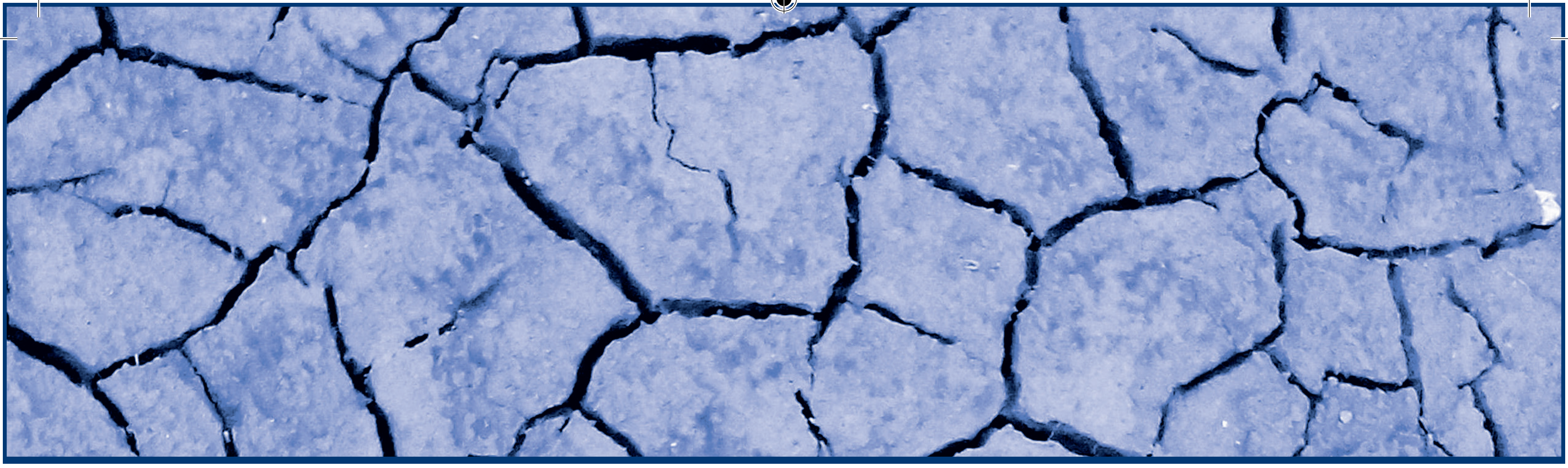
