

**APPENDIX SECT1/C – SOIL INVESTIGATION REPORT**



**GEOTECHNICAL ENGINEERING PTE LTD**

**SOIL INVESTIGATION WORKS FOR PROPOSED ADDITIONAL  
AND ALTERATION WORKS AT SINGAPORE EXPO**

**Location: Changi South Ave 1**

**SOIL INVESTIGATION REPORT**

Client	: Singapore Tourism Board (STB)		
Consultant	: RSP Architects Planners & Engineers Pte Ltd (RSP)		
Specialist Builder (S.I)	: KIMARO Geotechnical Engineering Pte Ltd		
Document Number	SI/RSP/353/01	Revision Number	1
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Prepared By	Aung Aung	Reviewed By	San Lwin

**KIMARO GEOTECHNICAL ENGINEERING PTE. LTD.**

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Co.Reg.No.200809676R [www.kimaro.com.sg](http://www.kimaro.com.sg)





## CERTIFICATION BY PROFESSIONAL ENGINEER FOR SOIL INVESTIGATION REPORT

Project Title : Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo  
 Boreholes : BH-1 & BH-2  
 Location : Changi South Ave 1

1. I, Er. Cheang Yew Kee, the Professional Engineer, PE Registration No. 3297 certify that Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo comprising all field and laboratory data tests and results therein has been carried out by me or under my supervision or direction, and I have verified the accuracy of the information given in the site investigation report, and to the best of my knowledge and belief, all have been prepared in compliance in all respects with the provision of the Building Control Act and Regulations, relevant Codes of Practice and Standards.
2. I, further certify that I have the appropriate qualifications and experience, and I am familiar with the purpose of the investigation for which this Site Investigation Report is prepared in reference to Project Ref.
3. Total number of pages in the Site Investigation Report is 77 pages.

Date: 10<sup>th</sup> Feb 2017



Professional Engineer for Site Investigation

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## 1.0 INTRODUCTION

RSP Architects Planners & Engineers Pte Ltd, Singapore, has engaged KIMARO Geotechnical Engineering Pte Ltd to conduct Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo.

The site investigation is carried out in accordance with Eurocode 7 (BS EN 1997), "Geotechnical Investigation and Testing" (BS EN ISO 22475; BS EN ISO 22476). This report presents the facts of Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo. The investigation was performed by KIMARO Geotechnical Engineering Pte Ltd and laboratory tests were conducted by the SAC-SINGLAS accredited laboratory in accordance with BS EN ISO 14688 ; BS EN ISO 14689. The particulars of this project are as follows:

Project Title	: Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo
Location	: Changi South Ave 1
Client	: Singapore Tourism Board (STB)
Consultant	: RSP Architects Planners & Engineers Pte Ltd (RSP)

### 1.1 Purpose of Works

The main purpose of the soil investigation is to explore subsurface soil condition at the site and to obtain the geotechnical information that required for the design and construction works.

The operation work was strictly performed by under the fully supervision of Senior Geologists and well experienced Geotechnical Engineers from KIMARO Geotechnical Engineering Pte Ltd. This factual report presents the results of field works, geotechnical geological interpretation and recommendation.

## 2.0 SITE CONDITIONS

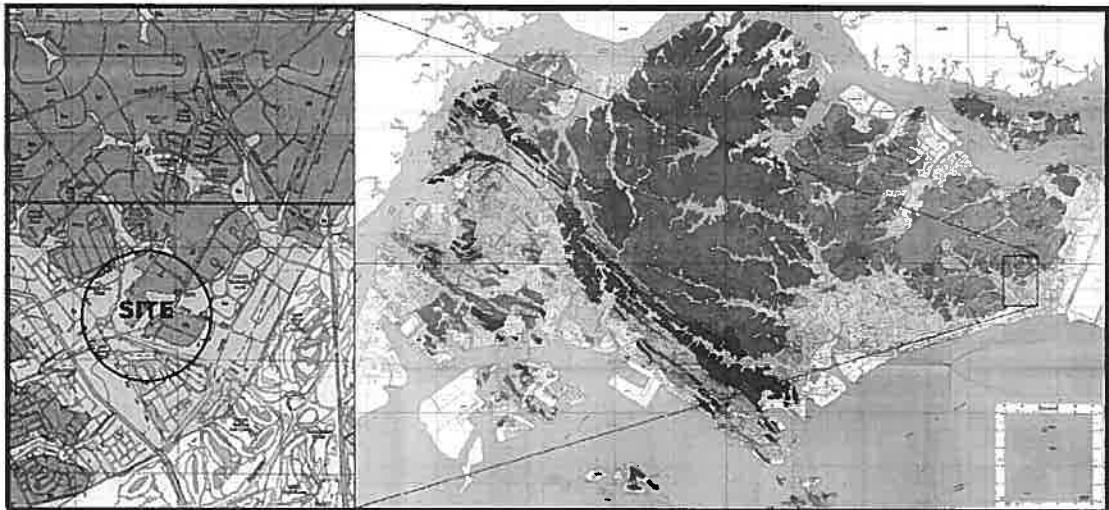
### 2.1 Location

The proposed site is generally situated at Eastern part of Singapore Island. The area is located at Changi South Ave 1, Expo, Singapore. The site and the borehole's location plan are shown in Appendix A.

### 2.2 General Geology

A review of the geology of Singapore by PWD (1976) and DSTA (2009) indicates that the prevailing geological formation underlying the site is the **Old Alluvium**. The superficial soils at the proposed site consist of Fill.

The following geological map, *Figure (2.1)* shows the setting and site location of Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo



(After DSTA, 2009)

Figure (2.1) Geology and site location of Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo



### **3.0 SCOPE OF WORK**

The scope of the soil investigation work of this project can be summarized as follows:

- Drilling two (2) exploratory boreholes associated with disturbed and undisturbed soil sampling, and in-situ testing at various depths.
- Conducting laboratory tests for engineering properties of soil layers.
- Submission of Soil Investigation factual report.

#### **3.1 Field Investigation**

Field investigation works are carried out in accordance with BS EN ISO 22475 and BS EN ISO 22476. Field in-situ tests were performed on Client's requirement.

##### **3.1.1 General**

The fieldworks were performed after seeking the approval of necessary documents from relevant organization and authority of Singapore. The field investigation of the project, **Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo**, was conducted from 12<sup>th</sup> Jan 2017 to 14<sup>th</sup> Jan 2017.

##### **3.1.2 Setting Out**

The proposed boreholes location indicated in the plan were proposed by the client representatives and were set out by registered surveyor. The survey works carried out on 13<sup>rd</sup> Jan 2017 and based on the Singapore Department of Survey Grid System (SVY21) and elevations are referenced to the Reduced Level (RL).

The as-built and Reduced Level of the borehole and in-situ tests location is presented in Appendix A.

##### **3.1.3 Ground Water Level Measurement**

The ground water levels were measured by site geologists/engineers twice a day, during the soil investigation works. The summaries of water levels are shown in the bore logs, Appendix B.

In order to record the fluctuation of water level, three water standpipes were installed in BH-1 & BH-2 at the depth of 15.00m. The reading and installation record of the water standpipe is presented in Appendix D.



### 3.1.4 Drilling Work

The site investigation was performed by using rotary drilling method. A metal cutting tool was attached to the drilling rod to produce 100 mm diameter boreholes and jointed casings were used to prevent the collapsing of the borehole wall. Circulated mud water was pumped through the hollow rods into the hole to wash out the cutting soils to the ground surface by pressure.

Field investigation works described in this report were carried out as per specification and instruction of the client and consultants. All boreholes were backfilled with cement-bentonite grout upon the completion of drillings. Detailed boring logs along with terms and symbols used are shown in Appendix B.

### 3.1.5 Undisturbed Sampling

Undisturbed samples (UD) were extracted from the borehole at the depth of relevant interval. Each sample was taken using a 7.5 cm diameter by 100cm long 'Shelby' type sample tube driven by means of hydraulic push. After collection, the samples were sealed with wax at both ends of the tube and send to the laboratory for analysis and testing at the end of the day.

### 3.1.6 Standard Penetration Test

Standard Penetration Tests were generally carried out at every 3.0m intervals or as per specified. Split-Barrel sample tube with a 5.1-cm external diameter was used for determination of penetration resistance (SPT).

The test consists of driving the sample tube into the soil by impact of 63.5 kg hammer falling from a height of 76 cm. The number of blows required to penetrate each of three 15-cm intervals into the soil is recorded by the Field Engineer/ Site Geologist. The N-value is defined, as the total number of blows required to achieve the final 30cm of penetration. A small portion of the sample was taken and keeps inside a small plastic container for reference and logging.

SPT hammer energy measurement is presented in Appendix E.



### 3.2 Laboratory Testing

Laboratory soil tests are carried out in accordance with BS EN ISO 14688, BS EN ISO 14689 by the SAC-SINGLAS accredited laboratory. Laboratory testing on the soil samples were performed on the basis of laboratory testing programme developed by the Client Representative. The soil testing results are presented in Appendix C.

#### 3.2.1 Moisture Content

To measure moisture content, a specimen is taken from an undisturbed sample, weighed and placed in a tin, where it is oven dried at 105-110° for 18-24 hours. The soil is weighed after the drying and the weight of water content is calculated simply by subtracting the two values. The moisture content is then defined as the percentage of the weight of water over weight of dry soil.

#### 3.2.2 Bulk and Dry Density

The bulk density is the measured weight of a solid cylindrical soil specimen taken from an undisturbed sample divided by its volume. The dry density was calculated from bulk density and moisture content.

#### 3.2.3 Specific Gravity

The particle density of a soil is defined as the density of the soil divided by the density of distilled water at 4°C. It is also known as specific gravity. This value is necessary to compute the void ratio of a soil and it is used in the hydrometer analysis.

This method covers the determination of particle density of a soil sample containing up to 10% of particles retained on a 37.5mm test sieve.

#### 3.2.4 Atterberg Limits

The liquid limit of a specimen is derived using the Cone Penetrometer method as to BS 1377. The plastic limit is defined as the moisture content of a specimen at the point where it can be satisfactorily rolled into a 3 mm diameter thread with cracking. The soils plasticity index is then derived by subtracting the plastic limit from the liquid limit.



### **3.2.5 Grain Size Distribution**

The grain size analysis was carried out utilizing Sieve & Hydrometer Analysis method. The sieve process involves passing an oven dried, representative portion of each sample through a series of square mesh sieves, which become progressively finer down to 60 mm mesh. Each fraction thus collected is then weighed. The weight of individual fraction is then divided by the total sample weight to determine the particle size distribution for the specimen. From this process different fractions are separated, weighed and divided by the total sample weight to arrive at a particle size distribution value. Hydrometer analysis was carried out to determine the finer particles to distinguish between silt and clay.

### **3.2.6 Triaxial Testing (Unconsolidated Undrained)**

Unconsolidated Undrained Triaxial test was conducted to determine the undrained shear strength of the soil. The soil specimen is subjected to a constant confining pressure. Axial load is increased by applying a constant rate of strain until specimen fail. This test is generally performed as a set of three single tests. However, if the sample is not enough, the test is conducted using two or single (multi-stage) specimen. The three cell pressures correspond to  $0.5 \sigma' v$ ,  $\sigma' v'$ ,  $\sigma' v'^2$  where  $\sigma' v'$  is effective overburden pressure. For a multi-stage test, the shearing was stopped when the peak deviator stress was imminent, and the consolidation and shearing stages were repeated for the next cell pressure.

### **3.2.7 Triaxial Testing (Consolidated Undrained)**

The consolidated- undrained test (CU) is the most common type of triaxial test to determine the effective shear strength parameters of soil including the measurement of pore pressure. The saturated soil specimen is first consolidated by all-around fluid pressure. After consolidation, increase the cell pressure and adjust the back pressure to give a difference equal to the required effective consolidation pressure, start the consolidation stage by opening the back pressure valves, record reading of the volume change indicator at suitable intervals of time and allow consolidation to continue until there is no further volume change, record the pore pressure. The specimen is ready for un-drained compression test.

### **3.2.8 1-D Consolidation (Oedometer Test)**

One dimensional compression and swelling characteristic of soft soil layers are measured in the laboratory performing oedometer test. A cylindrical specimen of soil enclosed in a metal ring is subjected to a series of increasing load, while changes in thickness are recorded against time. In the oedometer, lateral movement of the soil is prevented by containing the soil in a stiff metal ring so that only vertical (one-dimensional) soil movements are possible. Drainage is only permitted from the horizontal faces so that the water in the pores is also constrained to flow vertically. The parameters that are required to estimate settlement and the rate of settlement of the foundation on the soft soil are determined from the result of oedometer tests.

## **4.0 SUBSURFACE INVESTIGATION**

### **4.1 Soil Classification**

The soil classification is based on the geological classification and Euro Codes classification system. The consistencies of clay/silt and relative densities of sand have been classified according the following criteria:

**Table 4.1 Determination of consistency**

**BS EN ISO 14688-1, 5.14**

<b>Consistency of cohesive soil</b>	<b>Identification and description</b>
Very soft	It exudes between the fingers when squeezed in hand.
Soft	It can be moulded by light finger pressure.
Firm	It cannot be moulded by fingers, but rolled in hand to thick threads without breaking or crumbling.
Stiff	It crumbles and breaks when rolled to 3mm thick threads but is still sufficiently moist to be moulded to a lump again.
Very stiff	It has dried out and is mostly light colored. It can be longer be moulded but crumbles under pressure. It can be indented by thumbnail.

**Table 4.2 Undrained shear strength of fine soils**

BS EN ISO 14688-2, 5.3, Table 5

Undrained shear strength of clays	Undrained Shear Strength $C_u$ kPa
Extremely low	<10
Very low	10 to 20
Low	20 to 40
Medium	40 to 75
High	75 to 150
Very high	150 to 300
Extremely high <sup>a</sup>	>300

<sup>a</sup> Materials with shear strength greater than 300 kPa may behave as weak rocks and should be described as rocks according to ISO 14689-1

**Table 4.3 Correlations to classify density terms**

BS EN ISO 14688-2, 5.2, Table 4

Term	Density Index $I_D$ %
Very Loose	0 to 15
Loose	15 to 35
Medium Dense	35 to 65
Dense	65 to 85
Very Dense	85 to 100

**Table 4.4 Classification of Rock Quality**

(After ASTM D6032-02)

RQD (Rock Quality Designation)	Classification of Rock Quality
<25%	Very Poor
25 – 50%	Poor
50 – 75%	Fair
75 – 90%	Good
90 – 100%	Excellent

**Table 4.5 Weathering Classification for Old Alluvium**

(After LTA Civil Design Criteria - A1, 2010)

Class	Classifier	Characteristics	Indicative SPT, Blows/300mm*
A	Unweathered	Original strength	>50 (cannot usually be penetrated by CPTs with 20ton load capacity)
B	Partially Weathered	Slightly reduced strength	
C	Distinctly Weathered	Further weakened	30 to 50
D	Destructured	Greatly weakened, often mottled, bedding disturbed	10 to 30
E	Residual	No bedding remains	<10

#### 4.2 Borehole Logging

A site record was prepared for every bore hole done on site to record the soil description and the SPT 'N' value. These site records were used for the proper borehole logs latter.

The proper borehole logs generally summarize all the field data and the laboratory tests results as well as give a general indication of the soil conditions at each location.

Each borehole log shows:

- Soil description
- Stratum changes
- SPT results
- Laboratory testing results
- General information such as sample reference, sample recovery

#### 4.3 Termination Criteria

All boreholes were terminated as instructed by the client representative. The summary of boreholes' termination depths with the relative Standard Penetration Test (SPT) reference numbers are shown in the table 4.5.

**Table 4.5 Boreholes' Termination Depths with relative CR Reference Numbers**

BH No.	Termination Depth (m)	SPT Reference	CR Reference	Remark
BH-1	23.45	P 8	-	Terminated as instructed by the client's representative
BH-2	23.40	P 8	-	



## 5.0 GEOLOGICAL FORMATIONS

General Subsurface Geology has been briefly described as below, based on the subsoil condition of the project area-

There are FILL layer and one type of formation namely OLD ALLUVIUM which are underlying at the project area. It can be determined in geological succession as follow-

1. FILL
2. OLD ALLUVIUM

FILL layer is the upper most topsoil layer. The layer underlying the Fill is OLD ALLUVIUM which can be found as Silty/Clayey SAND and Sandy CLAY/SILT.

In order to understand the subsoil and geological condition, interpolated soil profiles are presented in Appendix-B.



## REFERENCES

- BS EN ISO 1997, Eurocode 7 : Geotechnical Design
- BS EN ISO 14688, Geotechnical investigation and testing – Identification and classification of soil
- BS EN ISO 14689, Geotechnical investigation and testing – Identification and classification of rock
- BS EN ISO 22475, Geotechnical investigation and testing – Sampling methods and groundwater measurements
- BS EN ISO 22476, Geotechnical investigation and testing – Field testing
- DSTA, 2009. Geology of Singapore. 2<sup>nd</sup> Edi, Defence Science & Technology Agency, Singapore.
- LTA, 2010. Civil design criteria for road and rail transit systems revision A1, Rail & Engineering Group, Land Transport Authority, Singapore.
- PWD, 1976. Geology of Singapore. Public Work Department, Singapore.

*Disclaimer:*

*We have bestowed this factual report with the care and skill normally exercised, under similar circumstances by experienced geotechnical engineers. This factual report is prepared based on the information available from the borehole logs and laboratory test results at the time. The interpolated soil profile or geological cross-section between adjacent boreholes is only representative and may not be the actual profile as subsurface conditions can vary both laterally and vertically. No other warranty, expressed or implied is made as to the recommendations included in this report. The recommendations given in this report shall only be used as a guide. The design engineer is expected to exercise his/her own judgment in the use of this report. Laboratory tests were conducted by the SAC-SINGLAS accredited laboratory which shall be fully responsible for the interpretation, analysis and results of the laboratory tests. This report cannot be transferred to or used by another party without permission from KIMARO Geotechnical Engineering Pte Ltd. We shall not be responsible nor liable for any misrepresentation in the exact reduced level and global positioning coordinates of the boreholes which were carried out by third party registered Surveyor Company*

KIM\RO

**CLIENT** : RSP Architects Planners & Engineers (Pte) Ltd  
**PROJECT** : Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo

S/N	BH NO	BH	FIELD WORKS	COORDINATES	NORTHING	EASTING	DATE OF COMPLETION	DATE OF COMMENCEMENT	TERMINATION DEPTH OF BORERHOLE (m)	DEPTH OF RILLING IN SOIL (m)	DEPTH OF CORING IN ROCK (m)	WSP	PMT	PBT	UD	MC	Seiving	Specific Gravity	Hydro	CU	UU	CU	LABORATORY TESTS		
1	BH-1	12/01/17	14/01/17	34933.525	41984.467	105.624	23.45	-	1	8	-	-	2	2	2	2	1	2	1	1	2	2	2	2	2
2	BH-2	12/01/17	13/01/17	34926.296	41964.985	105.395	23.40	-	1	8	-	-	2	2	2	2	2	1	2	1	1	2	2	2	2
								<b>TOTAL</b>		<b>46.85</b>	<b>-</b>	<b>2</b>	<b>16</b>	<b>-</b>	<b>-</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>2</b>	<b>4</b>	<b>2</b>	<b>4</b>	<b>4</b>	<b>4</b>

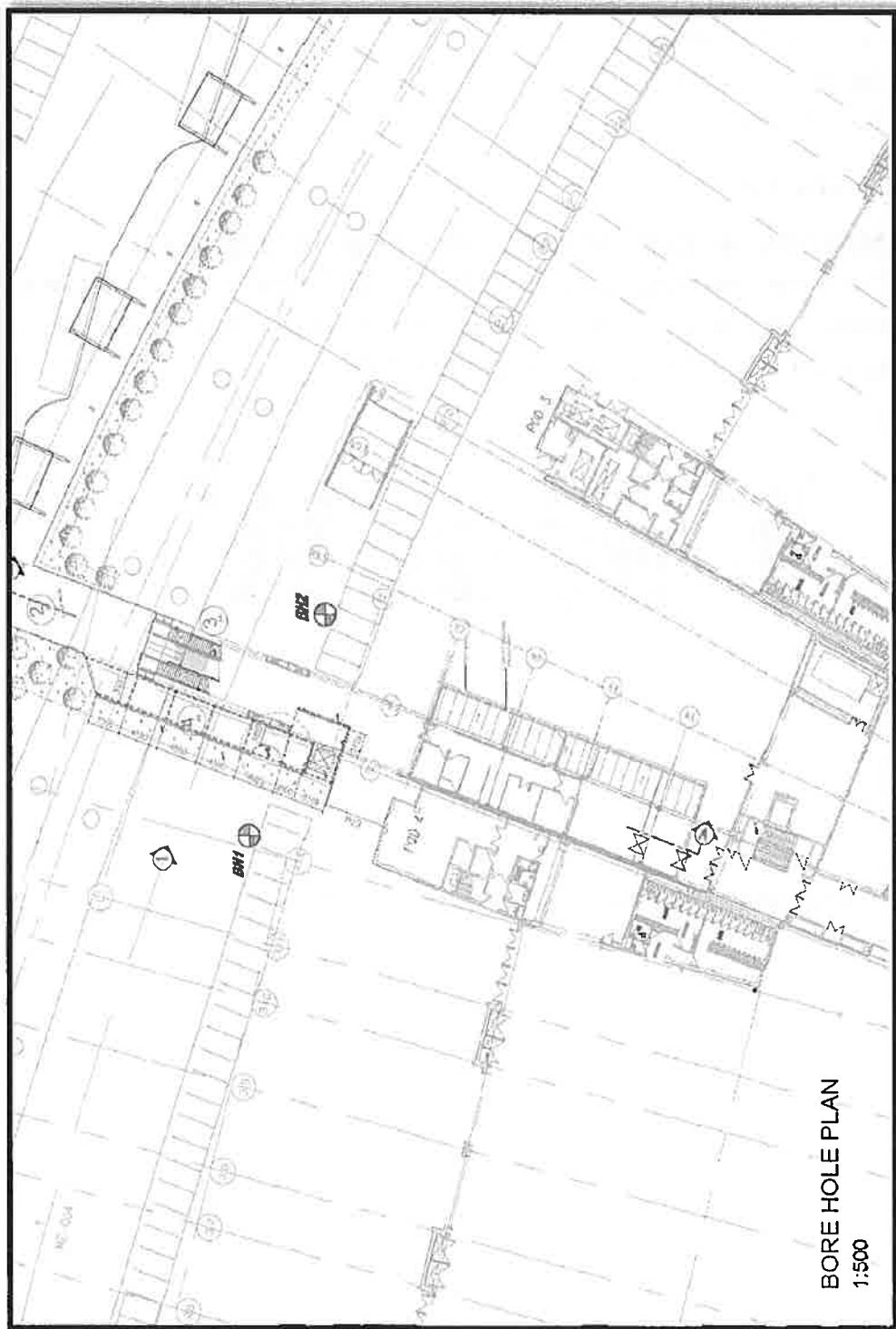
DS *Disturb Sample*  
 UD *Undisturbed Sample*  
 SPT *Standard Penetration Test*  
 PMT *Pressure Meter Test*  
 PKT *Packer Test*  
 PBT *Field Permeability Test*  
 WSP *Water Standpipe*  
 PZ *Casagrande Piezo*

MC *Moisture Content*  
 BD *Bulk Density*  
 SG *Particle Density*  
 UU *Unconsolidated Undrained (Triaxial Test)*  
 CU *Consolidated Undrained (Triaxial Test)*

UCT *Unconfined Compressive Test*  
 PL *Point Load Test*



**APPENDIX A:**  
**SITE AND BOREHOLES LOCATION PLAN**



Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo



# YJP Surveyors Pte Ltd

10 Genting Road, #05-00 The Blue Building  
Singapore 349473

bizSAFE<sub>3</sub>



CERT NO. 2004-2-1382  
ISO 9001 2008

25<sup>th</sup> January 2017

To: Kimaro Geotechnical Engineering Pte Ltd.,  
24 Sungei Kadut Street 4,  
Singapore 729050  
Tel: 6515 7877

Attn: Mr Alex Teo

Re: **Setting out survey of Singapore Expo, Changi South Avenue 1**

The survey works carried out on 13<sup>th</sup>January 2017 based on SVY21 datum and PLD datum using SLA VRS RTK System. The calibration report for this instrument is enclosed behind. The coordinates are shown below,

Borehole No.	(Co-ordinates SVY21)		Reduced level PLD (m)
	Northing (m)	Easting (m)	
BH 1	34933.525	41984.467	105.624
BH 2	34926.296	41964.985	105.395

Note:

Information shown hereon are correct at time of survey.

