.2	Construction of a Tailings Dam	2-9
2.3	Suctions in a Tailings Dam	2-12
2.4	Suction Measurement Devices	2-17
2.5	Total Suction Measurement Devices	2-18
2.5.1.	<i>Psychrometer</i>	2-18
2.5.2.	<i>Filter Paper</i>	2-23
2.6	Matric Suction Measurement Devices	2-26
2.6.1.	<i>Cavitation</i>	2-26
2.6.2.	<i>Suction and Pressure Plate</i>	2-29
2.6.3.	<i>Thermal Blocks</i>	2-31
2.6.4.	<i>Gypsum Blocks</i>	2-32
2.6.5.	<i>Tensiometer</i>	2-34
2.6.6.	<i>Imperial College Suction probe</i>	2-37
2.7	Discussion of the Literature Review	2-39

3	DESIGN AND DEVELOPMENT OF THE SUCTION PROBE	3-1
3.1	Description of Instrument	3-1
3.2	Machining and Assembly of Probe	3-2
3.3	Saturation and De-airing of Probe	3-3
4	TEST PROCEDURE AND CALIBRATION	4-1
4.1.	Calibration	4-1
4.1.1.	<i>Calibration of the Suction Probe in the Positive Pressure Range</i>	<i>4-1</i>
4.1.2.	<i>Calibration of the Probe in the Negative Pressure Range</i>	<i>4-2</i>
4.2.	Testing in the Laboratory	4-3
5	DEVELOPMENT OF A MID-PLANE SUCTION PROBE	5-1
5.1	Design of the Mid-plane Suction probe	5-1
5.2	Maching and Assembly	5-2
5.3	De-airing an Saturation	5-2
5.4	Calibration	5-2
5.5	Laboratory Tests	5-3
6	DISCUSSION	6-1
7	CONCLUSIONS	7-1
8	REFERENCES	8-1

LIST OF TABLES

Table 2.1:	Summary of Suction Measurement Devices	2-42
Table 4.1:	Fundamental Properties of Pay Tailings Dam	4-8
Table 4.2:	Laboratory Desorption Test Results using the Original Suction Probe	4-9
Table 5.1:	Laboratory Desorption Test Result using the Mid-plane Suction Probe	5-4

LIST OF FIGURES

Figure 2.1:	Total, matric and osmotic suctions for glacial till (after Krahn and Fredlund, 1972)	2-43
Figure 2.2:	The surface tension phenomenon at the air-water interface, a) Intermolecular forces on contractile skin and water b) Pressure and surface tension acting on curve two dimensional surface (after Fredlund and Rehardjo, 1993)	2-43
Figure 2.3:	Simplified model- Ions attached to rubber-like bands. Salt content is higher at centre than in free water (after Sparks, 1995)	2-44
Figure 2.4:	Typical desorption and adsorption curves for silty soil (after Aubertin et al, 1998)	2-44
Figure 2.5:	Cycloning by upstream method (after Messrs et al, 1989)	2-45
Figure 2.6:	Cycloning by downstream method (after Messrs et al, 1989)	2-45
Figure 2.7:	Cycloning by centreline method (after Messrs et al, 1989)	2-45
Figure 2.8:	The relationship between χ parameter and the degree of saturation (S) a) χ values for a cohesionless silt (after Donald, 1961) and b) χ values for compacted soils (after Blight, 1961)	2-46
Figure 2.9:	Relationship between the soil water characteristic curve and shear strength (after Fredlund et al, 1995)	2-46
Figure 2.10:	The influence of matric suction on the factor of safety of the Lethabo ash dump for shallow, planar failure surfaces (after Fourie et al, 1998)	2-47
Figure 2.11:	A typical thermistor psychrometer (after Richards, 1965)	2-47
Figure 2.12:	Diaphragm of the thermistor transistor (after Kay and Low, 1970)	2-47
Figure 2.13:	Calibration curves for Peltier and wet-loop thermocouple psychrometer (after Zollinger et al, 1966)	2-48
Figure 2.14:	Thermocouple psychrometer (after Ridley and Brady, 1997)	2-48
Figure 2.15:	Calibration curves of probe No 7 at different cooling currents showing the drift in output for a time interval of 7 days (after Baker et al, 1973)	2-48
Figure 2.16:	Typical output of a psychrometer (after Ridley and Wray, 1996)	2-49
Figure 2.17:	Deterioration in sensitivity with continued usage (after Zerhouni, 1995)	2-49
Figure 2.18:	Comparison of desorption isotherm for Millville silt loam obtained by two types of thermocouple psychrometers (after Zollinger et al, 1966)	2-49