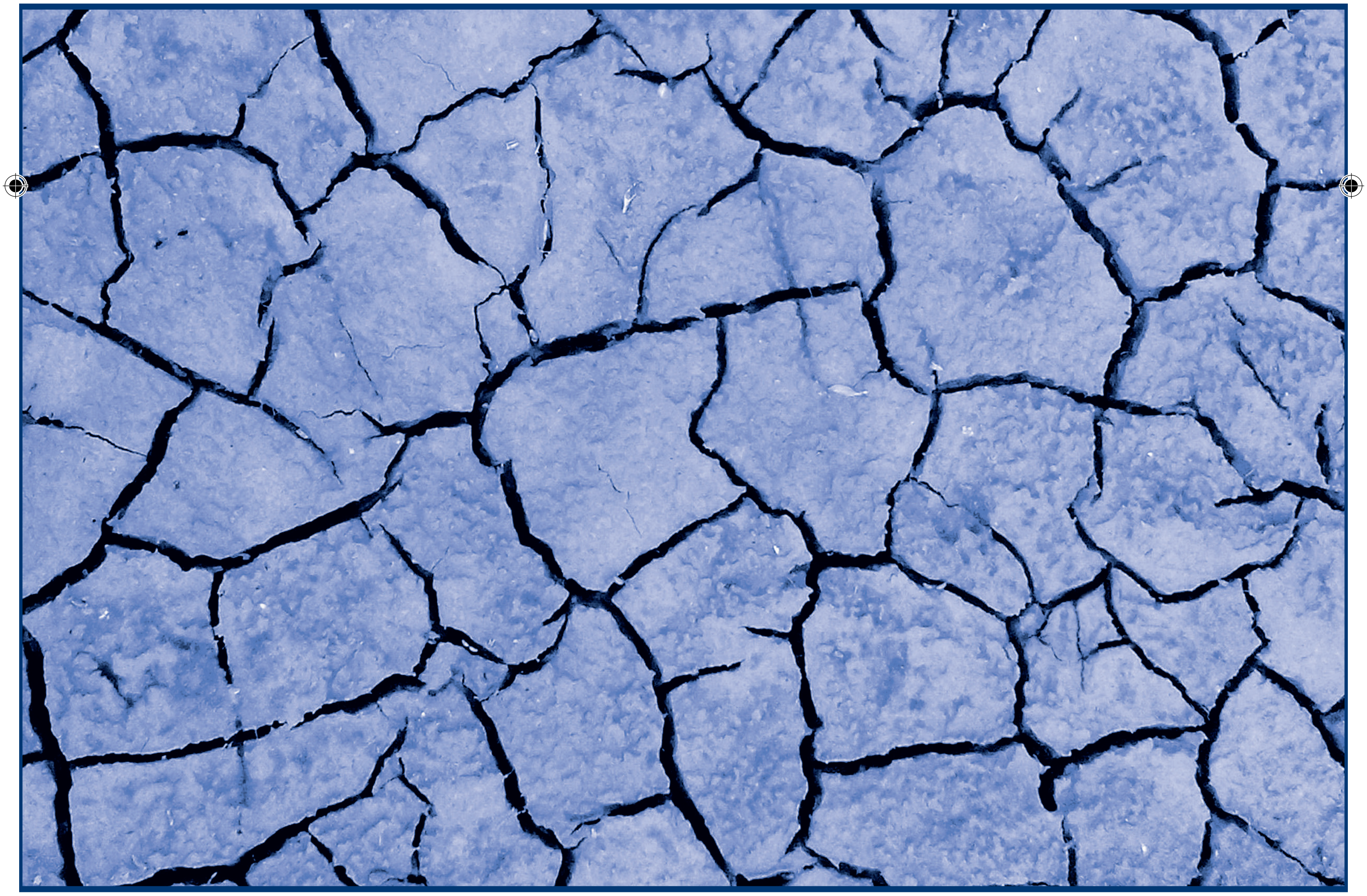