**Andrew Yap Chee Ming**  
Registered Surveyor (Singapore)  
IHO/FIG Category A Hydrographer  
Bsc. (Hons) Surveying and Mapping Science (UK)



**APPENDIX B:**  
**INTERPOLATED SOIL PROFILE, BORÈ LOGS**



GEOTECHNICAL ENGINEERING PTE LTD

## GEOLOGICAL CLASSIFICATION



FILL

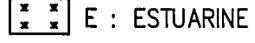
### KALLANG FORMATION



F1 : FLUVIAL SAND



F2 : FLUVIAL CLAY



E : ESTUARINE



M : MARINE CLAY

### OLD ALLUVIUM



O (A)



O (D)



O (B)

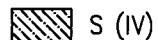


O (C)

### JURONG FORMATION



S (I)



S (IV)



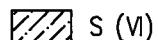
S (II)



S (V)



S (III)

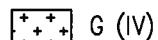


S (VI)

### BUKIT TIMAH GRANITE



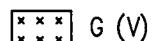
G (I)



G (IV)



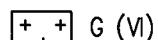
G (II)



G (V)



G (III)



G (VI)

## ENGINEERING CLASSIFICATION



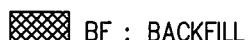
AS : ASPHALT, TAR



CS : SANDY CLAY



GPt : PEATY GRAVEL



BF : BACKFILL



CG : GRAVELY CLAY



GC : CLAYEY GRAVEL



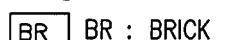
BE : BEDROCK



Cpt : PEATY CLAY



GR : GRANITE



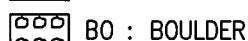
BR : BRICK



CNG : CONGLOMERATE



GO : ORGANIC GRAVEL



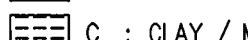
BO : BOULDER



CON : CONCRETE



LI : LIMESTONE



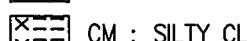
C : CLAY / MARINE CLAY



GM : SILTY GRAVEL



M : SILT



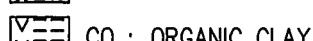
CM : SILTY CLAY



G : GRAVEL



MPt : PEATY SILT



CO : ORGANIC CLAY



GS : SANDY GRAVEL



MG : GRAVELLY SILT



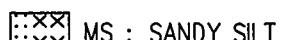
MU : MUDSTONE



PtC : CLAYEY PEAT



SI : SILTSTONE



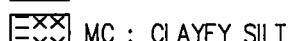
MS : SANDY SILT



S : SAND



SH : SHALE



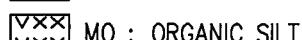
MC : CLAYEY SILT



SG : GRAVELLY SAND



SCH : SCHIST



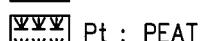
MO : ORGANIC SILT



SO : ORGANIC SAND



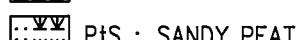
TB : TIMBER



Pt : PEAT



SM : SILTY SAND



PtS : SANDY PEAT



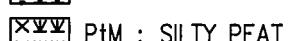
SC : CLAYEY SAND



PtG : GRAVELLY PEAT



SPt : PEATY SAND

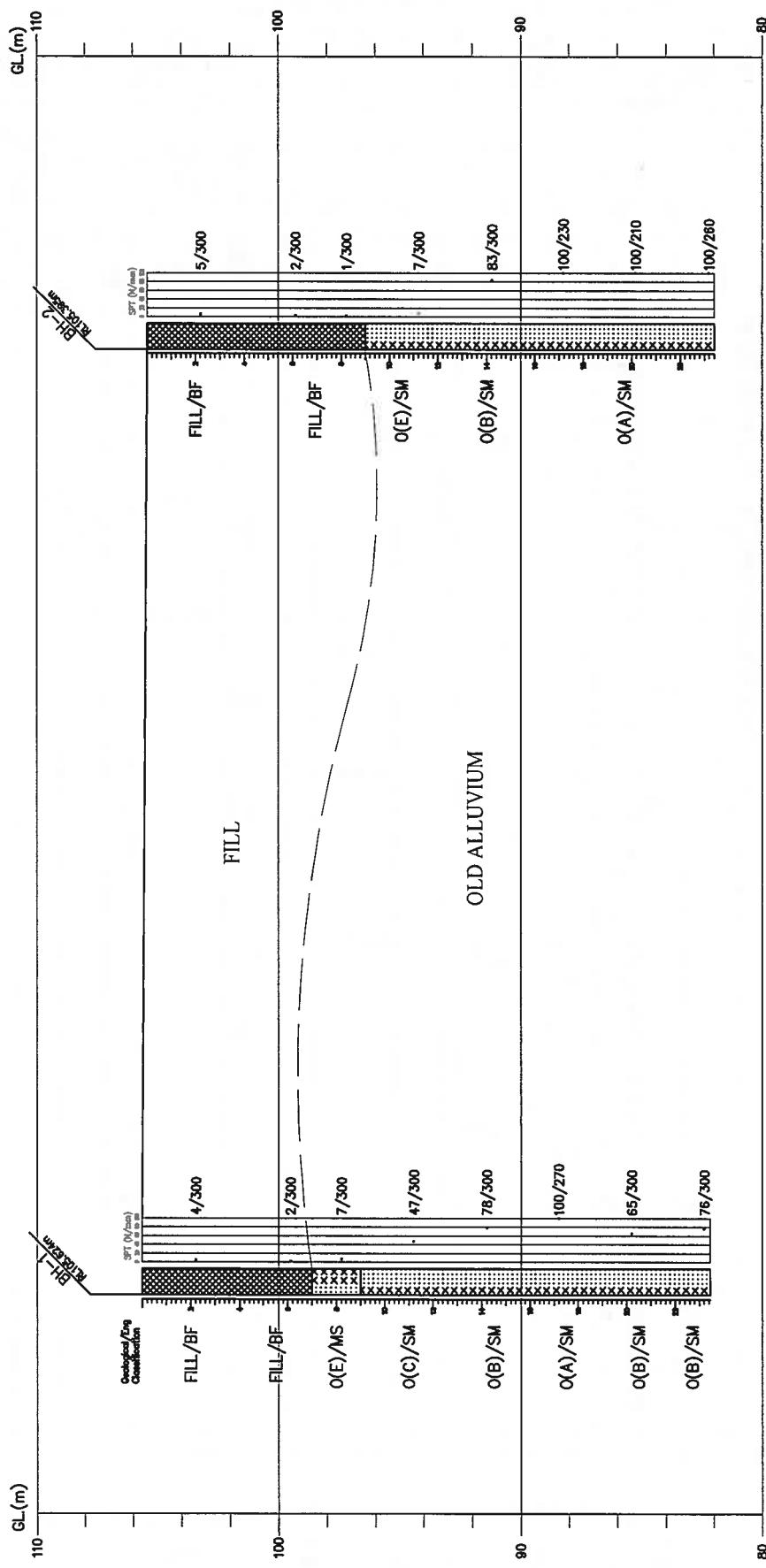


PtM : SILTY PEAT



SA : SANDSTONE

SOIL INVESTIGATION WORKS FOR PROPOSED ADDITIONAL AND ALTERATION WORKS AT SINGAPORE EXPO  
GEOLOGICAL CROSS SECTION 1, DRAWN THROUGH BH-1 AND BH-2



Note: Soil layers and rock strata in the profile are interpolated based on the available subsoil information from the recent soil investigation. The results may vary from the actual subsurface conditions between the boreholes.

Project: Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo

EXCEL FILE REF:  
AutoCAD FILE REF:

Client	RSP Architects Planners & Engineers (Pte) Ltd	Drawn by	Checked by
Consultant		Aung Aung	San Lwin
Drawing Title	GEOLOGICAL CROSS SECTION DRAWN THROUGH BH-1 & BH-2		
Section No.1	JB353	Date	09/02/2017
Scale	As shown		



## BORELOG

SHEET NO: 1 OF 2

 <b>GEOTECHNICAL ENGINEERING PTE LTD</b>		CLIENT: RSP Architects Planners & Engineers (Pte) Ltd																		
		PROJECT: Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo																		
		LOCATION: Changi South Ave 1												SPT HAMMER S/N: KGE/SPT/13						
PROJECT NO: JB353			BOREHOLE NO: BH-1												WATER LEVEL: 0.10m BGL (Highest)		1.20m BGL (Average)			
DRILLING DATE STARTED: 12/01/2017			BOREHOLE DIA: 100 mm												REDUCED LEVEL: 105.624		NORTHING: 34933.525			
PREPARED BY: AA/SaiSi/Motin			CORE DIA: 50 mm						DRILLING METHOD: RO		REVIEWED BY: SL		EASTING: 41984.467		Atterberg Limit (%)				Water Content (%)	
Description		Graphic Log	Depth (m) (Thickness)	Reduced Level (m)	Scale	SPT (N-Value)			Samples & Tests		Rock	Geological Classification	Grain Size Analysis G/SA/S/C	Soil Metres (m)	Shear Strength		Bulk Density (kg/m³)	Water Content (%)		Atterberg Limit (%)
Trial Pit 0.5x1.0x1.0m. Hand Auger 1.0m-2.0m. Loose, Grey & brown, Gravelly very Clayey SAND with traces of decayed vegetation, (FILL)				(4.00)		1			P1	2.00-2.45					C	$\phi$				
Very loose Dark grey, Gravelly Clayey SAND with traces of decayed vegetation, (FILL)				4.00	101.62	4	2/30 (1/2/2)	X	UD1	3.00-3.90		FILL	16/51/14/19	38 (UU) 5 (CU)	0	2.01	22	47	22	( $P_c=189 \text{ kN/m}^2$ ; $C_c=0.158$ )
Firm Reddish to yellowish brown, Sandy SILT, (OLD ALLUVIUM)				(3.00)		5			UD2	5.00-5.90			11/71/10/8	27 (UU)	0	1.87	33	43	21	( $P_c=104 \text{ kN/m}^2$ ; $C_c=0.415$ )
Dense Yellowish brown, Silty SAND, (OLD ALLUVIUM)				(2.00)		6			P2	5.90-6.35		FILL								
Very dense Yellowish brown mottled light grey, Silty SAND, (OLD ALLUVIUM)				9.00	96.62	7	7/30 (2/3/4)	X	P3	8.00-8.45	O(E)		MS							
Very dense Reddish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)				(4.00)		8			P4	11.00-11.45	O(C)		SM							
Very dense Yellowish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)				(3.00)		9	47/30 (13/21/28)	X	P5	14.00-14.45	O(B)		SM							
Very dense Reddish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)				(3.00)		10			P6	17.00-17.41	O(A)		SM							
Very dense Yellowish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)				(1.00)		11					O(B)		SM							
TO BE CONTINUED		REMARKS: Terminated at 23.45m. Water standpipe was installed at 15.00m below ground level.																		
<b>LEGEND:</b> <ul style="list-style-type: none"> <li>▼ -Pressuremeter Test (PMT)</li> <li>▢ -Standard Penetration Test (P)</li> <li>● -Vane Shear Test (V)</li> <li>⊗ -Undisturbed Sample (UD)</li> <li>⊗ -Open Drive Thickwall Sample (OD)</li> <li>⊗ -Permeability Test (PBT)</li> <li>⊗ -Mazier Sample (MZ)</li> <li>⊗ -Denison Sample (DS)</li> <li>■ -Piston Sample (PS)</li> <li>■ -Core Run (CR)</li> </ul>																				



## BORELOG

SHEET NO: 2 OF 2

 <b>GEOTECHNICAL ENGINEERING PTE LTD</b>		CLIENT: RSP Architects Planners & Engineers (Pte) Ltd														
		PROJECT: Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo														
		LOCATION: Changi South Ave 1      SPT HAMMER S/N: KGE/SPT/13														
PROJECT NO: JB353		BOREHOLE NO: BH-1												WATER LEVEL: 0.10m BGL (Highest)		
DRILLING DATE STARTED: 12/01/2017		BOREHOLE DIA: 100 mm												1.20m BGL (Average)		
DRILLING DATE COMPLETED: 14/01/2017		CORE DIA: 50 mm												REDUCED LEVEL: 105.624		
PREPARED BY: AA/SaiSi/Motin		DRILLING METHOD: RO				REVIEWED BY: SL				NORTHING: 34933.525						
										EASTING: 41984.467						
Description	Graphic Log	Depth (m) (Thickness)	Reduced Level (m)	Scale	SPT (N-Value)		Samples & Tests		Rock	Geological Classification	Grain Size Analysis G/SA/S/C	Shear Strength C = Atterberg Limit (%)	Shear Strength φ = Atterberg Limit (%)	Bulk Density (kg/m³)	Water Content (%)	Atterberg Limit (%)
					Test No.	Blows/cm	Legend	Type & No.								
Very dense Yellowish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)	X	(2.00)	21		65/30 (20/29/36)	P7	20.00-20.45									
Very dense Light grey mottled yellowish brown, Silty SAND, (OLD ALLUVIUM)	X	(1.45)	22		76/30 (21/38/40)	P8	23.00-23.45		O(B)	SM						
Borehole terminated at 23.45m			23						O(B)	SM						
			24													
			25													
			26													
			27													
			28													
			29													
			30													
			31													
			32													
			33													
			34													
			35													
			36													
			37													
			38													
			39													
			40													
REMARKS: Terminated at 23.45m. Water standpipe was installed at 15.00m below ground level.																
<b>LEGEND:</b>																
 -Pressuremeter Test (PMT)  -Vane Shear Test (V)  -Permeability Test (PBT)  -Packer Test (PKT)				 -Standard Penetration Test (P)  -Undisturbed Sample (UD)  -Open Drive Thickwall Sample (OD)  -Mazier Sample (MZ)  -Denison Sample (DS)				 -Attempted (UD), (OD), (PS), (MZ) & (DS)  -Piston Sample (PS)  -Core Run (CR)								

## BORELOG

SHEET NO: 1 OF 2

 <b>GEOTECHNICAL ENGINEERING PTE LTD</b>		CLIENT: RSP Architects Planners & Engineers (Pte) Ltd																			
		PROJECT: Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo																			
		LOCATION: Changi South Ave 1												SPT HAMMER S/N: KGE/SPT/05							
PROJECT NO: JB353			BOREHOLE NO: BH-2												WATER LEVEL: 2.70m BGL (Highest)						
DRILLING DATE STARTED: 12/01/2017			BOREHOLE DIA: 100 mm												2.70m BGL (Average)						
DRILLING DATE COMPLETED: 13/01/2017			CORE DIA: 50 mm												REDUCED LEVEL: 105.395						
PREPARED BY: AA/SaiSi/Chen			DRILLING METHOD: RO				REVIEWED BY: SL				NORTHING: 34926.296				EASTING: 41964.985						
Description		Graphic Log	Depth (m) (Thickness)	Reduced Level (m)	Scale	SPT (N-Value)	Bloos/cm	Legend	Type	No.	Depth (m)	TGR (%)	RDD (%)	Geological Classification	Grain Size Analysis G/SA/S/C	Soil Type M/S	Shear Strength C (kN/m²)	Shear Strength φ (%)	Bulk Density (kN/m³)	Water Content (%)	Atterberg Limit (%)
Trial Pit 0.5x1.0x1.0m. Hand Auger 1.0m-2.0m. Firm, Dark grey, Slightly Sandy Very organic SILT with decayed vegetation, (FILL)		X	(4.00)	4.00	101.40	1	5/30 (2/2/3)	X	P1		2.00-2.45										
Very soft Grey and yellow, Slightly Gravelly Sandy CLAY, (FILL)		X	(3.00)	7.00	98.40	2	2/30 (1/1/1)	X	UD1		3.00-3.90			0/21/42/37	32 (UU)	BF	0	1.31 (Pc=125kN/m², Cc=0.89)	122	155 74	
Very loose Light grey, Silty SAND, (FILL)		X	(2.00)	9.00	96.40	3	1/30 (0/0/1)	X	P2		5.00-5.90			21/37/19/23	56 (UU)	BF	0	2.09 (Pc=148kN/m², Cc=0.12)	16	48 21	
Loose Reddish brown spotted light grey, Silty SAND, (OLD ALLUVIUM)		X	(3.00)	12.00	93.40	4	7/30 (2/3/4)	X	P3		5.90-8.35			FILL		BF					
Very dense Yellowish brown mottled light grey, Silty SAND, (OLD ALLUVIUM)		X	(4.00)	16.00	89.40	5	83/30 (24/38/45)	X	P4		8.00-8.45			O(E)		SM					
Very dense Light grey mottled yellowish brown, Silty SAND, (OLD ALLUVIUM)		X	(4.00)	20.00	85.40	6	100/23 (25/61/39)	X	P5		11.00-11.45			O(B)		SM					
TO BE CONTINUED		REMARKS: Terminated at 23.4m. Water standpipe was installed at 15.00m below ground level.																			
<b>LEGEND:</b>																					
 -Pressuremeter Test (PMT)  -Vane Shear Test (V)  -Permeability Test (PBT)  -Packer Test (PKT)						 -Standard Penetration Test (P)  -Undisturbed Sample (UD)  -Open Drive Thickwall Sample (OD)  -Mazier Sample (MZ)  -Denison Sample (DS)						 -Attemped (UD), (OD), (PS), (MZ) & (DS)  -Piston Sample (PS)  -Core Run (CR)									

## BORELOG

SHEET NO: 2 OF 2

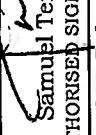
<b>KIM ARO</b> <b>GEOTECHNICAL</b> <b>ENGINEERING PTE LTD</b>		<b>CLIENT:</b> RSP Architects Planners & Engineers (Pte) Ltd <b>PROJECT:</b> Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo <b>LOCATION:</b> Changi South Ave 1															
		<b>SPT HAMMER S/N: KGE/SPT/05</b>															
<b>PROJECT NO:</b> JB353			<b>BOREHOLE NO:</b> BH-2										<b>WATER LEVEL:</b> 2.70m BGL (Highest)				
<b>DRILLING DATE STARTED:</b> 12/01/2017			<b>BOREHOLE DIA:</b> 100 mm										2.70m BGL (Average)				
<b>DRILLING DATE COMPLETED:</b> 13/01/2017			<b>CORE DIA:</b> 50 mm										<b>REDUCED LEVEL:</b> 105.395				
<b>PREPARED BY:</b> AA/SaiSi/Chen			<b>DRILLING METHOD:</b> RO				<b>REVIEWED BY:</b> SL				<b>NORTHING:</b> 34926.296				<b>EASTING:</b> 41964.985		
<b>Description</b>	<b>Graphic Log</b>	<b>Depth (m) (Thickness)</b>	<b>Reduced Level (m)</b>	<b>Scale</b>	<b>SPT (N-Value)</b>		<b>Samples &amp; Tests</b>		<b>Rock</b>		<b>Geological Classification</b>	<b>Grain Size Analysis G/SA/S/C</b>	<b>Shear Strength C (%)</b>	<b>Shear Strength φ (%)</b>	<b>Bulk Density (kN/m³)</b>	<b>Water Content (%)</b>	<b>Atterberg Limit (PL)</b>
					<b>Blow/cm</b>	<b>Legend</b>	<b>Type &amp; No.</b>	<b>Depth (m)</b>	<b>TCR (%)</b>	<b>RQD (%)</b>							
Very dense Light grey mottled yellowish brown, Silty SAND, (OLD ALLUVIUM)	X.....	(3.40)	82.00	21	● 100/21 (25/85/35)	P7	20.00-20.33										
Borehole terminated at 23.4m				22													
				23													
				24													
				25													
				26													
				27													
				28													
				29													
				30													
				31													
				32													
				33													
				34													
				35													
				36													
				37													
				38													
				39													
				40													
<small>REMARKS: Terminated at 23.4m. Water standpipe was installed at 15.00m below ground level.</small>																	
<b>LEGEND:</b> <ul style="list-style-type: none"> <li>▼ -Pressurometer Test (PMT)</li> <li>● -Standard Penetration Test (P)</li> <li>◐ -Vane Shear Test (V)</li> <li>⊗ -Undisturbed Sample (UD)</li> <li>⊗ -Open Drive Thickwall Sample (OD)</li> <li>⊗ -Permeability Test (PBT)</li> <li>⊗ -Mazier Sample (MZ)</li> <li>⊗ -Denison Sample (DS)</li> <li>■ -Attempted (UD), (OD), (PS), (MZ) &amp; (DS)</li> <li>■ -Piston Sample (PS)</li> <li>■ -Packer Test (PKT)</li> <li>■ -Core Run (CR)</li> </ul>																	
																	



**APPENDIX C:**  
**RESULTS OF LABORATORY SOIL TESTING**

**SUMMARY**

PROJECT Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo

LOCATION	-									
JOB NUMBER	1702/14289									
BOREHOLE NUMBER	BH-1	BH-1	BH-2	BH-2	BH-2	-				
SAMPLE NUMBER	UD-1	UD-2	UD-1	UD-2	-	-				
DEPTH (m)	from 3.00 to 3.90	5.00 5.90	3.00 3.90	5.00 5.90	-	-				
MOISTURE CONTENT (%)	22	33	122	16	-	-				
DENSITY (Mg/m <sup>3</sup> )	Bulk Density Dry Density	2.01 1.65	1.87 1.42	1.31 0.59	2.09 1.80	-				
ATTERBERG LIMIT (%)	Liquid Limit Plastic Limit Plasticity Index	47 22 25	43 21 22	155 74 81	48 21 27	-				
PINE SOIL GROUP	CII	CII	OrSH	CII	-	-				
PARTICLE SIZE DISTRIBUTION (%)	Clay Silt Sand Gravel	19 14 51 16	8 10 71 11	37 42 21 0	23 19 37 21	-				
CHEMICAL ANALYSIS	pH Value Total Sulphate Content, SO <sub>3</sub> (%) Soluble Chloride Content, Cl- (%) Organic Content (%)	- 0.10 0.02 1.20	- 0.49 0.01 1.42	4.25 0.61 0.03 16.85	- 0.09 0.01 0.42	-				
PARTICLE DENSITY (Mg/m <sup>3</sup> )	2.64	2.66	2.40	2.63	-	-				
UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (UU)	Cohesion, C (kN/m <sup>2</sup> ) Phi Angle, φ (degree)	38 0	27 0	32 0	56 0	-				
CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (CU)	Cohesion, Effective, C' (kN/m <sup>2</sup> ) Phi Angle, Effective, φ' (degree)	5 32	- -	- 34	- -	-				
CONSOLIDATION	Pre-Consolidated Pressure, P <sub>c</sub> (kN/m <sup>2</sup> ) Compression Index, C <sub>c</sub>	109 0.156	110 0.415	126 0.890	149 0.120	-				
BOREHOLE NUMBER	BH-1 BH-2 BH-2									
SAMPLE TYPE	Ground Water									
CHEMICAL ANALYSIS	pH Value Soluble Sulphate Content, SO <sub>3</sub> (g/l) Salinity (ppm)	7.21 0.25 164.00	7.75 0.34 634.00	Ground Water	Ground Water	Ground Water				
Lab Services Private Limited										
		TESTING OFFICER - C. Rajasekaran APPROVED / CHECKED -	  (AUTHORISED SIGNATORY)							
Lab Services Private Limited										
 Accredited Laboratory <b>SAC-SINGLAS</b> Cert No: LA-2001-0226-B										

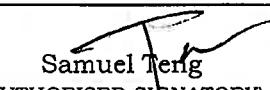
This Laboratory Is Accredited Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS) & Has Met The Requirements Of ISO / IEC 17025:2005.  
The Results Reported Herein Have Been Performed In Accordance With The Laboratory's Terms Of Accreditation.