Figure 2.19:	Arrangement for measuring suction using filter paper (after Ridley and Brady, 1997)	2-50
Figure 2.20:	Filter paper calibration for papers placed in contact with soil (after Chandler and Gutierrez, 1986)	2-50
Figure 2.21:	Berthelot tube (after Meyer, 1911)	2-50
Figure 2.22:	Crevice model of tension breakdown (after Harvey et al, 1944)	2-51
Figure 2.23:	Suction plate (after Ridley, 1993)	2-52
Figure 2.24:	Pressure plate (after Ridley and Brady, 1997)	2-52
Figure 2.25:	Pressure changes in pressure plate (after Ridley and Brady, 1997)	2-52
Figure 2.26(a):	Thermistor block details (after Aitchison and Richards, 1965)	2-53
Figure 2.26(b):	Thermal conductivity sensor (after Sattler and Fredlund, 1989)	2-53
Figure 2.27:	Calibration of a typical conductivity sensor(after Sattler and Fredlund, 1989)	2-53
Figure 2.28:	Gypsum block details (after Aitchison and Richards, 1965)	2-54
Figure 2.29:	Calibration curve for gypsum block (after Aitchison and Richards, 1965)	2-54
Figure 2.30:	Manometer tensiometer (after Stannard, 1992)	2-54
Figure 2.31:	Vacuum-gauge tensiometer (after Stannard, 1992)	2-55
Figure 2.31:	Pressure transducer tensiometer (after Stannard, 1992)	2-55
Figure 2.32:	Schematic view of an osmotic tensiometer (after Peck and Rabbidge, 1966)	2-55
Figure 2.33:	Imperial College suction probe (after Ridley, 1993)	2-56
Figure 2.34:	Suction measurement (after Ridley and Burland (1995)	2-56
Figure 3.1:	Machine drawing of suction probe	3-5
Figure 3.2:	Schematic illustration of de-airing equipment	3-6
Figure 4.1:	Suction probe in modified triaxial cell	4-9
Figure 4.2:	Combination calibration curve of adopted methods	4-10
Figure 4.3:	Machine drawing of modified oedometer top-cap	4-11
Figure 4.4:	Modified manometer calibration apparatus	4-12
Figure 4.5:	Grading analysis of mine tailings samples (after Vermeulen)	4-13
Figure 4.6:	Relationship between matric suction and degree of saturation of fine tailings for the various desorption tests	4-14
Figure 4.7:	Relationship between matric suction and degree of saturation of coarse tailings for the various desorption tests	4-15

Figure 4.8:	Combination soil water characteristic curve and shrinkage curve of fine tailings	4-16
Figure 4.9:	Combination soil water characteristic curve and shrinkage curve of coarse tailings	4-17
Figure 5.1:	Machine drawing of mid-plane suction probe	5-5
Figure 5.2:	Construction of mid-plane suction probe	5-6
Figure 5.3:	Combination soil water characteristic curve and shrinkage curve of fine tailings	5-7
Figure 5.4:	Combination soil water characteristic curve and shrinkage curve of coarse tailings	5-8
Figure 6.1:	Pressure gradient in a tailings sample	6-6
Figure 6.2:	Relationship between matric suction and time for both fine and coarse tailings	6-7
Figure 6.3:	Combination soil water characteristic and shrinkage curve of fine and coarse tailings	6-8
Figure 6.4:	Soil water characteristic curve of fine tailings using the mid-plane suction probe	6-9
Figure 6.5:	Soil water characteristic curve of fine tailings using the mid-plane suction probe	6-10

LIST OF SYMBOLS

a, m, n	fitting parameters
C_s	the concentration of the solute
C_ψ	correction factor introduced by Fredlund and Xing (1994) to ensure that θ reach zero as ψ reach a limiting value (ψ_0) equal to 10^7 cm of water.
c'	intercept of the "extended" Mohr-Coulomb failure envelope on the shear stress axis where the net normal stress and the matric suction at failure are equal to zero: it is also referred to as the "effective cohesion"
h	pressure head
h_{oc}	corresponding water head which is linear to the suction
m	undetermined parameter with $m = 1 - (1/n)$
n	porosity
π	osmotic suction
p	slope of linear part of SWCC
q	intercept of linear part of SWCC
R	universal (molar) gas constant i.e. 8.31432J/mol K
R_s	radius of curvature
S	degree of saturation
T	absolute temperature i.e. $T = (273.16 + t^\circ)$ (K)
T_s	tensile pressure
t°	temperature ($^\circ\text{C}$)
$(u_a - u_w)$	matric suction
$(u_a - u_w)_f$	matric suction on the failure plane at failure
u_a	pore-air pressure
u_{af}	pore-air pressure on the failure plane at failure
u_{vo}	saturated pressure of water vapour over a flat surface of pure water at the same temperature (kPa)
v_{wo}	specific volume of water or the inverse of the density of water i.e. $1/\rho_w$ (m^3/kg)
Δu	$u_a - u_w$
Ω	the molar osmotic coefficient of the solute
Ψ	soil suction or total suction (kPa)

\bar{u}_v	partial pressure of the water vapour (kPa)
α	undetermined parameter
χ	a parameter related to the degree of saturation of the soil
ϕ_b	angle indicating the rate of increase in shear strength relative to the matric suction, $(u_a - u_w)_f$
ϕ'	angle of internal friction associated with the net normal stress state variable, $(\sigma_f - u_a)_f$
θ	volumetric water content
θ_r	residual water content
θ_r	residual volumetric water content
θ_s	saturated volumetric water content
$(\sigma_f - u_a)_f$	net normal stress state on the failure plane at failure
ρ_w	density of water i.e. 998kg/ m ³ at t° = 20 °C
ω_v	molecular mass of water vapour i.e. 18.016 kg/kmol
ψ	soil suction
ψ_r	soil suction corresponding to the residual volumetric water content