AGS VICTORIA 2017 SYMPOSIUM

Reactive clays and light structures

Wednesday, 25 October 2017, 8:15am – 7:00pm

Rydges Hotel, 186 Exhibition Street, Melbourne



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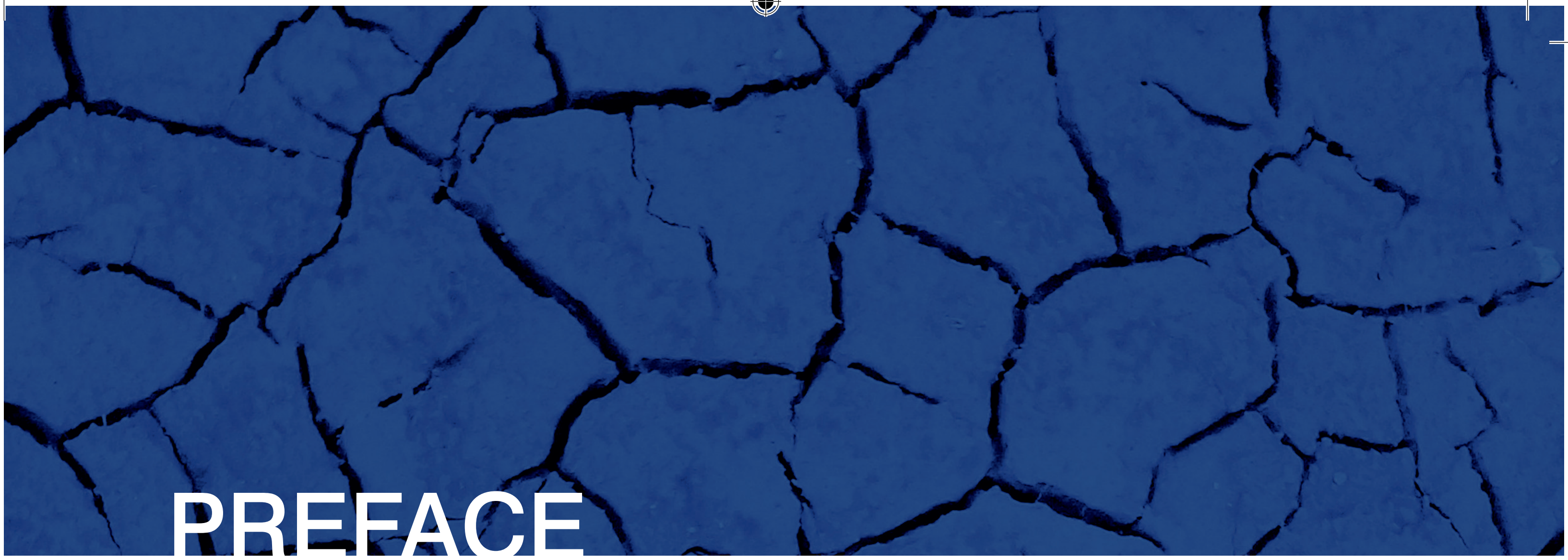

PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2017 Australian Geomechanics Society Victorian Symposium on ‘Reactive clays and light structures’ held on 25 October 2017.

The reactive soils of the Melbourne region form a large portion of its complex and variable geology. In particular, the basaltic volcanics situated to the north and west of Melbourne, which cover some 40% of the Melbourne region present numerous geotechnical challenges, particularly for lightly loaded structures. The geotechnical design and behaviour of lightly loaded structures on reactive soils is one aspect of geotechnical engineering where the public tend to have greater awareness, which is often not the case for the variety of soil and rock mechanics problems geotechnical engineers deal with. This is often borne out through their experience with their own residence, and rightly or wrongly, this contributes greatly to the public’s perception of the geotechnical profession.

The 2017 Australian Geomechanics Society Victorian Symposium covered a variety of geotechnical challenges associated with reactive soils including residential slabs and footings, roads, pavements and other sensitive infrastructure that interact with reactive soils. The Symposium brought together practitioners from consulting, construction and academia to share and discuss their experiences on the topic of reactive soils and their related geotechnical applications.

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ENGINEERS AUSTRALIA

A correlation for the shrink swell index

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ABSTRACT

Site classification to AS2870-2011 requires the soil shrinkage index, Ips. A common assessment method is to carry out a shrink swell laboratory test to calculate the shrink swell index (Iss), which is then used to develop the soil shrinkage index. To undertake a shrink swell index test, an intact thin wall tube sample of cohesive material is required. In hotter and drier areas of Australia, including northern Victoria, it can be difficult to recover intact cohesive samples. The geotechnical practitioner is often required to consider other methods to estimate Iss in order to provide the required site classification. This paper considers a variety of laboratory tests results including Atterberg Limit, Particle Size Distribution, Hydrometer and Iss results from clay samples within Victoria (including Melbourne) to provide an improved correlation to estimate Iss when thin wall tube sampling is not practicable. The data presented to support the correlation includes published test results by others and unpublished test results from projects the author has been involved in.

Keywords: shrink swell, correlation, site classification, hydrometer, Atterberg limits

1 INTRODUCTION

Geotechnical practitioners are often asked to provide clients a site classification in accordance with AS2870-2011. A common process is to conduct shrink swell index (Iss) testing and use that result to assist in the site classification.

For a laboratory test to be successfully conducted, the sample is required to be intact when extracted from a thin wall tube. In practice, samples collected from drier parts of Australia, including northern Victoria, are often cracked and almost always cracked in the summer months. As a consequence the geotechnical practitioner in these areas often has to provide a site classification without the benefit of Iss test results on intact samples.