**MOISTURE CONTENT / DENSITY**

[TEST METHOD - BS 1377:1990:Part 2:Test 3.2 / 7.2]

PROJECT	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo					
LOCATION	-					
JOB NUMBER	1702/14289					
BOREHOLE NUMBER	SAMPLE NUMBER	DEPTH (m)	MOISTURE CONTENT (%)	BULK DENSITY (Mg/m3)	DRY DENSITY (Mg/m3)	PARTICLE DENSITY
BH-1	UD-	3.00 - 3.90	22	2.01	1.65	2.64
BH-1	UD-	5.00 - 5.90	33	1.87	1.42	2.66
BH-2	UD-	3.00 - 2.66	122	1.31	0.59	2.40
BH-2	UD-	5.00 - 5.90	16	2.09	1.80	2.63

BOREHOLE NUMBER	SAMPLE NUMBER	DEPTH (m)	VISUAL DESCRIPTION
BH-1	UD-	3.00 - 3.90	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation
BH-1	UD-	5.00 - 5.90	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation
BH-2	UD-	3.00 - 2.66	Dark grey slightly sandy very organic SILT with decayed vegetation
BH-2	UD-	5.00 - 5.90	Grey & yellow slightly gravelly sandy CLAY

	TESTING OFFICER - C. Rajasekaran	 (AUTHORISED SIGNATORY)	 SAC-SINGLAS <small>Cert. No: LA-2001-026-B</small>
	APPROVED / CHECKED -		

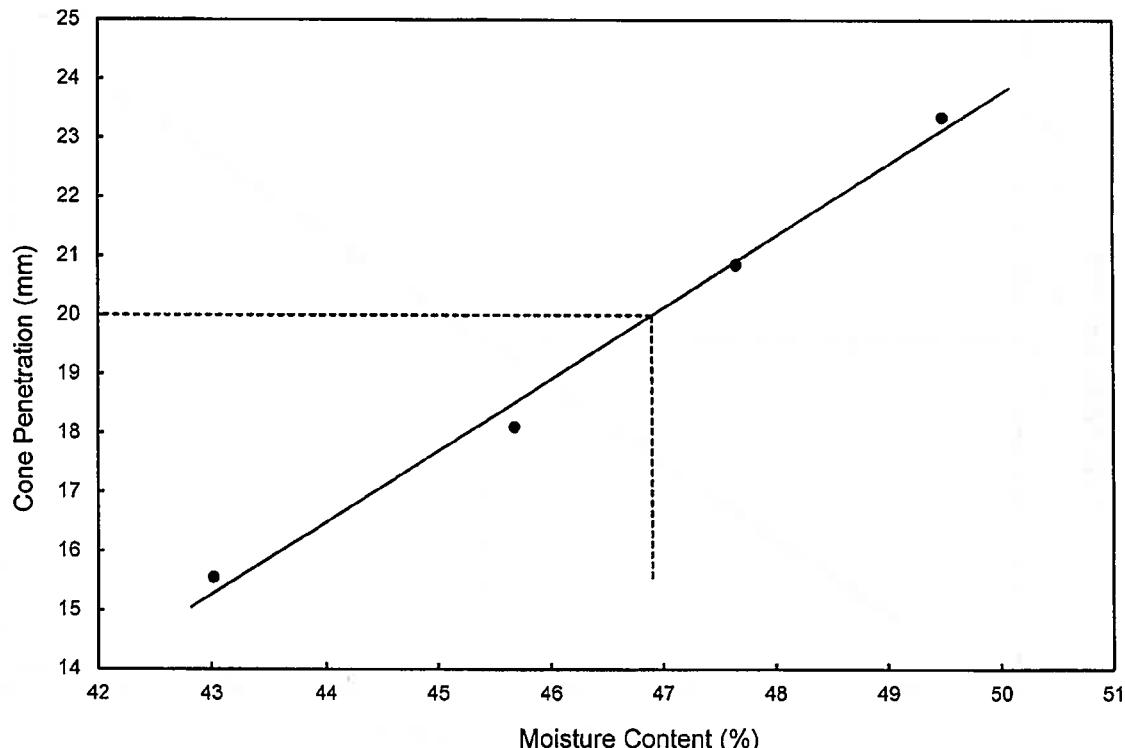
This Laboratory Is Accredited Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS) & Has Met The Requirements Of ISO / IEC 17025:2005.

The Results Reported Herein Have Been Performed In Accordance With The Laboratory's Terms Of Accreditation Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS).

## ATTERBERG LIMIT

[TEST METHOD - BS 1377:1990:Part 2:Test 4.3 / 5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
		SAMPLE:	UD-1
LOCATION:	-	DEPTH (m):	3.00 - 3.90
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.60 - 3.70



**SAMPLE HISTORY / PREPARATION -**

### **Wet Sieved Through 0.425mm Sieve**

**Percentage Passing On 0.425mm Sieve (%) -**

51

	LIQUID LIMIT (%)				PLASTIC LIMIT (%)	
CONTAINER WEIGHT (g)	3.826	3.900	3.803	3.645	8.197	8.041
WET MASS + CONTAINER WEIGHT (g)	16.260	16.571	16.302	17.586	18.674	18.568
DRY MASS + CONTAINER WEIGHT (g)	12.520	12.598	12.268	12.971	16.789	16.648
MOISTURE CONTENT (%)	43.0	45.7	47.7	49.5	21.9	22.3
PENETRATION (mm)	15.55	18.10	20.85	23.35		

LIQUID LIMIT (%) -	47	<u>Notes:</u>
PLASTIC LIMIT (%) -	22	Si - SILT (below A-Line)
PLASTICITY INDEX (%) -	25	Cl - CLAY (above A-Line)
FINE-GRAINED SOIL GROUP -	CII	L - Low, I - Intermediate, H - High Plasticity, O - Organic
LIQUIDITY INDEX (%) -	0.84	MOISTURE CONTENT OF: -
CONSISTENCY INDEX (%) -	0.16	NATURAL SOIL (%) - 22
		SOIL CORRECTED FOR FRACTION PASSING 0.425mm (%) - 43

Note: Table extracted from EN ISO 14688-2, table 6 - Consistency Index of silts & clays (Liquidity Index may be used as an alternative)

Consistency Index -	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	>1.00
Consistency of Silts & Clays -	Very soft	Soft	Firm	Stiff	Very stiff

TESTED DATE : 31/01/2017

CHECKED DATE : 08/02/2017



**TESTING OFFICER**

R. Mani

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

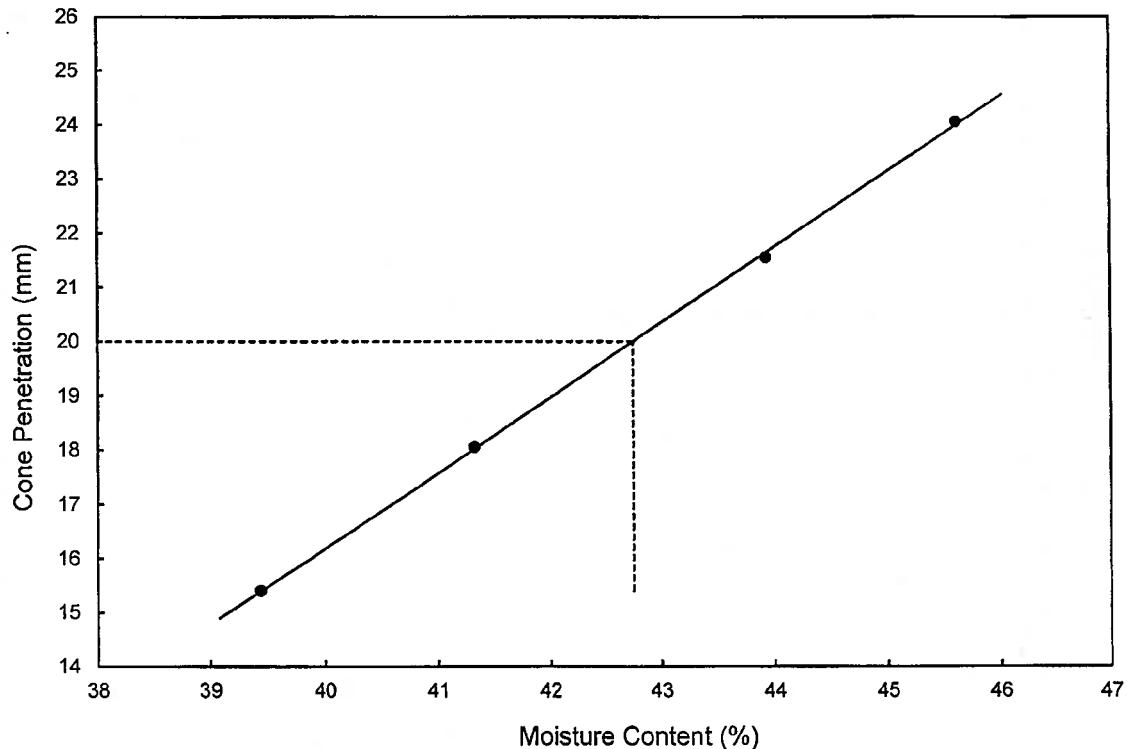
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SV/CLAS.



**ATTERBERG LIMIT**

[TEST METHOD - BS 1377:1990:Part 2:Test 4.3 / 5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.60 - 5.70



SAMPLE HISTORY / PREPARATION - Wet Sieved Through 0.425mm Sieve  
Percentage Passing On 0.425mm Sieve (%) - 38

CONTAINER WEIGHT (g)	LIQUID LIMIT (%)				PLASTIC LIMIT (%)	
	3.958	3.693	3.914	3.858	8.286	7.842
WET MASS + CONTAINER WEIGHT (g)	16.892	15.570	14.853	15.078	18.960	18.535
DRY MASS + CONTAINER WEIGHT (g)	13.234	12.097	11.514	11.563	17.106	16.719
MOISTURE CONTENT (%)	39.4	41.3	43.9	45.6	21.0	20.5
PENETRATION (mm)	15.40	18.05	21.55	24.05		

LIQUID LIMIT (%) - 43      Notes:  
 PLASTIC LIMIT (%) - 21      Si - SILT (below A-Line)  
 PLASTICITY INDEX (%) - 22      CI - CLAY (above A-Line)  
 FINE-GRAINED SOIL GROUP - CII      L - Low, I - Intermediate, H - High Plasticity, O - Organic  
 LIQUIDITY INDEX (%) - 5.77      MOISTURE CONTENT OF:-  
 CONSISTENCY INDEX (%) - -4.77      NATURAL SOIL (%) - 56  
 SOIL CORRECTED FOR FRACTION PASSING 0.425mm (%) - 148

Note: Table extracted from EN ISO 14688-2, table 6 - Consistency Index of silts & clays (Liquidity Index may be used as an alternative)

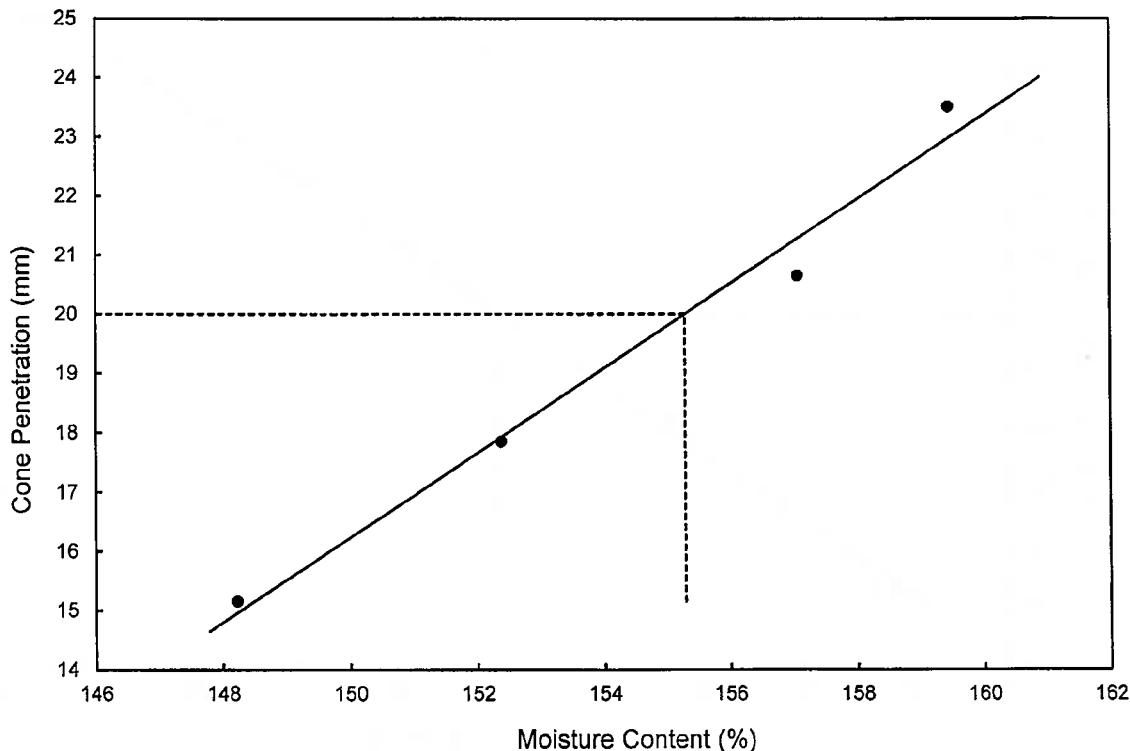
Consistency Index -	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	>1.00
Consistency of Silts & Clays -	Very soft	Soft	Firm	Stiff	Very stiff

TESTED DATE :	31/01/2017	CHECKED DATE :	08/02/2017
	TESTING OFFICER - R. Mani	APPROVED / CHECKED - (Authorised Signatory - Samuel Feng)	
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS			

**ATTERBERG LIMIT**

[TEST METHOD - BS 1377:1990:Part 2:Test 4.3 / 5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Dark grey slightly sandy very organic SILT with decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.60 - 3.70



SAMPLE HISTORY / PREPARATION -

Natural

Percentage Passing On 0.425mm Sieve (%) -

Not Applicable

	LIQUID LIMIT (%)				PLASTIC LIMIT (%)	
CONTAINER WEIGHT (g)	3.887	3.853	3.907	3.867	8.102	8.074
WET MASS + CONTAINER WEIGHT (g)	18.937	19.450	19.116	19.180	18.982	18.984
DRY MASS + CONTAINER WEIGHT (g)	9.950	10.033	9.823	9.769	14.344	14.343
MOISTURE CONTENT (%)	148.2	152.4	157.1	159.5	74.3	74.0
PENETRATION (mm)	15.15	17.85	20.65	23.50		

LIQUID LIMIT (%) - 155

Notes:

PLASTIC LIMIT (%) - 74

SI - SILT (below A-Line)

PLASTICITY INDEX (%) - 81

CL - CLAY (above A-Line)

FINE-GRAINED SOIL GROUP - OrSiH

L - Low, I - Intermediate, H - High Plasticity, Or - Organic

LIQUIDITY INDEX (%) - 0.59

MOISTURE CONTENT OF:-

CONSISTENCY INDEX (%) - 0.41

NATURAL SOIL (%) - 122

SOIL CORRECTED FOR FRACTION PASSING 0.425mm (%) - 122

Note: Table extracted from EN ISO 14688-2, table 6 - Consistency Index of silts &amp; clays (Liquidity Index may be used as an alternative)

Consistency Index -	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	>1.00
Consistency of Silts & Clays -	Very soft	Soft	Firm	Stiff	Very stiff

TESTED DATE: 31/01/2017

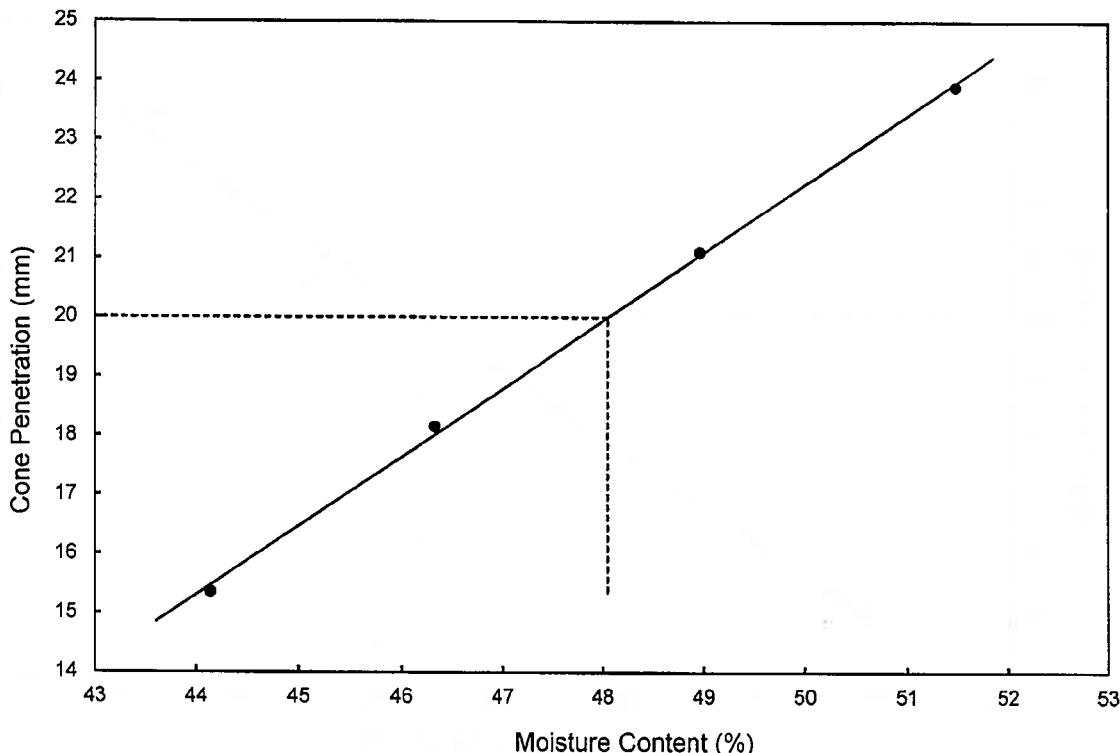
CHECKED DATE: 08/02/2017

 TESTING OFFICER - R. Mani	APPROVED / CHECKED - (Authorised Signatory - Samuel Teng)				
		The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS			

**ATTERBERG LIMIT**

[TEST METHOD - BS 1377:1990:Part 2:Test 4.3 / 5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.60 - 5.70



SAMPLE HISTORY / PREPARATION -

Natural

Percentage Passing On 0.425mm Sieve (%) -

Not Applicable

CONTAINER WEIGHT (g)	LIQUID LIMIT (%)				PLASTIC LIMIT (%)	
	3.861	3.946	3.871	3.845	8.117	8.110
WET MASS + CONTAINER WEIGHT (g)	18.056	18.964	18.425	19.966	18.741	18.840
DRY MASS + CONTAINER WEIGHT (g)	13.709	14.209	13.641	14.487	16.916	17.032
MOISTURE CONTENT (%)	44.1	46.3	49.0	51.5	20.7	20.3
PENETRATION (mm)	15.35	18.15	21.10	23.90		

LIQUID LIMIT (%) -	48	Notes:
PLASTIC LIMIT (%) -	21	SI - SILT (below A-Line)
PLASTICITY INDEX (%) -	27	CL - CLAY (above A-Line)
FINE-GRAINED SOIL GROUP -	CII	L - Low, I - Intermediate, H - High Plasticity, O - Organic
LIQUIDITY INDEX (%) -	-0.19	MOISTURE CONTENT OF: -
CONSISTENCY INDEX (%) -	1.19	NATURAL SOIL (%) - 16
		SOIL CORRECTED FOR FRACTION PASSING 0.425mm (%) - 16

Note: Table extracted from EN ISO 14688-2, table 6 - Consistency Index of silts &amp; clays (Liquidity Index may be used as an alternative)

Consistency Index -	<0.25	0.25 - 0.50	0.50 - 0.75	0.75 - 1.00	>1.00
Consistency of Silts & Clays -	Very soft	Soft	Firm	Stiff	Very stiff

TESTED DATE : 31/01/2017

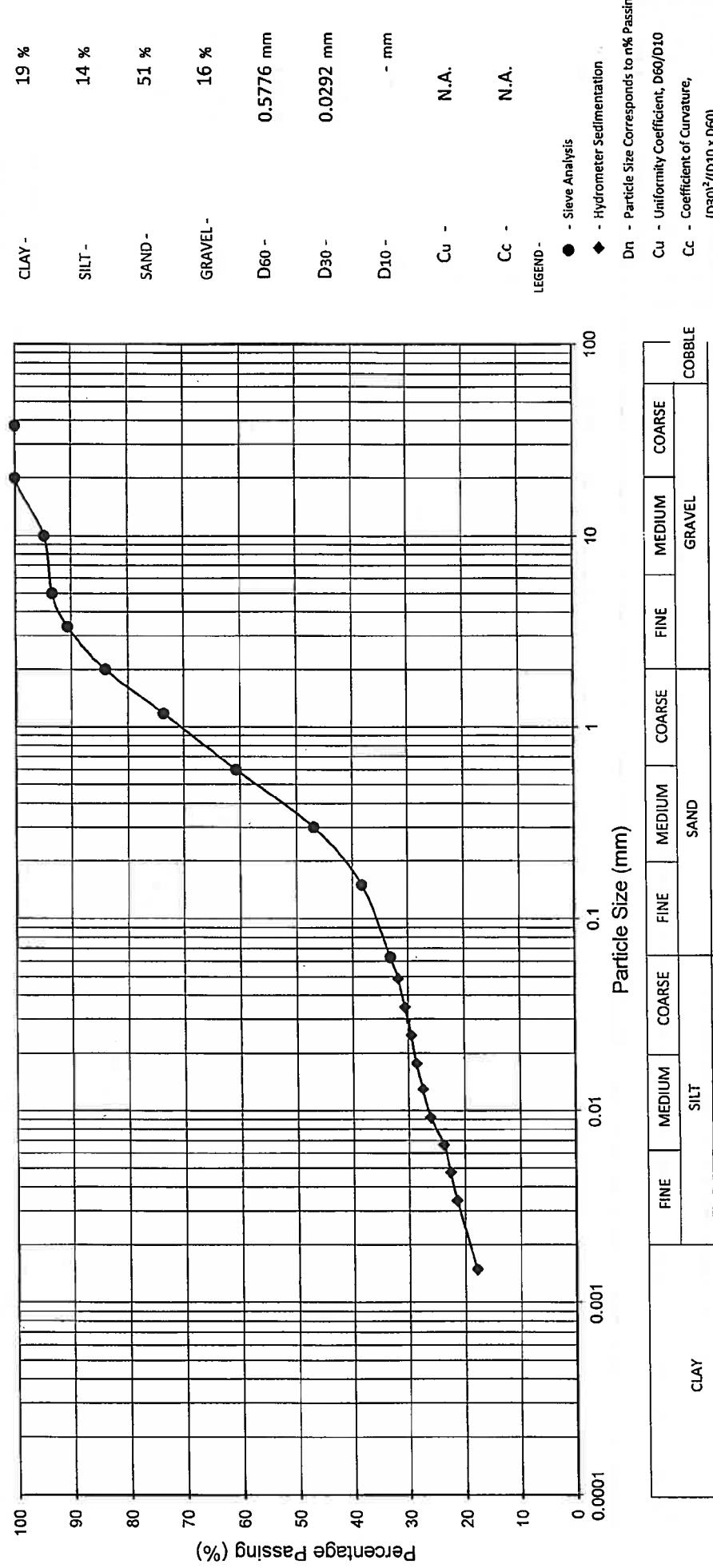
CHECKED DATE : 08/02/2017

 TESTING OFFICER - R. Mani	APPROVED / CHECKED -	(Authorised Signatory - Samuel Teng)		 ACCREDITED LABORATORY
		The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS		