This paper considers the use of various laboratory test results to provide correlations between Atterberg limit, clay fraction and Iss.

2 SHRINK SWELL TESTING

The Iss test, as the name “shrink swell” suggests, has two components: measuring the shrinkage of the soil on drying; and measuring the swell of the soil on wetting. In contrast to the tests that are commonly referred to as the “Atterberg Limits” (Liquid Limit – LL; Plastic Limit – PL, Linear Shrinkage – LS, though the linear shrinkage test is not strictly part of the Atterberg limits but is often performed in conjunction with them), the shrink swell test is conducted on intact soil that has not been disturbed apart from the sample collection process.

The tests that make up the Atterberg limits are undertaken on disturbed samples that are prepared in the laboratory. Importantly, the initial preparation process includes sieving the samples down to include only material passing 0.425 mm (425 μm) and then grinding the sample.

The hydrometer test provides a method of calculating size fraction of particles less than 75 μm, which in essence is based on the time it takes for the test sample material to settle out of solution. This is a method for calculating the clay fraction (<2 μm) and silt fraction (2 to 75 μm) of a soil.

3 SOME PREVIOUS STUDIES

Previous studies have attempted to find a correlation between shrink swell index results and the Atterberg limits tests. Li et. al. (2016) conducted a wide ranging study of samples from 47 sites, characterising shrink swell behaviour in different materials. The authors concluded that “there is no obvious correlation between the shrink-swell index values and the values of traditional soil indices such as liquid limit, plastic limit, plasticity index and linear shrinkage.”

A different approach was undertaken by Jayasekera and Mohajerani (2003) and Earle (2005). Both these author groups also conducted hydrometer tests on their samples and considered the clay fraction in their correlation equations. The concept of using the clay fraction to consider a soil’s reactive behaviour is not new, with it being proposed by Skempton (1953), who related this to what he termed “activity”. Van Der Merwe (1964) would later use activity to correlate directly to heave in South Africa.

Jayasekera and Mohajerani (2003) conducted tests on a series of clay liners. Eight of their 25 published samples contained Atterberg limit, clay fraction and Iss values.

Earl (2005) conducted a study on the Shepparton Formation (a Quaternary aged geological unit occurring across central and northern Victoria) as part of his Bachelor of Engineering. Earl (2005) conducted testing on 29 samples with Iss, Atterberg limit and clay fraction data.

Both Earl (2005) and Jayasekera and Mohajerani (2003) identified correlations between Iss and clay fraction and Atterberg limits. Jayasekera and Mohajerani (2003) in particular yielded strong correlations (using linear regression), being:

- Iss vs % clay, R^2 = 0.96
- Iss vs PI, R^2 = 0.91
- Iss vs LL, R^2 = 0.85

Earl (2005) in contrast achieved strongest correlations from:

- Iss vs PI x % clay/(%clay+%silt), R^2 = 0.82
- Iss vs LS x % clay/(%clay+%silt), R^2 = 0.82

4 ADDITIONAL TESTING

In order to test whether the correlations noted by these other authors extended beyond their data sets, from 2015 to 2017 Coffey conducted Atterberg limit, clay fraction (hydrometer) and Iss testing on 13 samples from a variety of geological conditions as time and opportunity presented. These test results are included in Table 1 along with data from Earl (2005) and Jayasekera and Mohajerani (2003) that had the full test suite relevant for this paper.

The additional tests included seven tests on insitu thin wall tube samples and five on remoulded samples (C1, C2, C4, C5 and C6). C1 and C2 were remoulded samples from separate tests from the same source sample.

The 13 additional samples included a wide variety of geological terrains, including:

- Newer Volcanics (Footscray and Wyndham Vale)
- Deutgam Silt (Werribee)
- Unnamed Quaternary alluvium (Torquay and Wyndham Vale)
- Mornington Volcanics
- Coode Island Silt

5 DATA ANALYSIS

The combined Earl (2005), Jayasekera and Mohajerani (2003) and Coffey data sets (as relevant for this paper) are displayed in Table 1.