**PARTICLE SIZE DISTRIBUTION**

[TEST METHOD - BS 1377:1990:Part 2:Test 9.3 / 9.5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo		
LOCATION:	-	BOREHOLE:	BH-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	SAMPLE:	UD-1
		DEPTH (m):	3.00 - 3.90



TESTED DATE - 21/01/2017

C. Pandi

CHECKED DATE - 08/02/2017

(Authorised Signatory)

APPROVED / CHECKED -

(Samuel Teng)



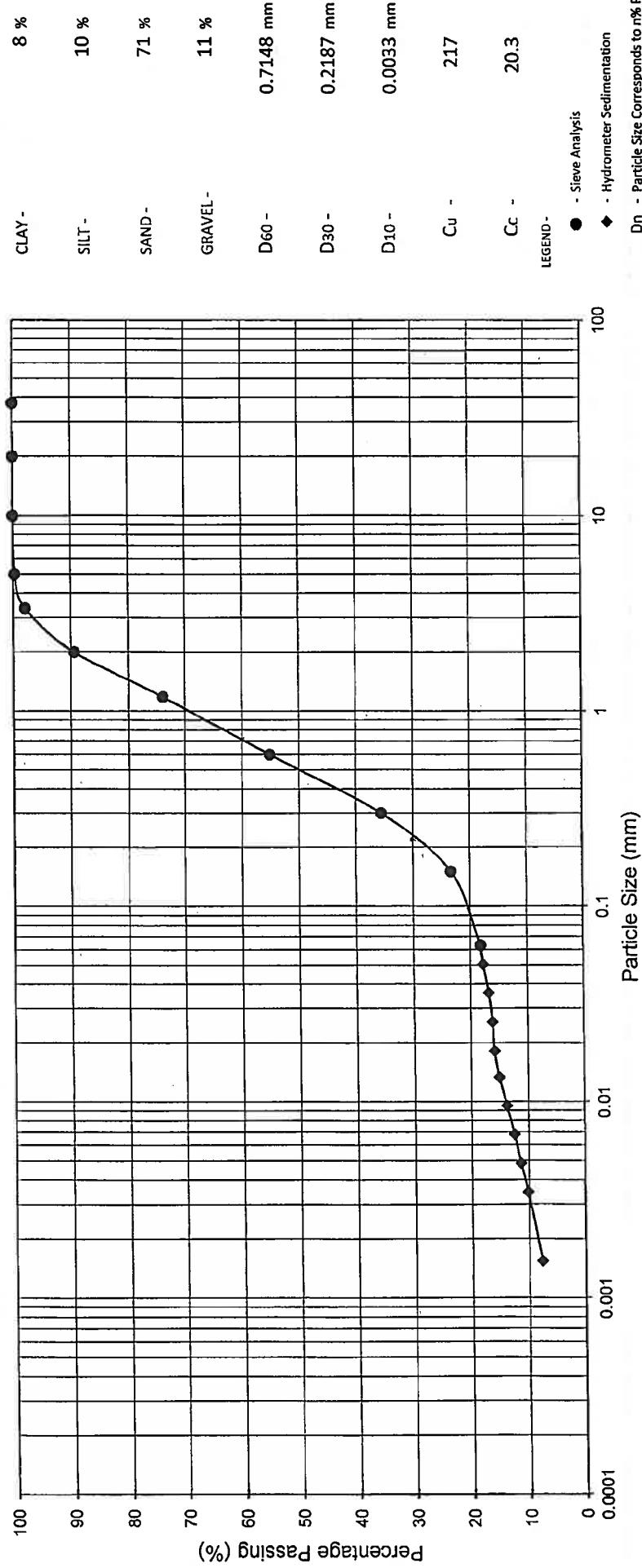
ACCREDITED  
TESTING LABORATORY  
**SAC-SINGLAS**  
CERTIFICATE NO: ZAP/002

The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS

## PARTICLE SIZE DISTRIBUTION

[TEST METHOD - BS 1377:1990:Part 2:Test 9.3 / 9.5]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	
LOCATION:	-	-
SOIL DESCRIPTION:	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation	-
BOREHOLE:	BH-1	UD-2
SAMPLE:	UD-2	-
DEPTH (m):	5.00 - 5.90	-
JOB NUMBER:	1702/14289	-
SPECIMEN DEPTH (m):	3.70 - 3.80	-



CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL	COBBLE

TESTED DATE - 21/01/2017  
TESTING OFFICER - C. Pandi

CHECKED DATE - 08/02/2017  
APPROVED / CHECKED -

(Authorised Signatory - Samu Feng)

(Authorised Signatory - Samu Feng)

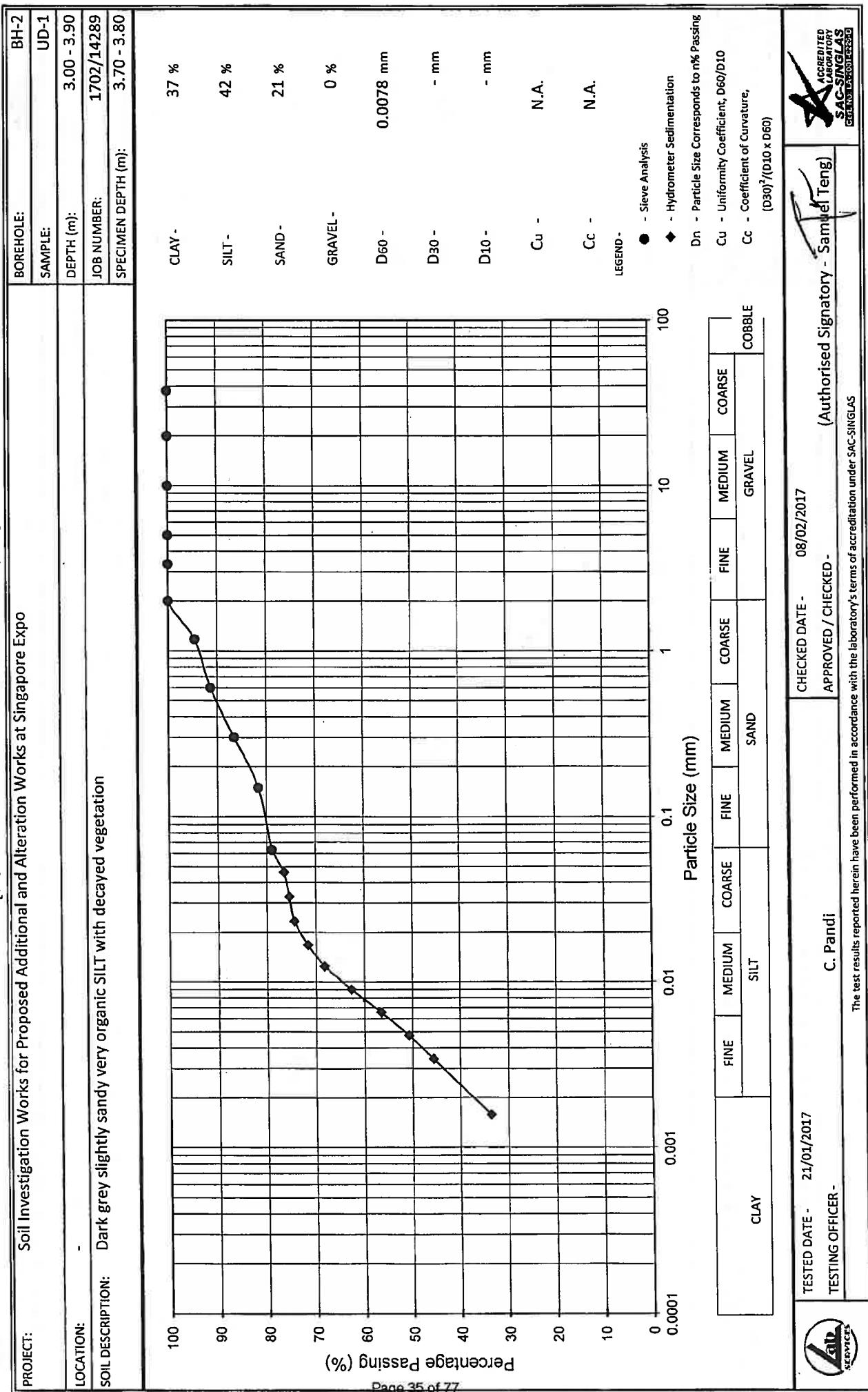
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS  
Cert No. LAFZ/2012/0033



ACCREDITED  
LABORATORY  
SAC-SINGLAS  
Cert No. LAFZ/2012/0033

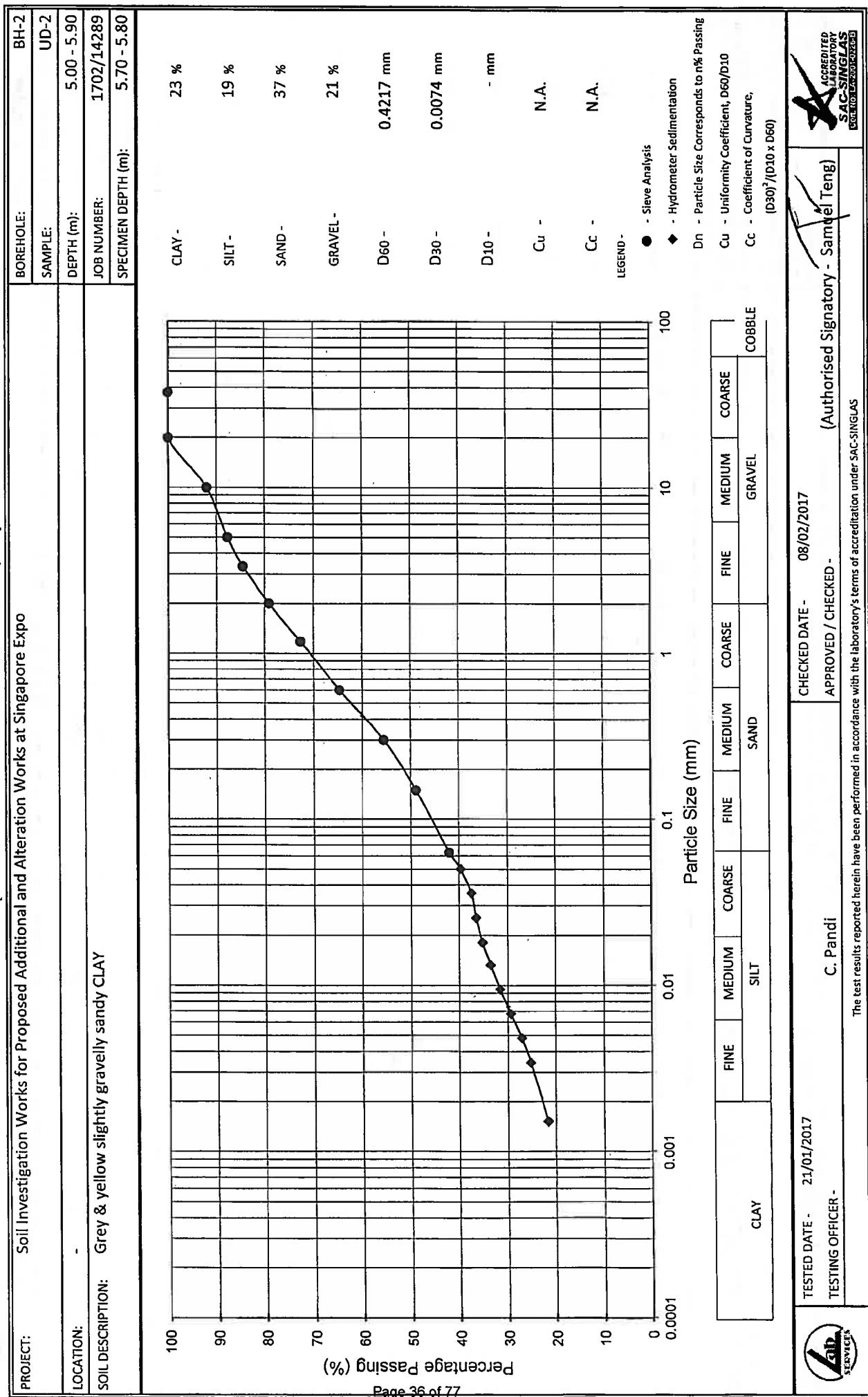
**PARTICLE SIZE DISTRIBUTION**

[TEST METHOD - BS 1377:1990:Part 2:Test 9.3 / 9.5]



PARTICLE SIZE DISTRIBUTION

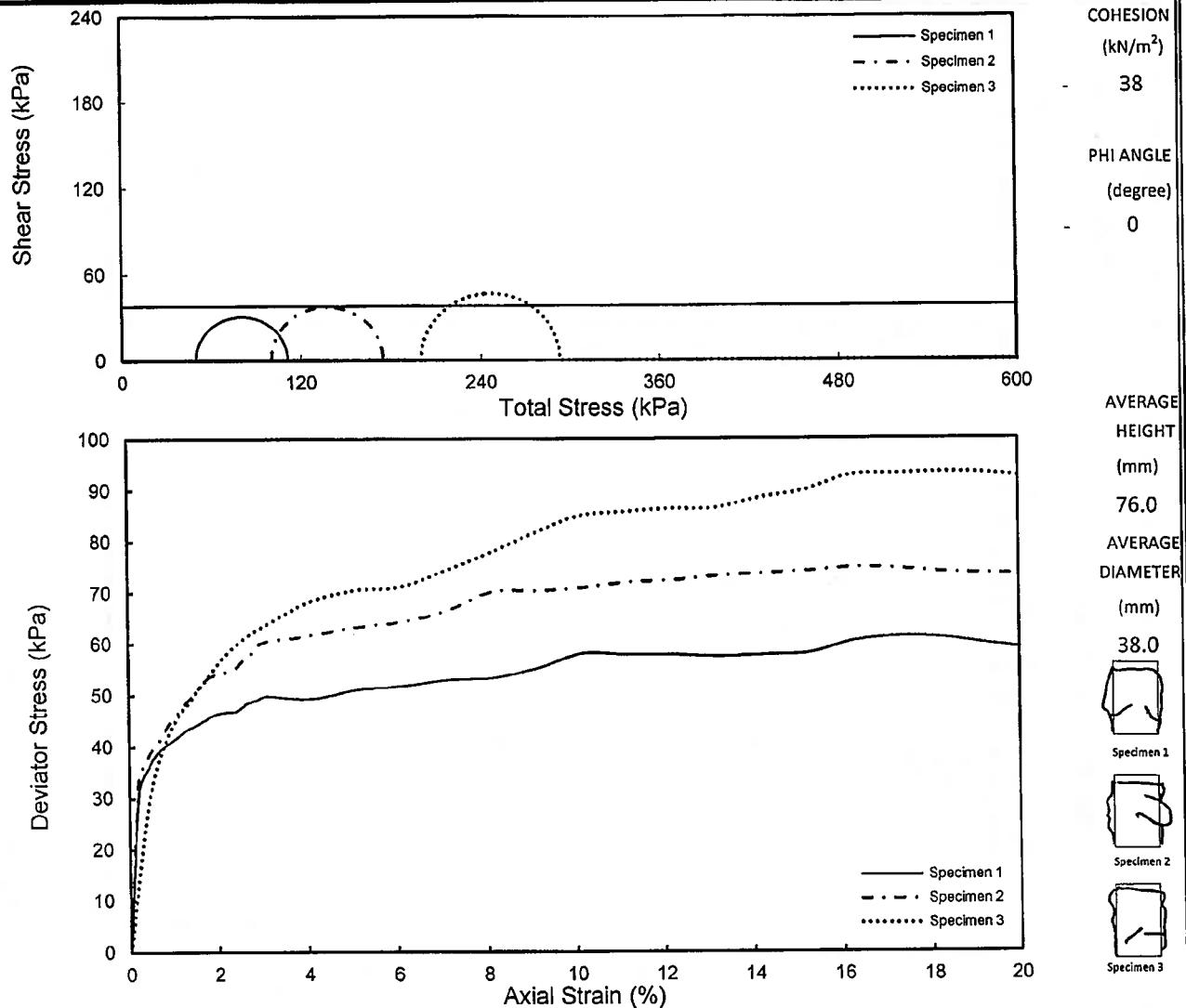
TEST METHOD - BS 1377:1990:Part 2:Test 9.3 / 9.5



## UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

[TEST METHOD - BS 1377:1990:Part 7:Test 8]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.40 - 3.70



## Terms to be used for the designated undrained shear strength in accordance to ISO 14688-2

Undrained Shear Strength of fine Soils	Extremely low	Very low	Low	Medium	High	Very high	Extremely high
Undrained Shear Strength Cu (kN/m²)	< 10	10 to 20	20 to 40	40 to 75	75 to 150	150 to 300	>300

Note: This test method covers the determination of undrained strength of cohesive soil when no change in total moisture content is allowed.

Hence specimen variation, degree of saturation of specimen and specimen type might influence the test result. User should determine the undrained shear strength ( $C_u$ ) from each individual stage of confining pressure whenever there is great difference in the undrained strength.

STAGE	CELL PRESSURE (kN/m²)	CORRECTED MAXIMUM DEVIATOR STRESS (kN/m²)	UNDRAINED SHEAR STRENGTH, $C_u$ (kN/m²)	STRAIN AT FAILURE (%)	MOISTURE CONTENT (%)	BULK / DRY DENSITY (Mg/m³)	VOID RATIO	DEGREE OF SATURATION (%)
1.	50	61	31	17.3	26	1.97	1.56	0.692
2.	100	75	38	16.4	21	2.00	1.65	0.600
3.	200	93	47	18.2	18	2.07	1.75	0.509

SPECIMEN TYPE - Undisturbed PARTICLE DENSITY (Mg/m³) - 2.64 SHEARING RATE (%/min) - 1.32

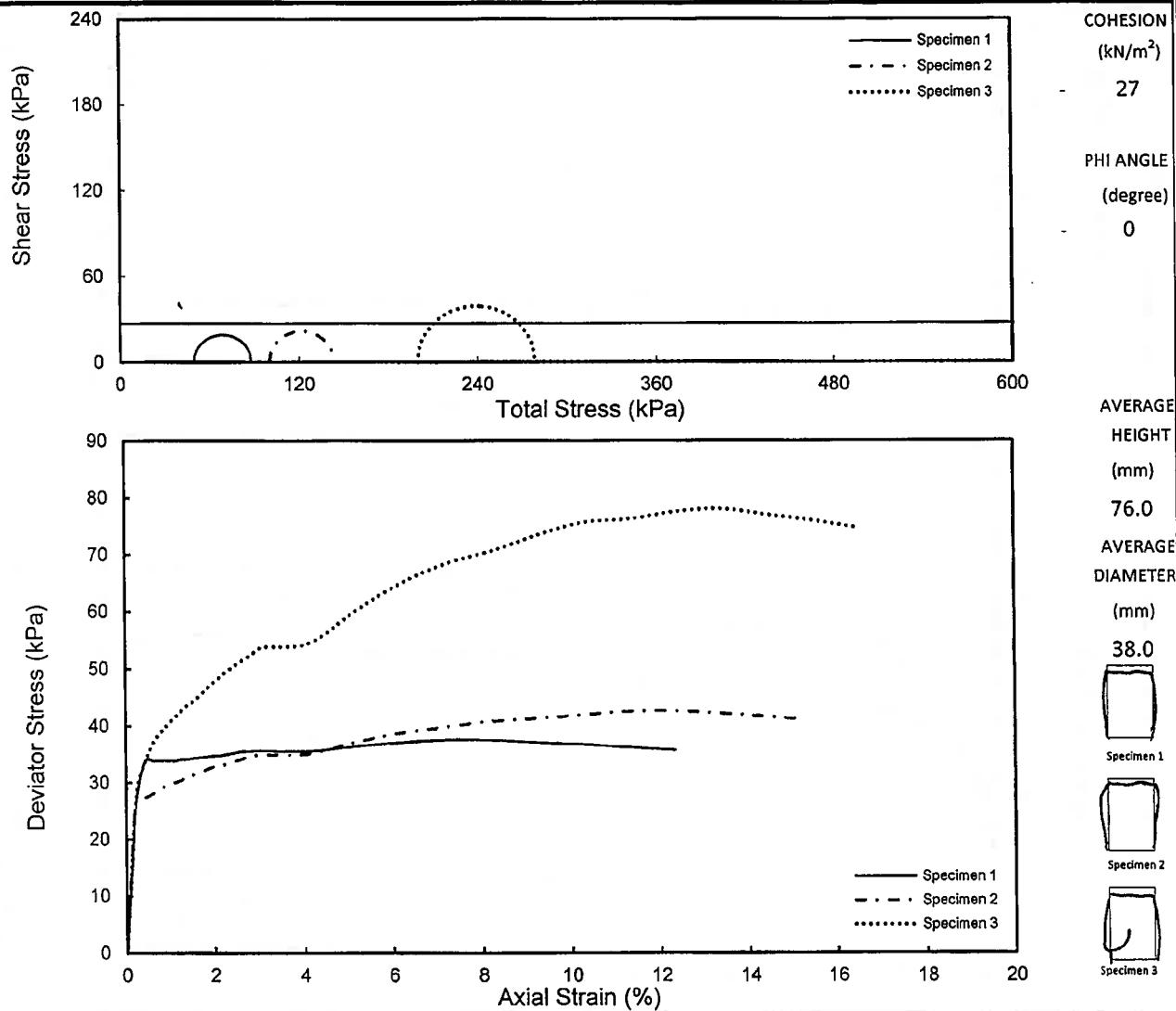
TESTED DATE : 25/01/2017 CHECKED DATE : 08/02/2017

	TESTING OFFICER - Chia Z.Y.	APPROVED / CHECKED - (Authorised Signatory - Samuel Teng)	
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS CCE No. LA-2001/0226-E			

## UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

[TEST METHOD - BS 1377:1990:Part 7:Test 8]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.50 - 5.80



## Terms to be used for the designated undrained shear strength in accordance to ISO 14688-2

Undrained Shear Strength of fine Soils	Extremely low	Very low	Low	Medium	High	Very high	Extremely high
Undrained Shear Strength Cu (kN/m <sup>2</sup> )	< 10	10 to 20	20 to 40	40 to 75	75 to 150	150 to 300	>300

Note: This test method covers the determination of undrained strength of cohesive soil when no change in total moisture content is allowed.