Pearson's correlation coefficient (r) was run on a number of different mathematical functions (Table 2), to provide initial screening for correlation (Pearson's correlation coefficient is a more suitable tool for data with a normal distribution and thus its use in this analysis was restricted to the screening process only).

The higher correlations were identified and then graphed and linear regressions were undertaken to provide R^2 values. Figure 1 displays Iss vs (LL x %clay)/<425 µm and Figure 2 displays Iss vs Liquid Limit. The linear regression for Figure 1 was R^2 = 0.65 and for Figure 2 was R^2 = 0.64.

Table 2: Pearson's Correlation Coefficients

Pearson's Correlation Coefficient (r)	Value correlated with Iss
0.81	(LL x %clay)/<425 µm
0.80	Liquid Limit
0.79	(LL x % clay)/(% clay + % silt)
0.74	% clay
0.73	%clay/<425 µm
0.72	Plasticity Index
0.68	(LS x % clay)/<425 µm
0.66	(LS x % clay)/(% clay + % silt)
0.64	Plastic Limit
0.59	Linear Shrinkage

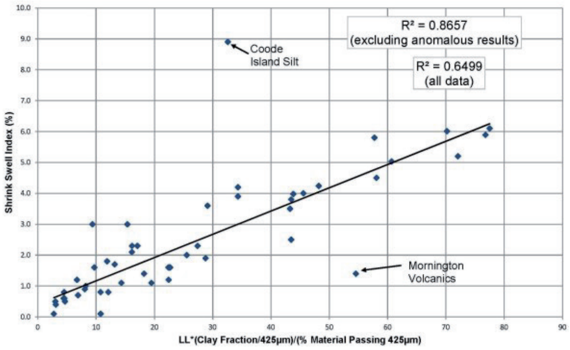

Figure 1. Iss (%) vs (LL x %clay)/<425 µm

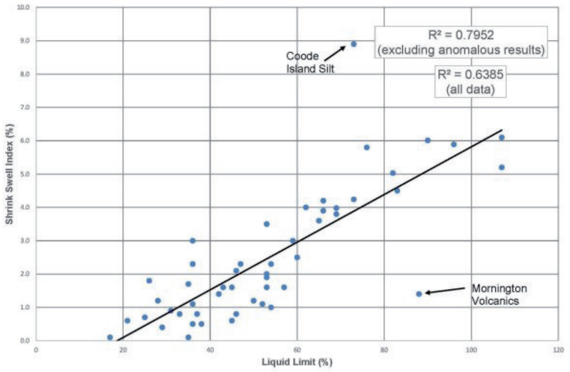

Figure 2. Iss (%) vs Liquid Limit (%)

Examination of the data showed that the tests results from C3, from the Mornington Volcanics and C13, from the Coode Island Silt, were highly anomalous and have substantially affected the linear regression result. The unusual geological nature of the Coode Island Silt, being a saturated normally consolidated marine clay, is likely to be a significant contributing factor to its unusual result. The Mornington Volcanics is part of a series of Early Tertiary basalts in southern Victoria that was once collectively known as the Older Volcanics. Li et al (2016) conducted two tests from the similarly aged Neerim Volcanic Group and reported that these two samples returned low Iss values in comparison to the basaltic clay derived from the Newer Volcanics, thus we consider that there may be a geological control, such as the type of clay, that is influencing the lower Iss values in the Mornington Volcanics and this geological control is not being screened out by identifying the percentage of clay.

The author considers that both the Coode Island Silt and the Mornington Volcanics are geologically anomalous as regards to the greater data set and thus in each case, should not be examined for correlations unless it is within a data set from a similar geological setting.