Hence specimen variation, degree of saturation of specimen and specimen type might influence the test result. User should determine the undrained shear strength ( $C_u$ ) from each individual stage of confining pressure whenever there is great difference in the undrained strength.

STAGE	CELL PRESSURE (kN/m <sup>2</sup> )	CORRECTED MAXIMUM DEVIATOR STRESS (kN/m <sup>2</sup> )	UNDRAINED SHEAR STRENGTH, Cu (kN/m <sup>2</sup> )	STRAIN AT FAILURE (%)	MOISTURE CONTENT (%)	BULK / DRY DENSITY (Mg/m <sup>3</sup> )	VOID RATIO	DEGREE OF SATURATION (%)	
1.	50	38	19	8.2	40	1.79	1.28	1.078	98.7
2.	100	43	22	12.2	34	1.86	1.39	0.914	98.9
3.	200	78	39	13.4	24	1.97	1.59	0.673	94.9

SPECIMEN TYPE - Undisturbed PARTICLE DENSITY (Mg/m<sup>3</sup>) - 2.66 SHEARING RATE (%/min) - 1.32

TESTED DATE : 25/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Chia Z.Y.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

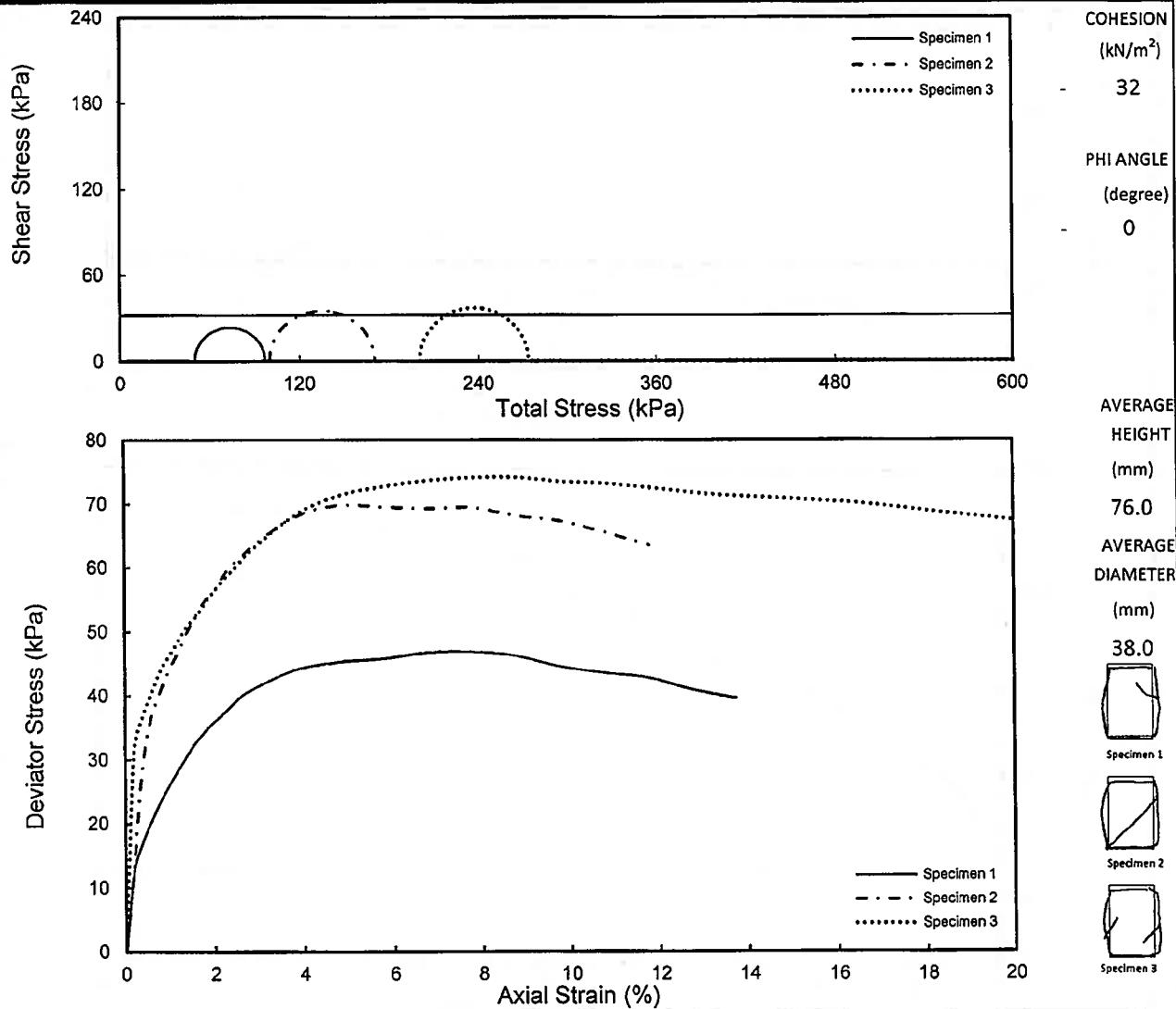
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



## UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

[TEST METHOD - BS 1377:1990:Part 7:Test 8]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Dark grey slightly sandy very organic SILT with decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.50 - 3.80



## Terms to be used for the designated undrained shear strength in accordance to ISO 14688-2

Undrained Shear Strength of fine Soils	Extremely low	Very low	Low	Medium	High	Very high	Extremely high
Undrained Shear Strength Cu (kN/m <sup>2</sup> )	< 10	10 to 20	20 to 40	40 to 75	75 to 150	150 to 300	>300

Note: This test method covers the determination of undrained strength of cohesive soil when no change in total moisture content is allowed.

Hence specimen variation, degree of saturation of specimen and specimen type might influence the test result. User should determine the undrained shear strength ( $C_u$ ) from each individual stage of confining pressure whenever there is great difference in the undrained strength.

STAGE	CELL PRESSURE (kN/m <sup>2</sup> )	CORRECTED MAXIMUM DEVIATOR STRESS (kN/m <sup>2</sup> )	UNDRAINED SHEAR STRENGTH, Cu (kN/m <sup>2</sup> )	STRAIN AT FAILURE (%)	MOISTURE CONTENT (%)	BULK / DRY DENSITY (Mg/m <sup>3</sup> )	VOID RATIO	DEGREE OF SATURATION (%)
1.	50	47	24	7.8	132	1.30	0.56	3.286
2.	100	70	35	4.8	117	1.32	0.61	2.934
3.	200	74	37	8.8	117	1.32	0.61	2.934

SPECIMEN TYPE - Undisturbed PARTICLE DENSITY (Mg/m<sup>3</sup>) - 2.40 SHEARING RATE (%/min) - 1.32

TESTED DATE : 25/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER - Chia Z.Y.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

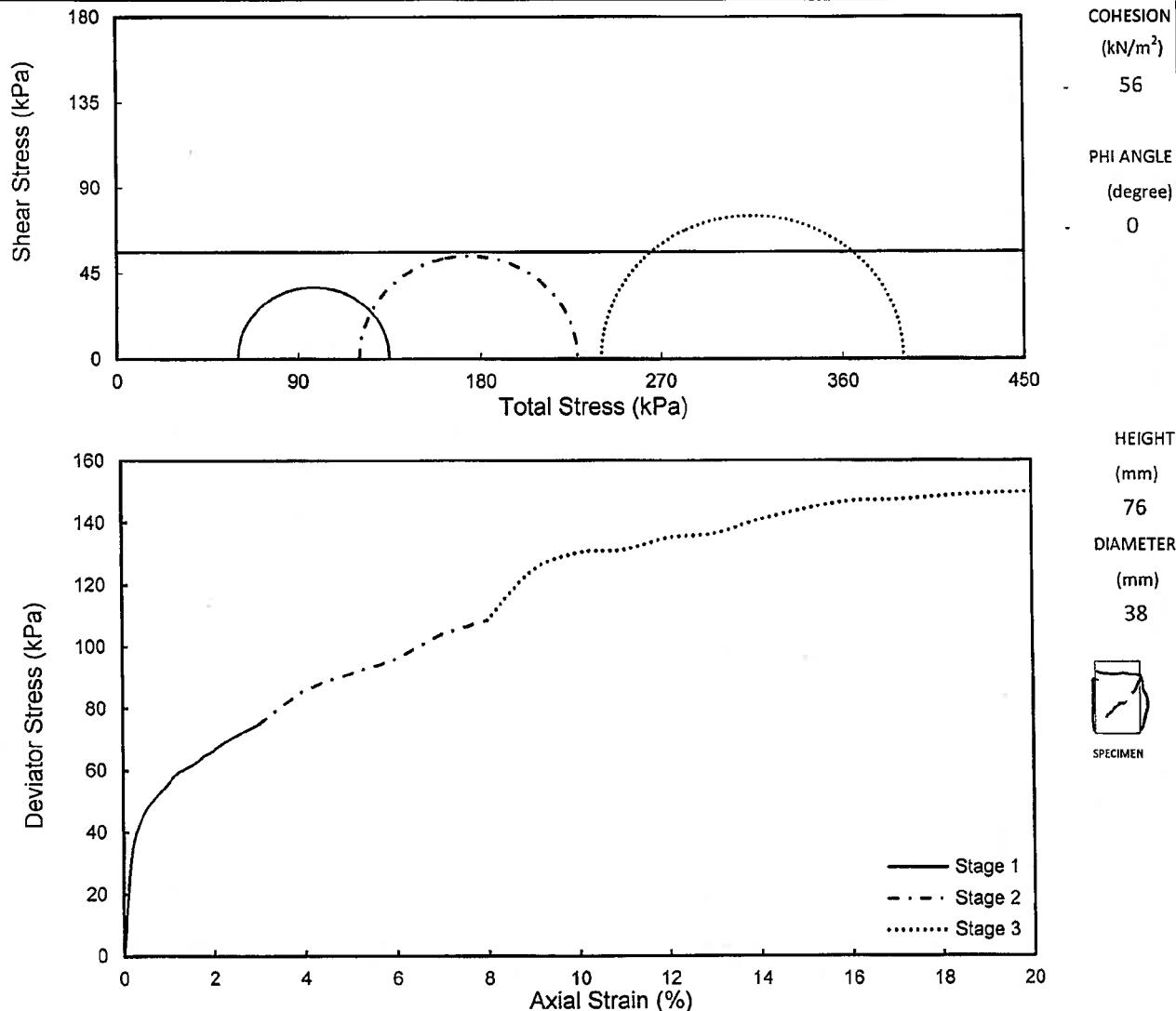
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



**UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 7:Test 9]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.60 - 5.70



Terms to be used for the designated undrained shear strength in accordance to ISO 14688-2

Undrained Shear Strength of fine Soils	Extremely low	Very low	Low	Medium	High	Very high	Extremely high
Undrained Shear Strength Cu (kN/m <sup>2</sup> )	< 10	10 to 20	20 to 40	40 to 75	75 to 150	150 to 300	>300

Note: This test method covers the determination of undrained strength of cohesive fine soil in terms of the total stress where drainage cannot occurred.

Hence degree of saturation of specimen and specimen type might influence the test result. User should determine the undrained shear strength ( $C_u$ ) from each individual stage of confining pressure whenever there is great difference in the undrained strength.

STAGE	CELL PRESSURE (kN/m <sup>2</sup> )	CORRECTED MAXIMUM DEVIATOR STRESS (kN/m <sup>2</sup> )	UNDRAINED SHEAR STRENGTH, Cu (kN/m <sup>2</sup> )	STRAIN AT FAILURE (%)	MOISTURE CONTENT (%)	BULK / DRY DENSITY (Mg/m <sup>3</sup> )	VOID RATIO	DEGREE OF SATURATION (%)
1.	60	75	38	3.0				
2.	120	108	54	8.0	16	2.09	1.80	0.461
3.	240	150	75	20.0				91.3

SPECIMEN TYPE - Undisturbed PARTICLE DENSITY (Mg/m<sup>3</sup>) - 2.63 SHEARING RATE (%/min) - 1.32

TESTED DATE : 25/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Sim L.H.

APPROVED / CHECKED -

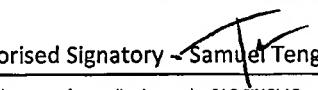
(Authorised Signatory - Samuel Teng)

The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

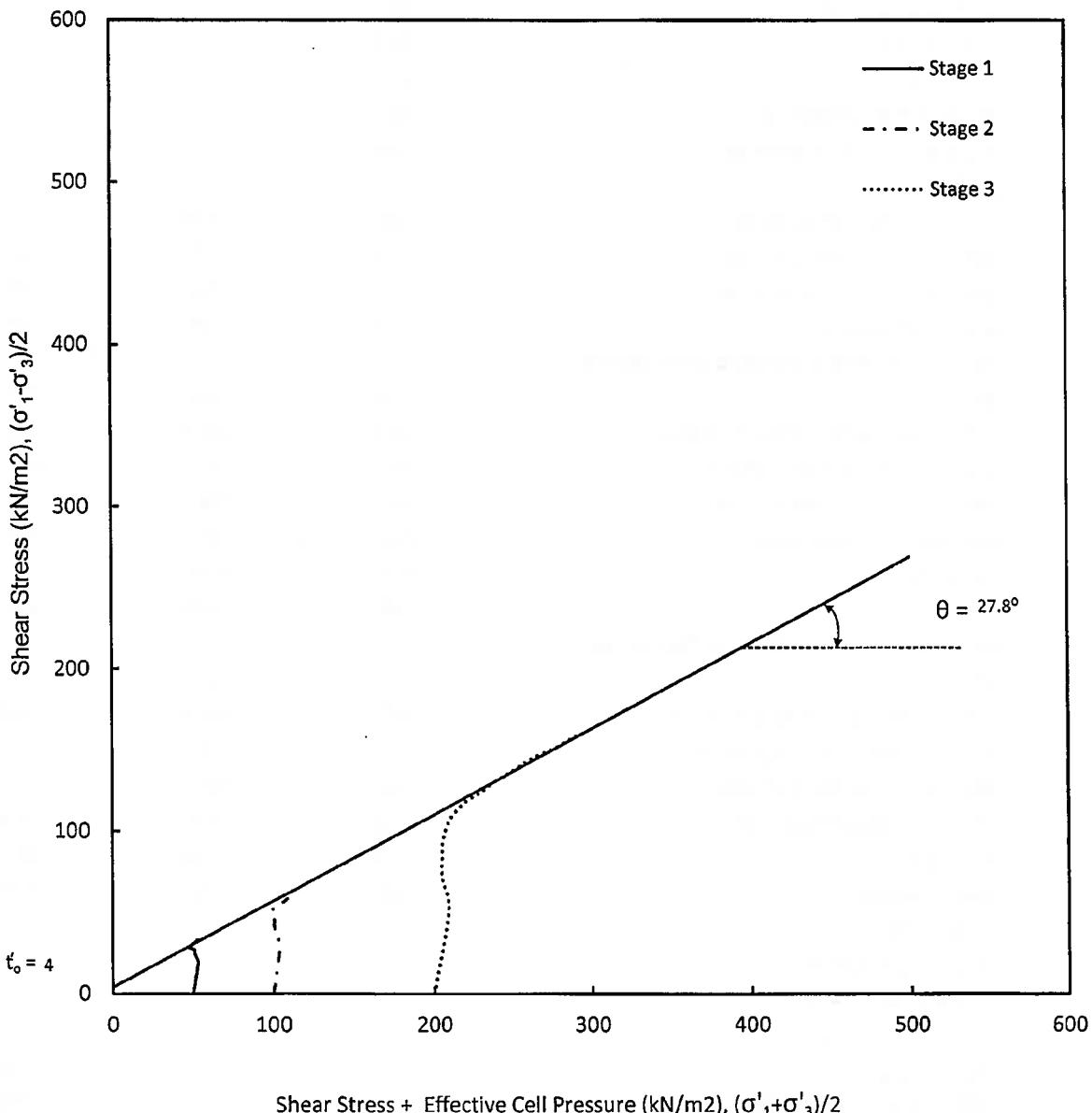
[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo		BOREHOLE:	BH-1
LOCATION:	-		SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation		DEPTH (m):	3.00 - 3.90
			JOB NUMBER:	1702/14289
			SPECIMEN DEPTH (m):	3.70 - 3.80
<b>MULTI-STAGE TEST</b>				
			1	2
				3
<b>INITIAL STAGE -</b>				
SAMPLE HEIGHT (mm)		75.3		
SAMPLE DIAMETER (mm)		38.1		
MOISTURE CONTENT (%)		20		
BULK DENSITY (Mg/m3)		2.06		
DRY DENSITY (Mg/m3)		1.72		
PARTICLE DENSITY		2.64		
VOID RATIO $e_o$		0.535		
DEGREE OF SATURATION $S_o$ (%)		98.7		
FINAL B VALUE AFTER SATURATION		0.96		
<b> SHEAR STAGE -</b>				
INITIAL CELL PRESSURE $\sigma_3$ (kN/m2)	350	400	500	
INITIAL PORE PRESSURE $u$ (kN/m2)	300	300	300	
INITIAL EFFECTIVE PRESSURE (kN/m2)	50	100	200	
STRAIN RATE (mm/min)	0.03	0.03	0.03	
<b>FAILURE CONDITION AT MAXIMUM DEVIATOR STRESS -</b>				
STRAIN (%)	3.86	3.38	8.03	
CORRECTED DEVIATOR STRESS $\sigma'_1-\sigma'_3$ (kN/m2)	66.1	116.9	320.1	
EFFECTIVE MINOR STRESS $\sigma'_3$ (kN/m2)	19.9	50.2	132.9	
EFFECTIVE MAJOR STRESS $\sigma'_1$ (kN/m2)	86.0	167.1	453.0	
PORE WATER PRESSURE (kN/m2)	330.1	349.8	367.1	
A VALUE $A_f$	0.455	0.426	0.210	
STRESS RATIO $\sigma'_1/\sigma'_3$	4.322	3.329	3.409	
<b>FAILURE CONDITION AT MAXIMUM STRESS RATIO -</b>				
STRAIN (%)	3.86	3.38	4.93	
CORRECTED DEVIATOR STRESS $\sigma'_1-\sigma'_3$ (kN/m2)	66.1	116.9	289.0	
EFFECTIVE MINOR STRESS $\sigma'_3$ (kN/m2)	19.9	50.2	118.2	
EFFECTIVE MAJOR STRESS $\sigma'_1$ (kN/m2)	86.0	167.1	407.2	
PORE WATER PRESSURE (kN/m2)	330.1	349.8	381.8	
A VALUE $A_f$	0.455	0.426	0.283	
STRESS RATIO $\sigma'_1/\sigma'_3$	4.322	3.329	3.445	
<b>FINAL STAGE -</b>				
MOISTURE CONTENT (%)				18
BULK DENSITY (Mg/m3)				2.13
DRY DENSITY (Mg/m3)				1.81
VOID RATIO $e_f$				0.463
DEGREE OF SATURATION $S_f$ (%)				100.0
<b> FAILURE MODE -</b>				
				 Specimen
TESTED DATE :	24/01/2017	APPROVED / CHECKED -	08/02/2017	
	TESTING OFFICER - Y. Simon P.	(Authorised Signatory ~ 		 Cert No: LA-2001-0226-B
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS				

**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.70 - 3.80

**SHEAR STAGE - STRESS PATH PLOT** $c' (\text{kN/m}^2)$  - 5 $\phi' (\text{degree})$  - 32

TESTED DATE :

24/01/2017

CHECKED DATE :

08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

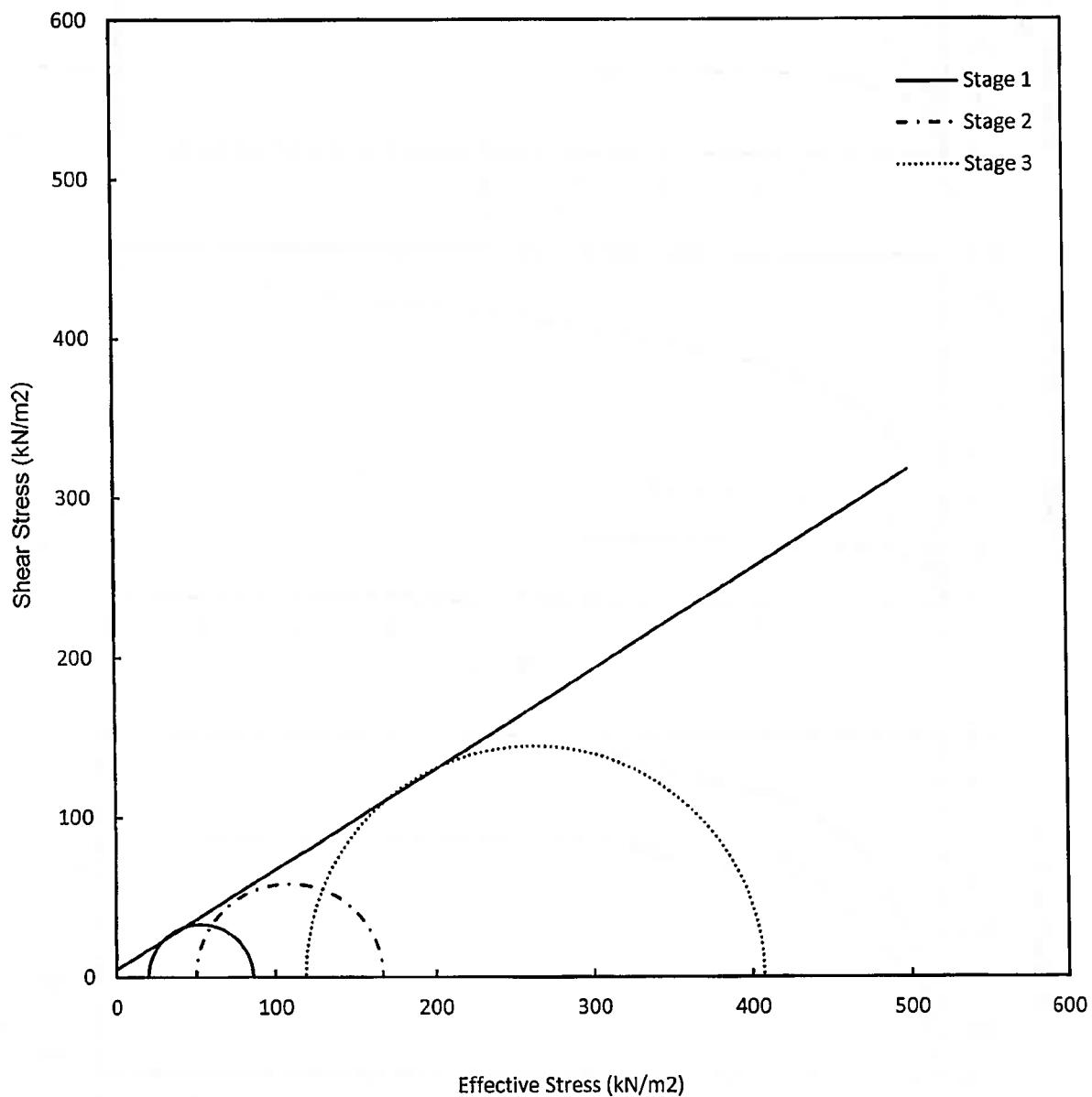


The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS

**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.70 - 3.80

**SHEAR STAGE - MAXIMUM STRESS RATIO** $c'$  (kN/m<sup>2</sup>) - 5 $\phi'$  (degree) - 32

TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

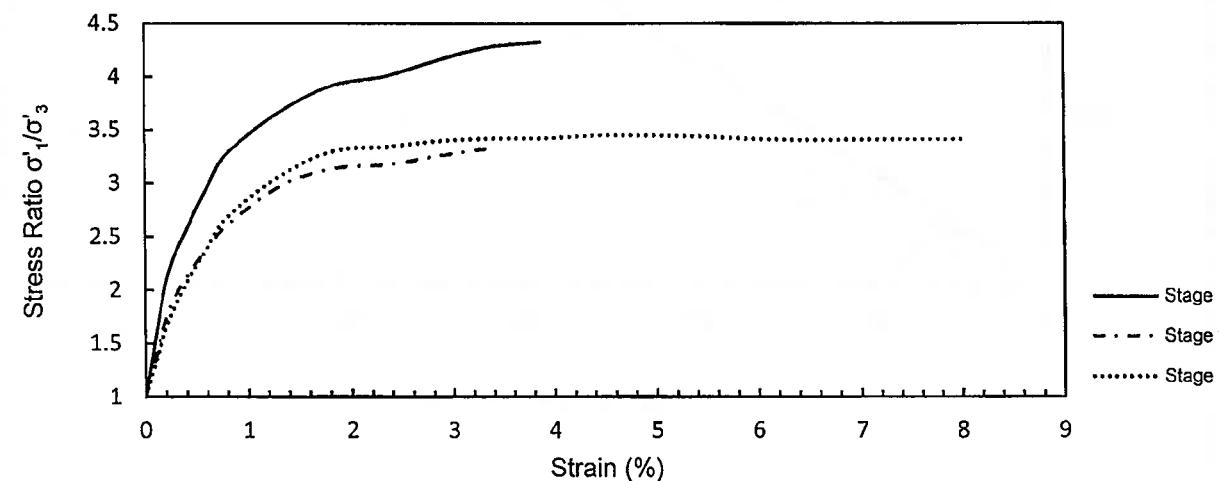
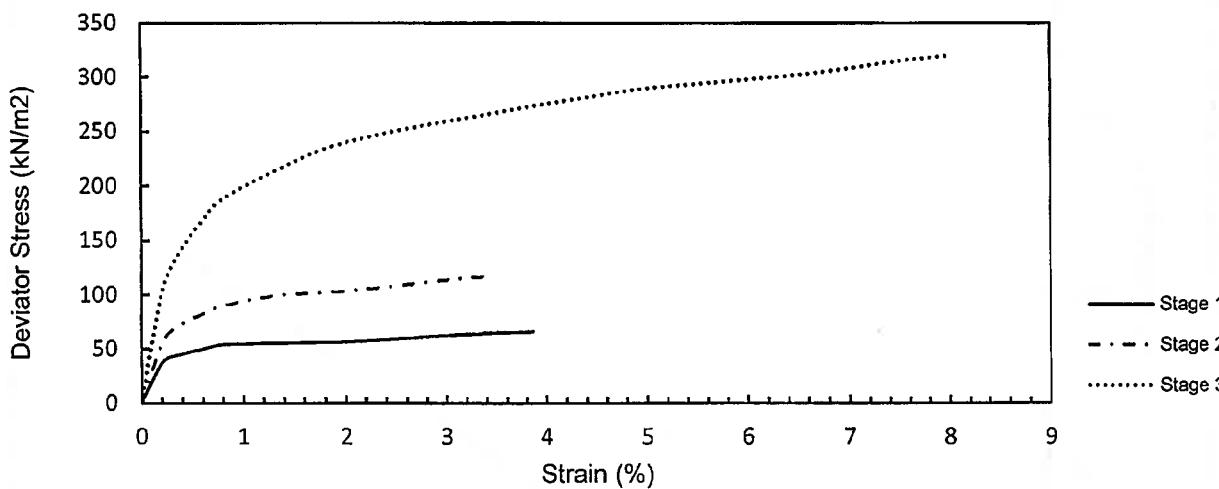
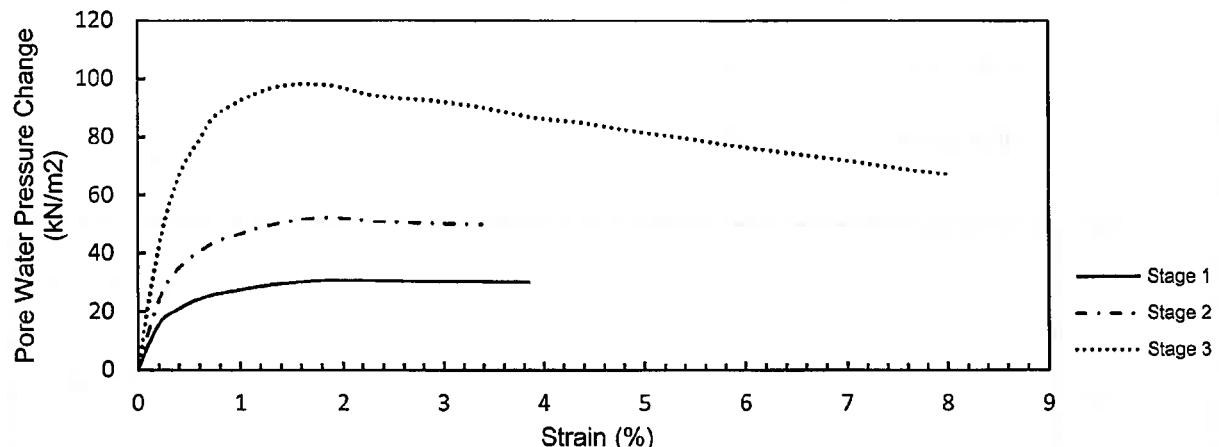


The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS

**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.70 - 3.80

**SHEAR STAGE**

TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS

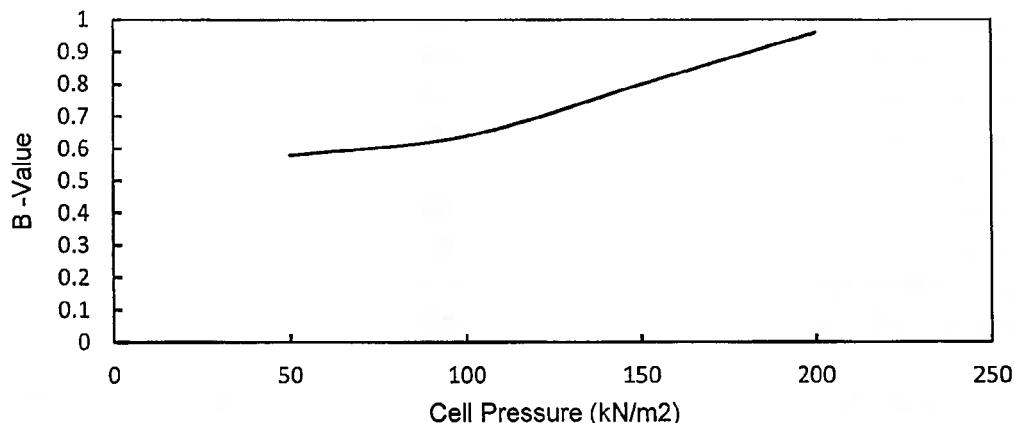


**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

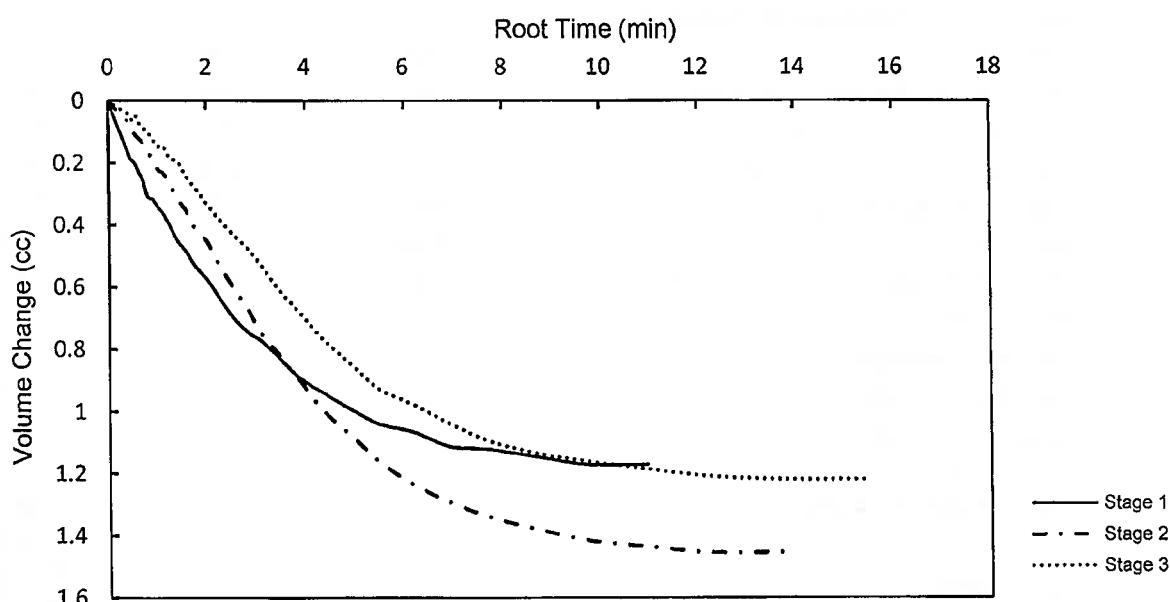
[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.70 - 3.80

SATURATION; BY INCREMENTS OF CELL PRESSURE &amp; BACK PRESSURE METHOD



CONSOLIDATION : DRAINAGE - TOP & SIDE DRAIN	1	2	3
INITIAL CELL PRESSURE $\sigma_3$ (kN/m <sup>2</sup> )	350	400	500
INITIAL PORE PRESSURE $u_i$ (kN/m <sup>2</sup> )	338	364	414
INITIAL BACK PRESSURE $u_b$ (kN/m <sup>2</sup> )	300	300	300
FINAL PORE PRESSURE $u_e$ (kN/m <sup>2</sup> )	300	300	300
VOLUME CHANGE (cc)	1.17	1.45	1.22
$T_{100}$ (min)	15.68	35.64	44.22
$C_{vI}$ (m <sup>2</sup> /Yr)	1.944	0.848	0.675
$m_{vi}$ (m <sup>2</sup> /MN)	0.359	0.268	0.128



TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

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**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.70 - 5.80
<b>MULTI-STAGE TEST</b>		1	2
<b>INITIAL STAGE -</b>			
SAMPLE HEIGHT (mm)	75.7		3
SAMPLE DIAMETER (mm)	38.0		
MOISTURE CONTENT (%)	15		
BULK DENSITY (Mg/m3)	2.08		
DRY DENSITY (Mg/m3)	1.81		
PARTICLE DENSITY	2.63		
VOID RATIO $e_o$	0.453		
DEGREE OF SATURATION $S_o$ (%)	87.1		
FINAL B VALUE AFTER SATURATION	0.96		
<b>SHEAR STAGE -</b>			
INITIAL CELL PRESSURE $\sigma_3$ (kN/m2)	350	400	500
INITIAL PORE PRESSURE $u$ (kN/m2)	300	300	300
INITIAL EFFECTIVE PRESSURE (kN/m2)	50	100	200
STRAIN RATE (mm/min)	0.03	0.03	0.03
<b>FAILURE CONDITION AT MAXIMUM DEVIATOR STRESS -</b>			
STRAIN (%)	3.34	3.84	7.85
CORRECTED DEVIATOR STRESS $\sigma'_1-\sigma'_3$ (kN/m2)	89.2	196.6	403.6
EFFECTIVE MINOR STRESS $\sigma'_3$ (kN/m2)	40.5	76.4	151.0
EFFECTIVE MAJOR STRESS $\sigma'_1$ (kN/m2)	129.7	273.0	554.6
PORE WATER PRESSURE (kN/m2)	309.5	323.6	349.0
A VALUE $A_f$	0.107	0.120	0.121
STRESS RATIO $\sigma'_1/\sigma'_3$	3.202	3.573	3.673
<b>FAILURE CONDITION AT MAXIMUM STRESS RATIO -</b>			
STRAIN (%)	3.34	3.34	2.35
CORRECTED DEVIATOR STRESS $\sigma'_1-\sigma'_3$ (kN/m2)	89.2	191.3	353.3
EFFECTIVE MINOR STRESS $\sigma'_3$ (kN/m2)	40.5	74.2	126.1
EFFECTIVE MAJOR STRESS $\sigma'_1$ (kN/m2)	129.7	265.5	479.4
PORE WATER PRESSURE (kN/m2)	309.5	325.8	373.9
A VALUE $A_f$	0.107	0.135	0.209
STRESS RATIO $\sigma'_1/\sigma'_3$	3.202	3.578	3.802
<b>FINAL STAGE -</b>			
MOISTURE CONTENT (%)			17
BULK DENSITY (Mg/m3)			2.18
DRY DENSITY (Mg/m3)			1.86
VOID RATIO $e_f$			0.412
DEGREE OF SATURATION $S_f$ (%)			100.0
<b>FAILURE MODE -</b>			
			 Specimen

TESTED DATE : 24/01/2017

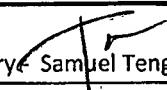
CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory)  Samuel Teng

The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS

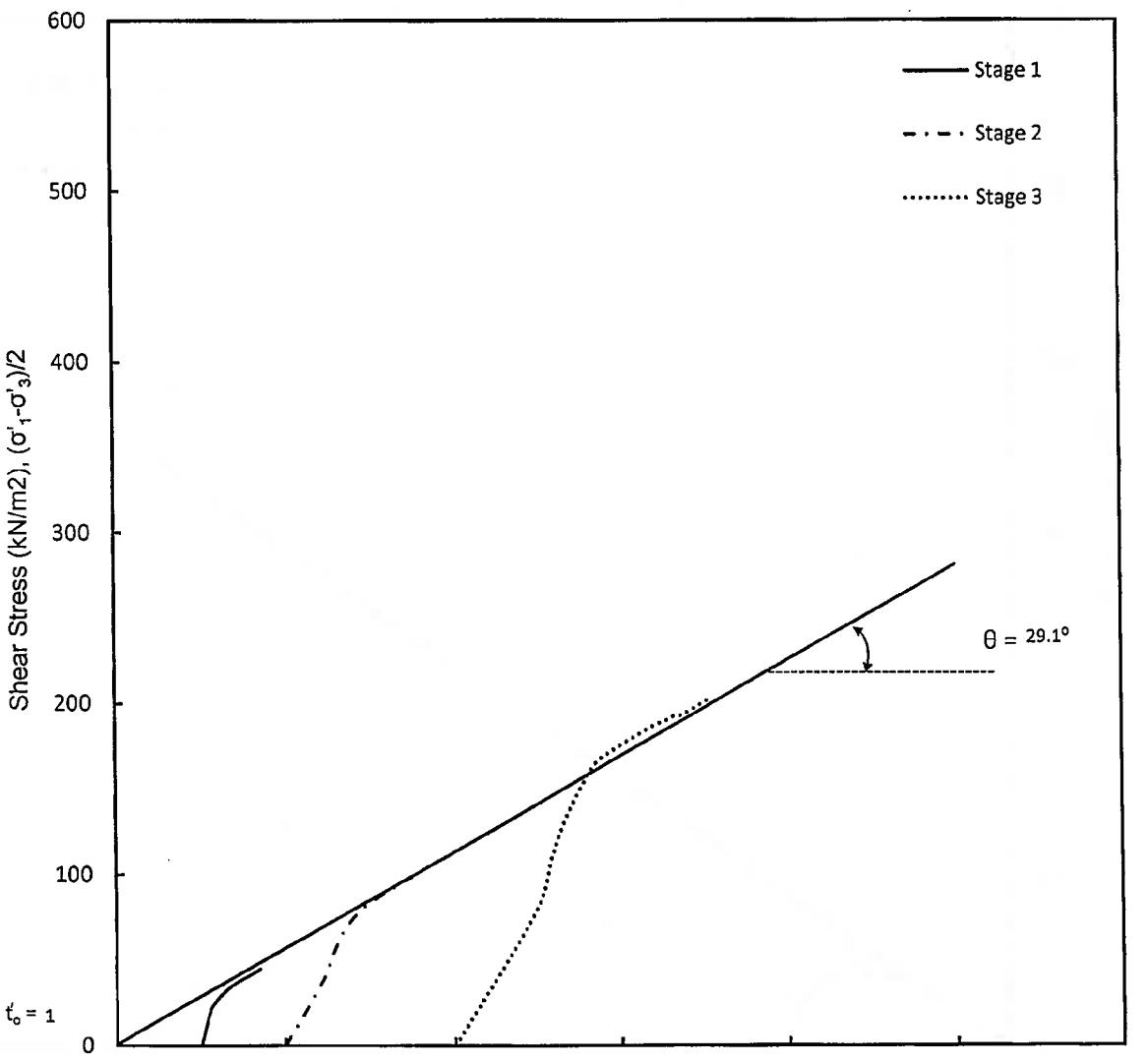


## CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.70 - 5.80

## SHEAR STAGE - STRESS PATH PLOT

 $c' (\text{kN/m}^2)$  - 1 $\phi' (\text{degree})$  - 34Shear Stress + Effective Cell Pressure ( $\text{kN/m}^2$ ),  $(\sigma'_1 + \sigma'_3)/2$ 

TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

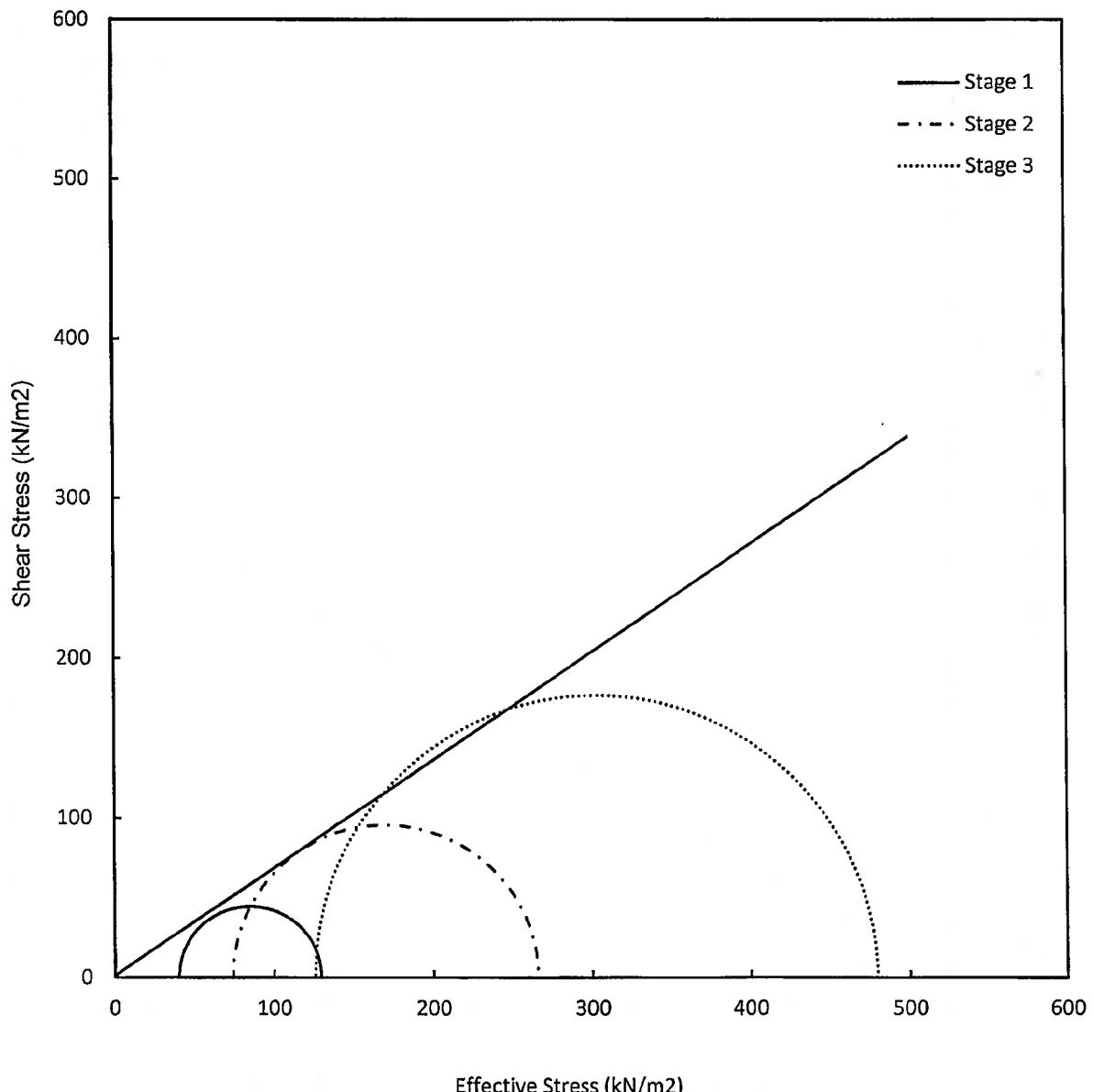
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.70 - 5.80