The linear regression was therefore re-calculated without referencing the samples from the Coode Island Silt and the Mornington Volcanics. The linear regression in Figure 1, being Iss vs LL x %clay)/<425 µm now has a linear regression of R^2 = 0.86, whereas the linear regression for Iss vs liquid limit (Figure 2) is now R^2 = 0.79.

6 DISCUSSION

The data analysis, after screening for anomalous geology, has provided a reasonable correlation for this data set between Iss, liquid limit and % clay, showing that the liquid limit and percentage of clay can be significant influences in the Iss value of a soil sample.

The high Pearson's Correlation Coefficient for liquid limit was surprising, given that Li et al (2016) recorded a linear regression correlation of 0.434 for Iss vs liquid limit and Earl (2005) recorded a linear regression correlation of 0.48 for Iss vs liquid limit. Given that other studies have not shown this correlation, the author considers that the high correlation in this study may be due to specific geological influence from the data set of Jayasekera and Mohajerani (2003) and the data points reported in this paper.

An Atterberg limit is a test is undertaken on all of the sample that is less than 425 μm in diameter, with the sand being ground down as part of the preparation process. This preparation process means that the test material includes clay, silt and sand. The presence of the inert sand and silt within the tested material would therefore reduce the reactivity indicated from the liquid limit, plastic limit and linear shrinkage test results. In addition the impact of this reactivity reduction will vary from sample to sample depending on the amount of sand and silt in each particular case. In contrast, a shrink/swell test is undertaken on the material as present insitu and there is no grinding of the coarser material. The improved correlation when the clay fraction is taken into account indicates the preparation process has probably been a significant factor in the difficulty in obtaining consistent correlations between Atterberg limits and Iss.

The data also indicated that in specific geological terrains (in this case the Mornington Volcanics and the Coode Island Silt) the correlations identified here are not valid.

In addition, the author notes that geotechnical practitioners who are embarking on a site classification should use these correlations with caution and undertake a thorough consideration of all the factors, geotechnical or otherwise, that may influence a site, including the processes and issues identified in AS2870, their local knowledge of the geotechnical environment, past performance of structures and consequences of incorrect classification.

ACKNOWLEDGEMENTS

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Table 1: Laboratory Test Results (including results from literature)

Report No.	Geology	Iss (%)	LL (%)	PL (%)	PI (%)	LS (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	<425µm (%)
050547[1]	SFM	0.1	17	16	1	0.5		25.0	61.0	14.0	93
050549[1]	SFM	0.6	21	16	5	2.5		36.0	45.0	19.0	95
050545[1]	SFM	0.7	25	14	11	5.0		18.0	56.0	26.0	97
050550[1]	SFM	1.8	26	11	15	9.0		27.0	40.0	33.0	85
050476[1]	SFM	1.2	28	13	15	9.0		6.0	69.0	24.0	100
050579[1]	SFM	0.4	29	17	12	6.0		18.0	73.0	10.0	97
050548[1]	SFM	1.7	35	13	22	10.5		31.0	35.0	34.0	95
050527[1]	SFM	0.5	36	14	22	11.5		17.0	75.0	8.0	98
050577[1]	SFM	1.1	36	13	23	11.0		10.0	51.0	39.0	99
050561[1]	SFM	2.3	36	13	23	11.0		23.0	39.0	38.0	92
050494[1]	SFM	3.0	36	13	23	13.0		9.0	67.0	23.0	94
050544[1]	SFM	0.8	37	14	23	10.5		16.0	52.0	32.0	99
050578[1]	SFM	0.5	38	15	23	13.0		8.0	80.0	12.0	99
050551[1]	SFM	1.4	42	14	28	15.0		14.0	45.0	40.0	96
050507[1]	SFM	1.6	43	15	28	14.5		24.0	31.0	45.0	93
050518[1]	SFM	0.6	45	15	30	14.0		21.0	71.0	8.0	89
050493[1]	SFM	1.6	45	15	30	13.5		2.0	49.0	49.0	99
050562[1]	SFM	0.8	46	16	30	13.0		16.0	76.0	9.0	96
050519[1]	SFM	2.1	46	15	31	14.0		13.0	53.0	33.0	97
050526[1]	SFM	2.3	47	16	31	15.5		9.0	34.0	56.0	98
050541[1]	SFM	1.1	52	16	36	16.0		5.0	59.0	36.0	98
050542[1]	SFM	3.5	53	17	36	13.5		4.0	16.0	80.0	99
050504[1]	SFM	1.0	54	16	38	16.5		15.0	71.0	14.0	96
050490[1]	SFM	2.3	54	16	38	17.5		7.0	62.0	31.0	99
050503[1]	SFM	1.6	57	18	39	17.0		7.0	76.0	17.0	100
050530[1]	SFM	3.0	59	16	43	17.5		7.0	68.0	25.0	98
050531[1]	SFM	2.5	60	18	42	18.0		5.0	24.0	71.0	99
050477[1]	SFM	4.0	62	20	42	15.0		3.0	24.0	72.0	99
050489[1]	SFM	3.6	65	21	44	20.0		6.0	51.0	43.0	98
1[2]	HPL	3.8	69	40	29					63.0	100
2[2]	HPL	4.0	69	40	29					63.5	100
5[2]	HPL	4.2	73	39	34					66.0	100
9[2]	HPL	4.5	83	42	41					70.0	100
15[2]	HPL	5.0	82	38	44					74.0	100
19[2]	HPL	5.8	76	28	48					76.0	100
22[2]	HPL	6.0	90	42	48					78.0	100
25[2]	HPL	5.9	96	37	59					80.0	100
C1[3,4]	QA (T)	3.9	66	25	41	18.5		6.0	36.0	52.0	100
C2[3,4]	QA (T)	4.2	66	25	41	18.5		6.0	36.0	52.0	100
C3[3]	MV	1.4	88	38	50	21.5		11.0	27.0	62.0	100
C4[3,4]	DS	1.6	53	22	31	12.0		3.0	57.0	42.0	99
C5[3,4]	DS	1.2	50	22	28	11.0		4.0	55.0	44.0	99
C6[3,4]	DS	1.9	53	23	30	13.0		2.0	46.0	49.0	95
C7[3]	NV (F)	5.2	107	17	90	14.5		3.0	31.0	66.0	99
C8[3]	QA (W)	6.1	107	32	75	22.0		10.0	19.0	71.0	99
C9[3]	DS	0.9	31	14	17	7.0		30.0	44.0	26.0	100
C10[3]	NV (W)	2.0	53	20	33	12.0	22.0	13.0	31.0	34.0	84
C11[3]	DS	0.8	33	15	18	7.0	0.0	49.0	28.0	23.0	84
C12[3]	DS	0.1	35	16	19	6.5		65.0	22.0	13.0	65
C13[3]	CIS	8.9	73	25	48	18.0	1.0	5.0	52.0	42.0	97

[1] Earl (2005)

[2] Jayasekara and Mohajerani (2003)

[3] This paper

[4] Shrink swell sample was remoulded in the laboratory

SFM = Shepparton Formation; HPL = High Plasticity Liners; QA (T) = Quaternary Alluvium; Torquay,
MV = Mornington Volcanics; DS =Deutgam Silt; NV (F) = Newer Volcanics, Footscray;
QA (W) = Quaternary Alluvium, Wyndham Vale; NV (W) = Newer Volcanics, Wyndham Vale;
CIS = Coode Island Silt

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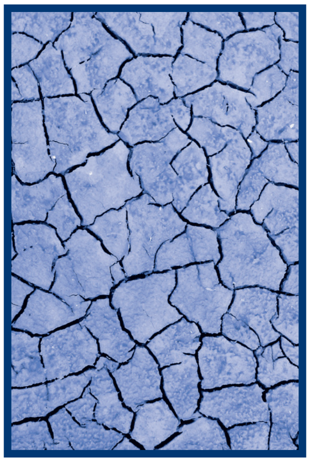

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