**SHEAR STAGE - MAXIMUM STRESS RATIO** $c'$  (kN/m<sup>2</sup>) - 1 $\phi'$  (degree) - 34

TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

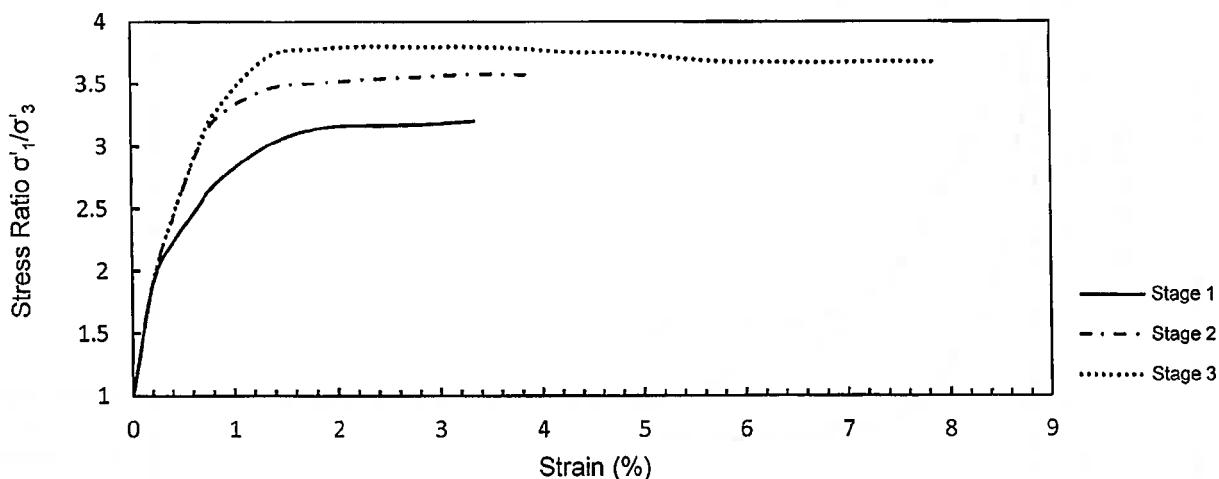
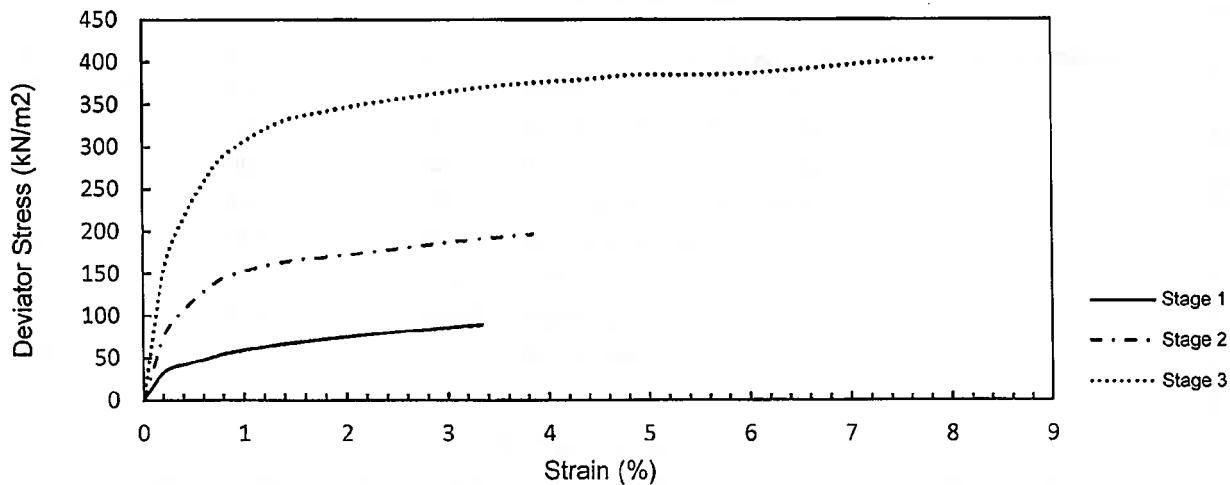
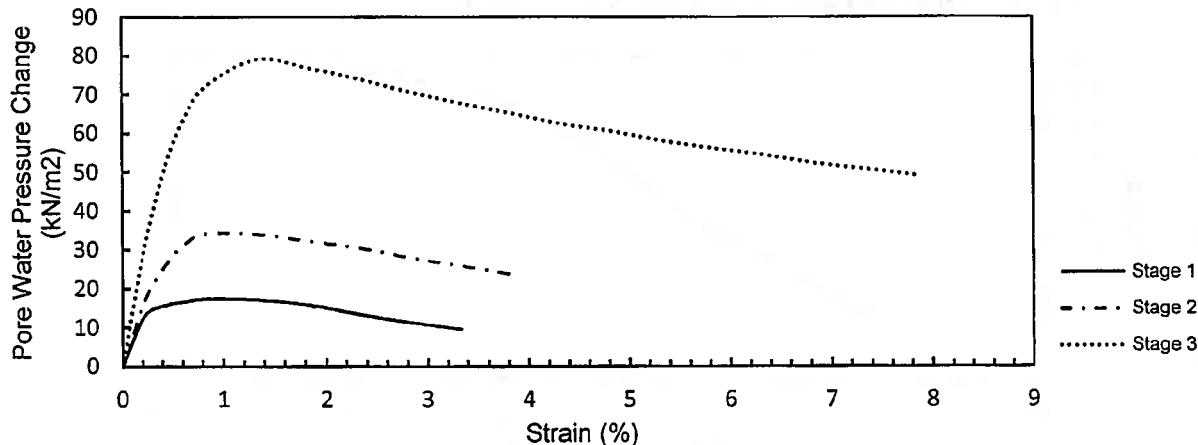
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**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.70 - 5.80

**SHEAR STAGE**

TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory) Samuel Feng

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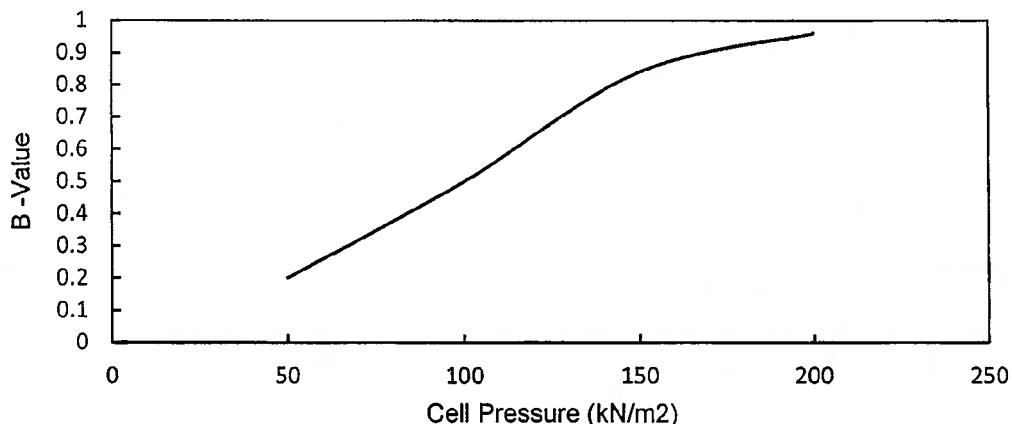


**CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION**

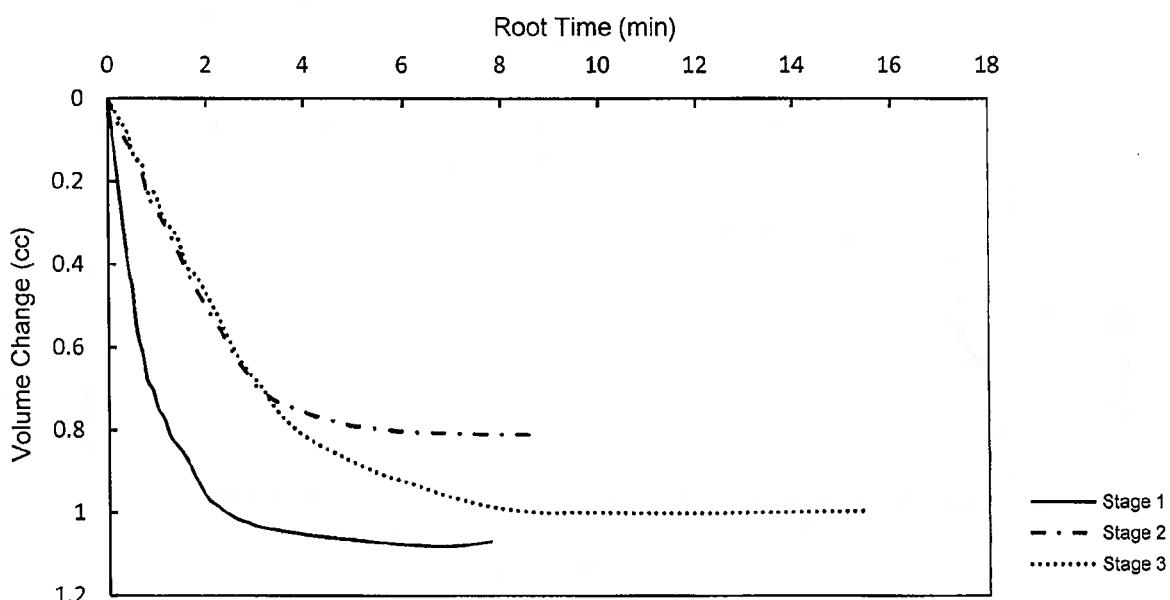
[TEST METHOD - BS 1377:1990:Part 8:Test 7]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.70 - 5.80

SATURATION; BY INCREMENTS OF CELL PRESSURE &amp; BACK PRESSURE METHOD



CONSOLIDATION : DRAINAGE - TOP & SIDE DRAIN	1	2	3
INITIAL CELL PRESSURE $\sigma_3$ (kN/m <sup>2</sup> )	350	400	500
INITIAL PORE PRESSURE $u_i$ (kN/m <sup>2</sup> )	344	357	417
INITIAL BACK PRESSURE $u_b$ (kN/m <sup>2</sup> )	300	300	300
FINAL PORE PRESSURE $u_c$ (kN/m <sup>2</sup> )	300	300	300
VOLUME CHANGE (cc)	1.08	0.81	1.00
$T_{100}$ (min)	1.00	9.73	17.89
$C_{vI}$ (m <sup>2</sup> /Yr)	30.041	3.062	1.655
$m_{vI}$ (m <sup>2</sup> /MN)	0.286	0.168	0.102



TESTED DATE : 24/01/2017

CHECKED DATE : 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory / Samuel Teng)

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**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.80 - 3.85

INITIAL -

SAMPLE HEIGHT (mm)	18.90
SAMPLE DIAMETER (mm)	50.0
MOISTURE CONTENT (%)	21
BULK DENSITY (Mg/m <sup>3</sup> )	2.04
DRY DENSITY (Mg/m <sup>3</sup> )	1.69
DEGREE OF SATURATION (%)	98.6
VOID RATIO	0.562
LABORATORY TEMPERATURE - AVERAGE (degree Celsius)	23.0
PARTICLE DENSITY (Mg/m <sup>3</sup> )	2.64

FINAL -

MOISTURE CONTENT (%)	16
BULK DENSITY (Mg/m <sup>3</sup> )	2.23
DRY DENSITY (Mg/m <sup>3</sup> )	1.92

STAGE	APPLIED PRESSURE (kN/m <sup>2</sup> )	CORRECTED HEIGHT CHANGE (mm)	VOID RATIO	Cv [CORRECTED FOR 20°C] (m <sup>2</sup> /yr)	Mv (m <sup>2</sup> /MN)
1.	12.5	0.188	0.546	18.281	0.796
2.	25.0	0.322	0.535	8.985	0.573
3.	50.0	0.495	0.521	13.596	0.372
4.	100.0	0.814	0.495	11.102	0.347
5.	200.0	1.168	0.465	9.210	0.196
6.	400.0	1.673	0.424	9.024	0.142
7.	800.0	2.235	0.377	6.904	0.082
8.	1600.0	2.718	0.337	7.967	0.036
9.	400.0	2.628	0.345		
10.	100.0	2.449	0.360		
11.	12.5	2.074	0.391		

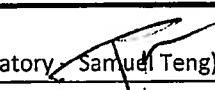
DATA BASED ON END OF LOAD INCREMENT

TIME FITTING METHOD -

Square Root

TEST DATE : 26/01/2017

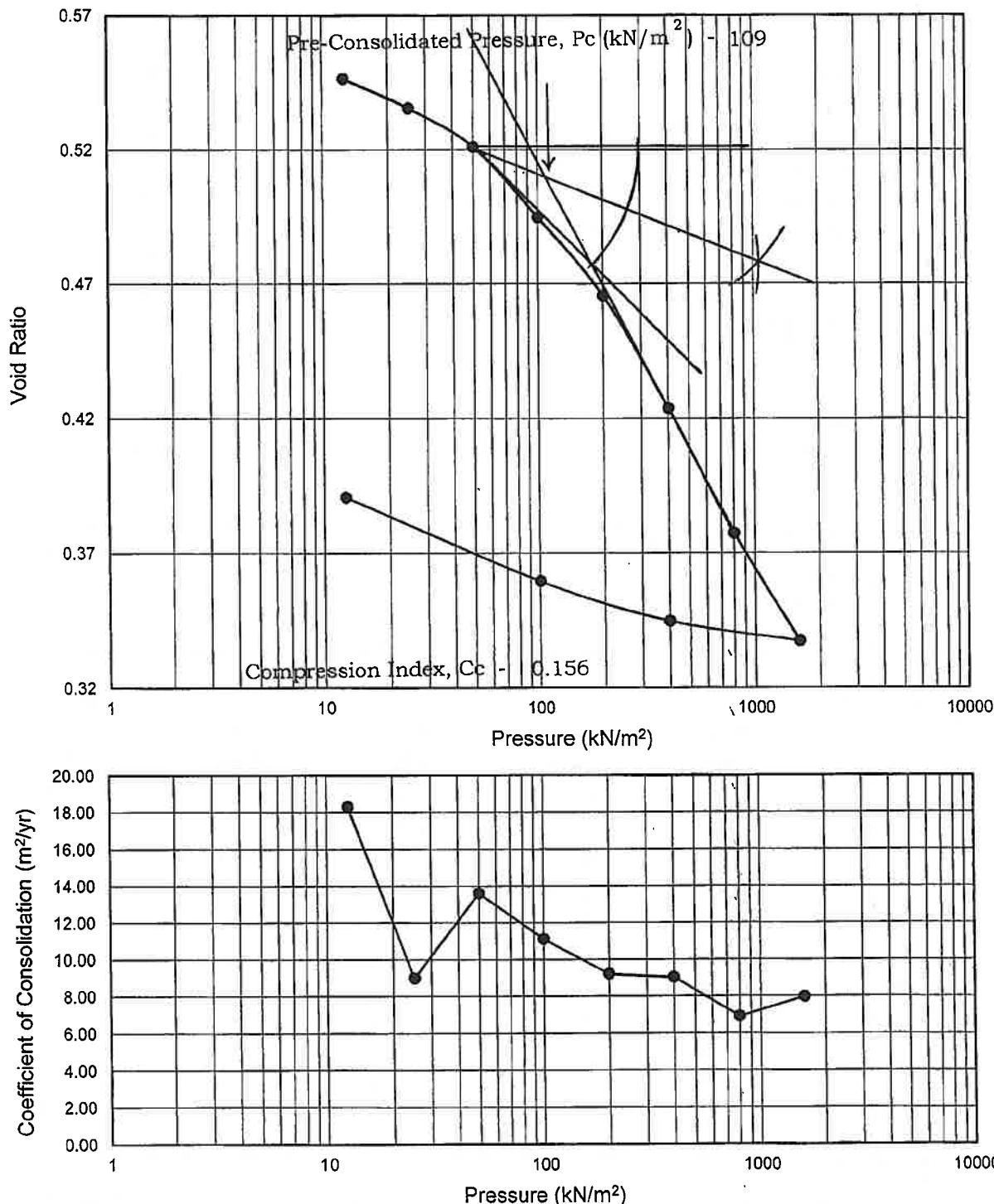
CHECK DATE: 08/02/2017

	TESTING OFFICER - Y. Simon P.	APPROVED / CHECKED - (Authorised Signatory) 	 Cert. No.: LA-2001-0226-13
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS			

## ONE DIMENSIONAL CONSOLIDATION

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.80 - 3.85



TEST DATE : 26/01/2017

CHECK DATE: 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

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**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.80 - 5.85

INITIAL -

SAMPLE HEIGHT (mm)	18.55
SAMPLE DIAMETER (mm)	50.0
MOISTURE CONTENT (%)	33
BULK DENSITY (Mg/m <sup>3</sup> )	1.66
DRY DENSITY (Mg/m <sup>3</sup> )	1.25
DEGREE OF SATURATION (%)	77.8
VOID RATIO	1.128
LABORATORY TEMPERATURE - AVERAGE (degree Celsius)	23.0
PARTICLE DENSITY (Mg/m <sup>3</sup> )	2.66

FINAL -

MOISTURE CONTENT (%)	31
BULK DENSITY (Mg/m <sup>3</sup> )	1.95
DRY DENSITY (Mg/m <sup>3</sup> )	1.49

STAGE	APPLIED PRESSURE (kN/m <sup>2</sup> )	CORRECTED HEIGHT CHANGE (mm)	VOID RATIO	Cv [CORRECTED FOR 20°C] (m <sup>2</sup> /yr)	Mv (m <sup>2</sup> /MN)
1.	12.5	0.484	1.072	13.860	2.087
2.	25.0	0.838	1.032	5.607	1.568
3.	50.0	1.213	0.989	7.559	0.847
4.	100.0	1.952	0.904	4.509	0.853
5.	200.0	2.703	0.818	3.401	0.452
6.	400.0	3.580	0.717	3.663	0.277
7.	800.0	4.673	0.592	3.360	0.183
8.	1600.0	5.514	0.495	4.680	0.076
9.	400.0	5.395	0.509		
10.	100.0	5.097	0.543		
11.	12.5	4.542	0.607		

DATA BASED ON END OF LOAD INCREMENT

TIME FITTING METHOD -

Square Root

TEST DATE : 26/01/2017

CHECK DATE: 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

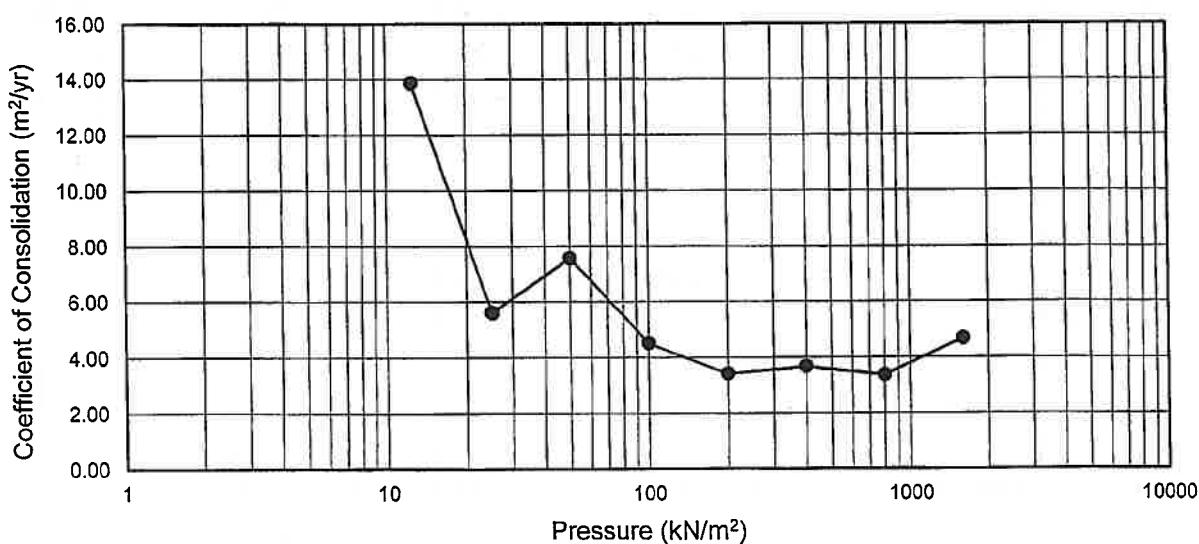
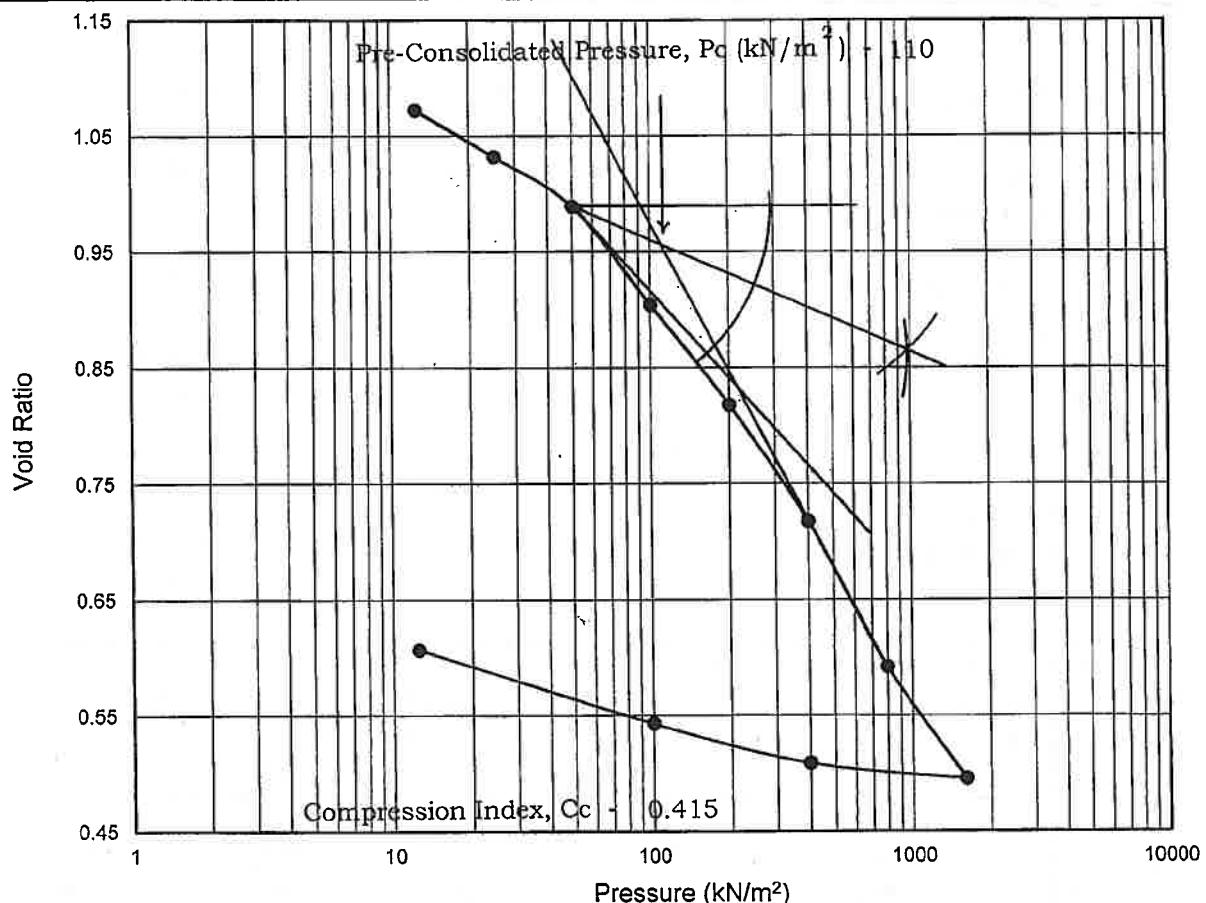
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**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-1
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.80 - 5.85



TEST DATE :	26/01/2017	CHECK DATE:	08/02/2017
	TESTING OFFICER - Y. Simon P.	APPROVED / CHECKED -  (Authorised Signatory - Samuel Teng)	 ACCREDITED LABORATORY SAC-SINGLAS Cert. No. LA-2001-0226-B
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS			

**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Dark grey slightly sandy very organic SILT with decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.80 - 3.85

INITIAL -

SAMPLE HEIGHT (mm)	18.90
SAMPLE DIAMETER (mm)	50.0
MOISTURE CONTENT (%)	76
BULK DENSITY (Mg/m <sup>3</sup> )	1.47
DRY DENSITY (Mg/m <sup>3</sup> )	0.84
DEGREE OF SATURATION (%)	98.2
VOID RATIO	1.857
LABORATORY TEMPERATURE - AVERAGE (degree Celsius)	23.0
PARTICLE DENSITY (Mg/m <sup>3</sup> )	2.40

FINAL -

MOISTURE CONTENT (%)	53
BULK DENSITY (Mg/m <sup>3</sup> )	1.75
DRY DENSITY (Mg/m <sup>3</sup> )	1.14

STAGE	APPLIED PRESSURE (kN/m <sup>2</sup> )	CORRECTED HEIGHT CHANGE (mm)	VOID RATIO	Cv [CORRECTED FOR 20°C] (m <sup>2</sup> /yr)	Mv (m <sup>2</sup> /MN)
1.	12.5	0.236	1.821	20.260	0.999
2.	25.0	0.507	1.780	3.988	1.162
3.	50.0	0.926	1.717	2.407	0.911
4.	100.0	1.884	1.572	1.500	1.066
5.	200.0	2.883	1.421	0.873	0.587
6.	400.0	4.380	1.195	0.594	0.467
7.	800.0	6.152	0.927	0.495	0.305
8.	1600.0	7.298	0.754	0.480	0.112
9.	400.0	6.820	0.826		
10.	100.0	6.022	0.947		
11.	12.5	5.303	1.055		

DATA BASED ON END OF LOAD INCREMENT

TIME FITTING METHOD -

Square Root

TEST DATE : 26/01/2017

CHECK DATE: 08/02/2017

TESTING OFFICER -  
Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

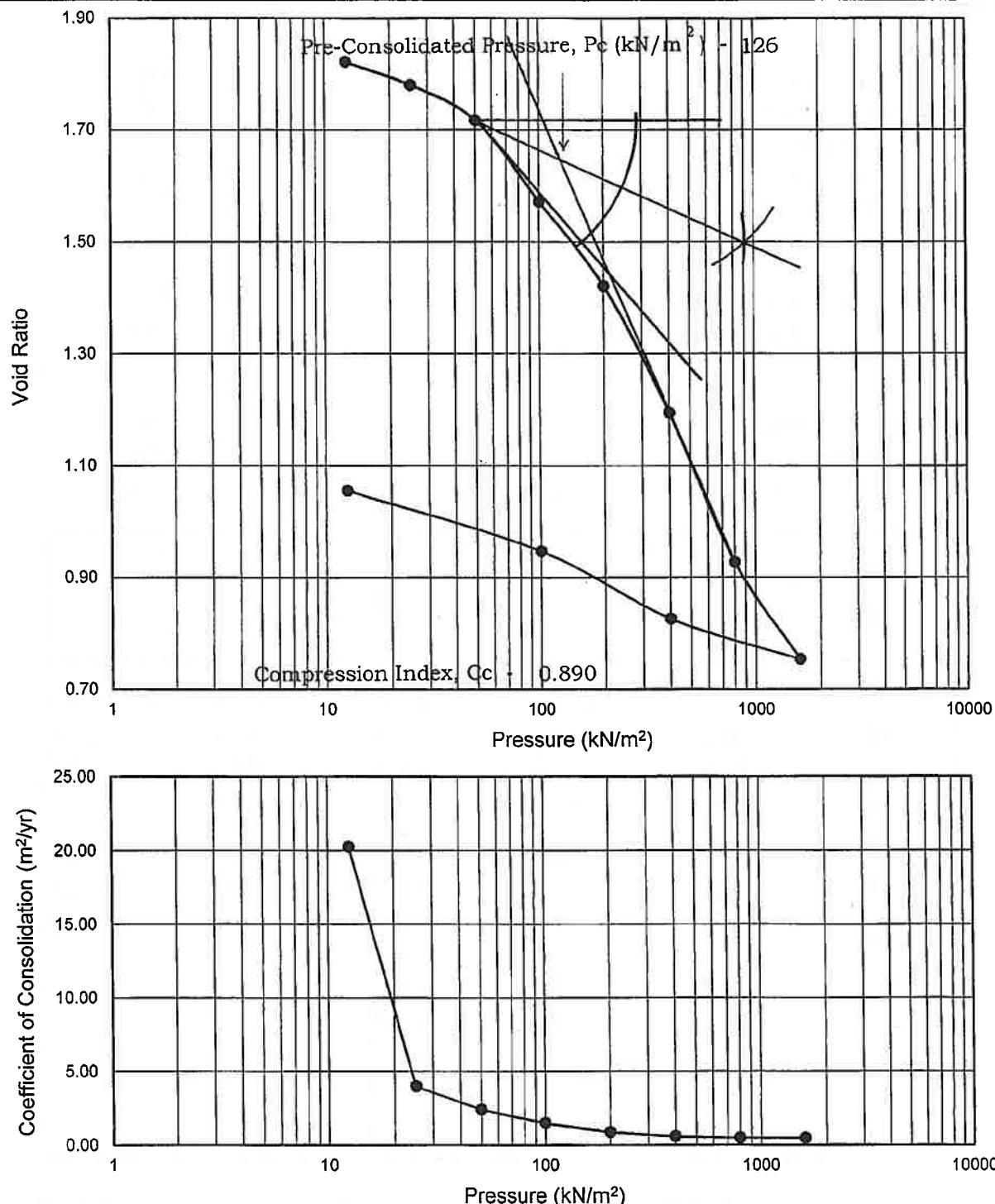
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-1
SOIL DESCRIPTION:	Dark grey slightly sandy very organic SILT with decayed vegetation	DEPTH (m):	3.00 - 3.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	3.80 - 3.85



TEST DATE : 26/01/2017

CHECK DATE: 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory - Samuel Teng)

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**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
		SAMPLE:	UD-2
LOCATION:	-	DEPTH (m):	5.00 - 5.90
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.80 - 5.85

INITIAL -

SAMPLE HEIGHT (mm)	18.94
SAMPLE DIAMETER (mm)	50.0
MOISTURE CONTENT (%)	14
BULK DENSITY (Mg/m <sup>3</sup> )	2.06
DRY DENSITY (Mg/m <sup>3</sup> )	1.81
DEGREE OF SATURATION (%)	81.3
VOID RATIO	0.453
LABORATORY TEMPERATURE - AVERAGE (degree Celsius)	23.0
PARTICLE DENSITY (Mg/m <sup>3</sup> )	2.63

FINAL -

MOISTURE CONTENT (%)	15
BULK DENSITY (Mg/m <sup>3</sup> )	2.28
DRY DENSITY (Mg/m <sup>3</sup> )	1.98

STAGE	APPLIED PRESSURE (kN/m <sup>2</sup> )	CORRECTED HEIGHT CHANGE (mm)	VOID RATIO	Cv [CORRECTED FOR 20°C] (m <sup>2</sup> /yr)	Mv (m <sup>2</sup> /MN)
1.	12.5	0.125	0.443	46.050	0.528
2.	25.0	0.258	0.433	25.956	0.566
3.	50.0	0.415	0.421	25.556	0.336
4.	100.0	0.667	0.402	43.745	0.272
5.	200.0	0.931	0.382	34.022	0.144
6.	400.0	1.274	0.355	23.495	0.095
7.	800.0	1.745	0.319	20.939	0.067
8.	1600.0	2.235	0.282	14.851	0.036
9.	400.0	2.138	0.289		
10.	100.0	1.960	0.303		
11.	12.5	1.641	0.327		

DATA BASED ON END OF LOAD INCREMENT

TIME FITTING METHOD -

Square Root

TEST DATE : 26/01/2017

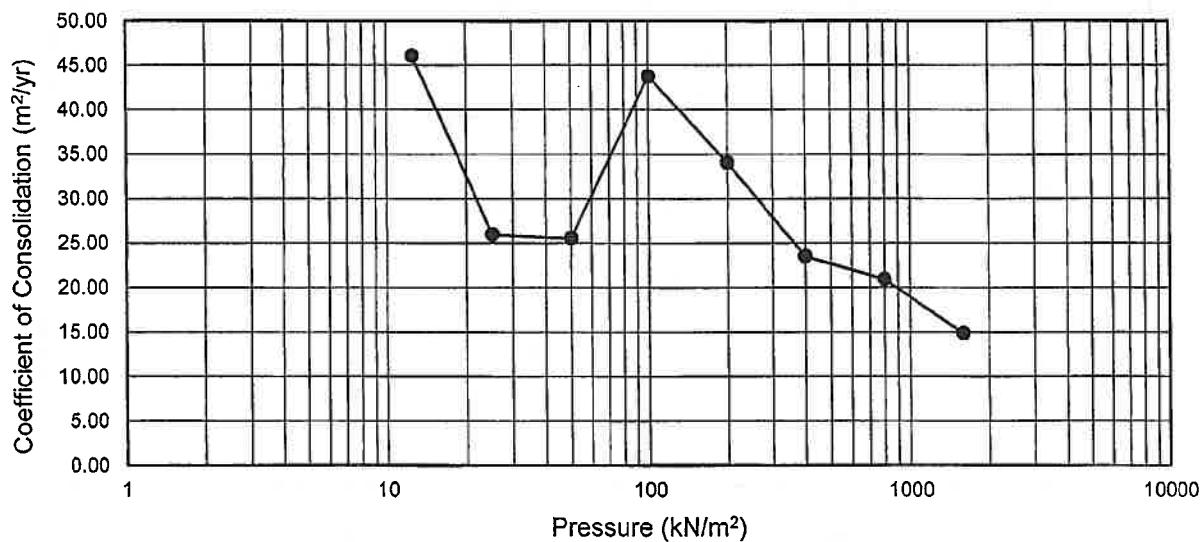
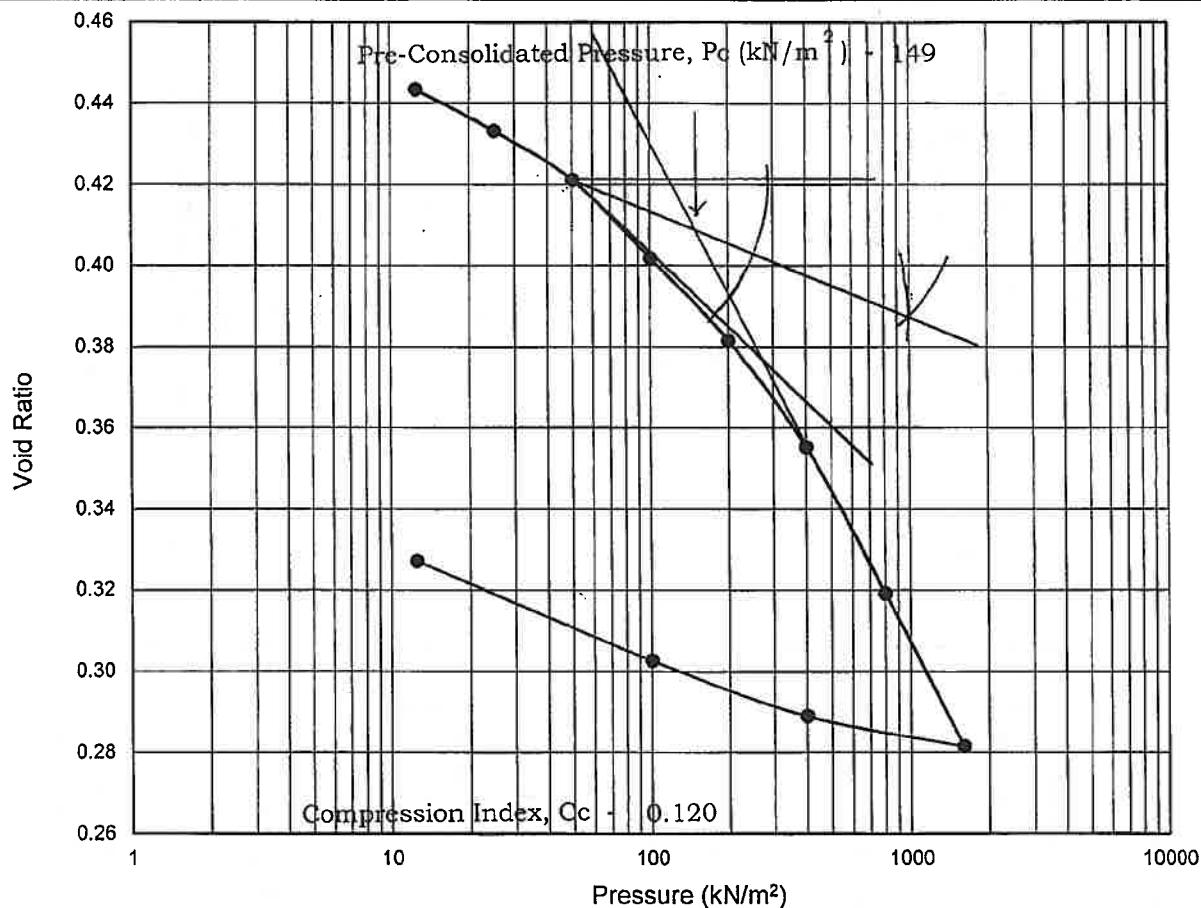
CHECK DATE: 08/02/2017

	TESTING OFFICER - Y. Simon P.	APPROVED / CHECKED - (Authorised Signatory - Sambel Teng)	 Cert No. LA-2001-0226-B
The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS			

**ONE DIMENSIONAL CONSOLIDATION**

[TEST METHOD - BS 1377:1990:Part 5:Test 3]

PROJECT:	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo	BOREHOLE:	BH-2
LOCATION:	-	SAMPLE:	UD-2
SOIL DESCRIPTION:	Grey & yellow slightly gravelly sandy CLAY	DEPTH (m):	5.00 - 5.90
		JOB NUMBER:	1702/14289
		SPECIMEN DEPTH (m):	5.80 - 5.85



TEST DATE : 26/01/2017

CHECK DATE: 08/02/2017



TESTING OFFICER -

Y. Simon P.

APPROVED / CHECKED -

(Authorised Signatory Samuel Teng)

The test results reported herein have been performed in accordance with the laboratory's terms of accreditation under SAC-SINGLAS



**CHEMICAL ANALYSIS - SOIL**

[TEST METHOD - BS 1377:1990:Part 3]

PROJECT	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo					
LOCATION	-					
JOB NUMBER	1702/14289					

BOREHOLE NUMBER	SAMPLE NUMBER	DEPTH (m)	pH VALUE [TEST 9.0] electrometric method	TOTAL SULPHATE CONTENT, SO <sub>3</sub> (%) [TEST 5.5] acid reaction	SOLUBLE CHLORIDE CONTENT, Cl <sup>-</sup> (%) [TEST 7.2] water-soluble method	ORGANIC CONTENT (%) [TEST 3.0] dichromate oxidation
BH-1	UD-1	3.00 – 3.90	-	0.10	0.02	1.20
BH-1	UD-2	5.00 – 5.90	3.81	0.49	0.01	1.42
BH-2	UD-1	3.00 – 3.90	4.25	0.61	0.03	16.85
BH-2	UD-2	5.00 – 5.90	-	0.09	0.01	0.42

BOREHOLE NUMBER	SAMPLE NUMBER	DEPTH (m)	SOIL DESCRIPTION
BH-1	UD-1	3.00 – 3.90	Grey & brown gravelly very clayey fine to coarse SAND with traces of decayed vegetation
BH-1	UD-2	5.00 – 5.90	Dark grey gravelly clayey fine to coarse SAND with traces of decayed vegetation
BH-2	UD-1	3.00 – 3.90	Dark grey slightly sandy very organic SILT with decayed vegetation
BH-2	UD-2	5.00 – 5.90	Grey & yellow slightly gravelly sandy CLAY

	TEST DATE -	24/01/2017	 ACCREDITED LABORATORY <b>SAC-SINGLAS</b> <small>Cert No: LA-2014226B</small>
	TESTING OFFICER -	Yusubkhan Shajahan	
	CHECK DATE -	06/02/2017	
	APPROVED / CHECKED -	Samuel Teng (AUTHORISED SIGNATORY)	
<b>Lab Services Private Limited</b>			

This Laboratory Is Accredited Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS) & Has Met The Requirements Of ISO / IEC Guide 17025:2005.

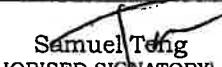
The Results Reported Herein Have Been Performed In Accordance With The Laboratory's Terms Of Accreditation Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS).

**CHEMICAL ANALYSIS - WATER**

[TEST METHOD - BS 1377:1990:Part 3]

PROJECT	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo			
LOCATION	-			
JOB NUMBER	1702/14289			

BOREHOLE NUMBER	SAMPLE NUMBER	pH VALUE [TEST 9.0]	SOLUBLE SULPHATE CONTENT, SO <sub>3</sub> (g/l) [TEST 5.5]	SALINITY (ppm) [TEST 7.3]
BH-1	WSP	7.21	0.25	164
BH-2	WSP	7.75	0.34	634

	TEST DATE - 23/01/2017	TESTING OFFICER - Yusubkhan Shajahan	 Samuel Teng (AUTHORISED SIGNATORY)	 ACCREDITED LABORATORY SAC-SINGLAS Cert No: LA-2001-0226-B
	CHECK DATE - 07/02/2017			
	APPROVED / CHECKED -		Lab Services Private Limited	

This Laboratory Is Accredited Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS) & Has Met The Requirements Of ISO / IEC Guide 17025:2005.

The Results Reported Herein Have Been Performed In Accordance With The Laboratory's Terms Of Accreditation Under The Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS).

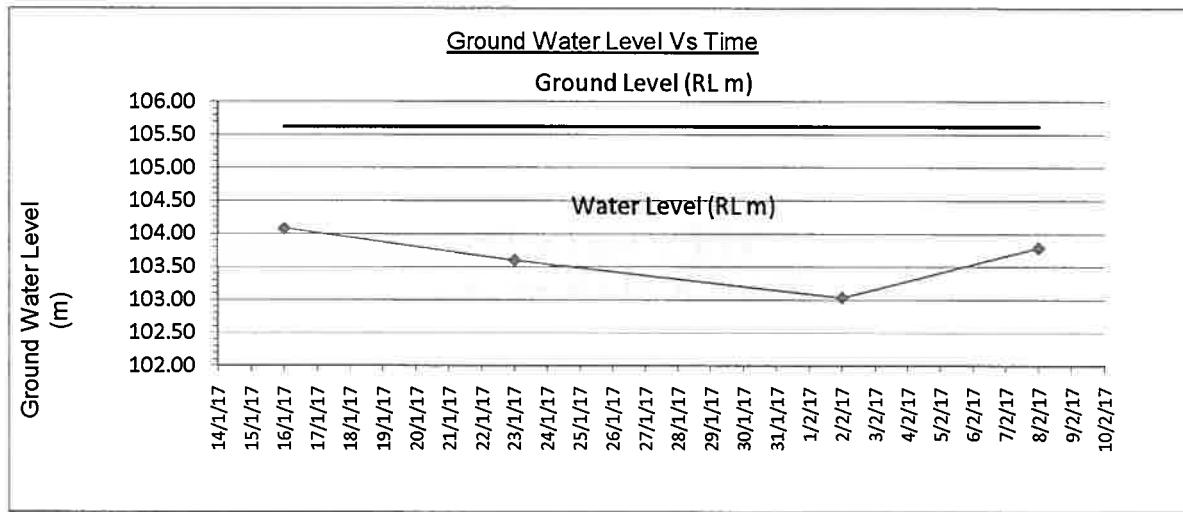


## **APPENDIX D: WATER STANDPIPES**



## WATER STANDPIPE MONITORING READINGS

<b>PROJECT :</b>	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo		<b>Date</b>	14/1/2017
<b>BOREHOLE No :</b>	BH-1		<b>Recorded by</b>	Sai Si Thu Aung
<b>CLIENT:</b>	RSP Architects Planners & Engineers (Pte) Ltd		<b>Check by</b>	Aung Aung
<b>CONTRACT No:</b>	-		<b>RL (m)</b>	105.624
<b>ORDER:</b>	-		<b>Northing</b>	34933.525
			<b>Easting</b>	41984.467
<b>INSTRUMENT NO:</b>	BH-1 / WSP		<b>Pipe Top Level</b>	105.924



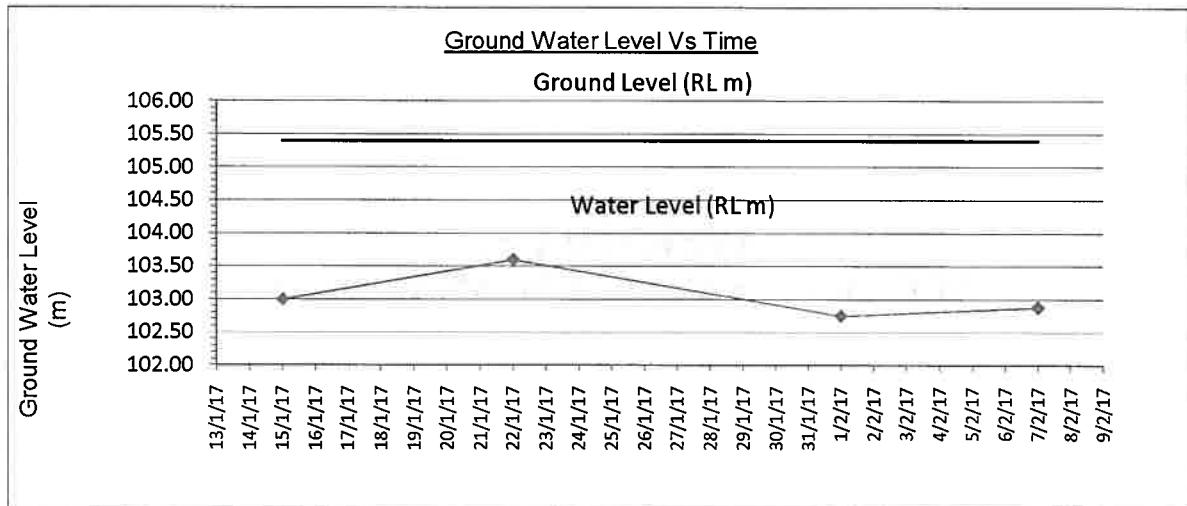
No	Date Monitored (D/M/Y)	Elapsed Time (Days)	Ground Level (RL m)	Pipe Top Level (RL m)	Measured Reading (m)	Current WL (RL m)	Current Change of GWT (m)	Cumulative of GWT Change (m)	Remarks
1	16/1/2017		105.624	105.924	1.85	104.07			
2	23/1/2017	7	105.624	105.924	2.33	103.59	0.48	0.48	
3	2/2/2017	17	105.624	105.924	2.89	103.03	0.56	1.04	
4	8/2/2017	23	105.624	105.924	2.14	103.78	-0.75	0.29	
5									
6									
7									
8									
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18									
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23									
24									

Remark; WSP was installed on 14.1.2017 at the depth of 15.00m BGL.



## WATER STANDPIPE MONITORING READINGS

<b>PROJECT :</b>	Soil Investigation Works for Proposed Additional and Alteration Works at Singapore Expo		<b>Date</b>	13/1/2017
<b>BOREHOLE No :</b>	BH-2		<b>Recorded by</b>	Sai Si Thu Aung
<b>CLIENT:</b>	RSP Architects Planners & Engineers (Pte) Ltd		<b>Check by</b>	Aung Aung
<b>CONTRACT No:</b>	-		<b>RL (m)</b>	105.395
<b>ORDER:</b>	-		<b>Northing</b>	34926.296
			<b>Easting</b>	41964.985
<b>INSTRUMENT NO:</b>	BH-2 / WSP		<b>Pipe Top Level</b>	105.695



No	Date Monitored (D/M/Y)	Elapsed Time (Days)	Ground Level (RL m)	Pipe Top Level (RL m)	Measured Reading (m)	Current WL (RL m)	Current Change of GWT (m)	Cumulative of GWT Change (m)	Remarks
1	15/1/2017		105.395	105.695	2.70	103.00			
2	22/1/2017	7	105.395	105.695	2.10	103.60	-0.60	-0.60	
3	1/2/2017	17	105.395	105.695	2.95	102.75	0.85	0.25	
4	7/2/2017	23	105.395	105.695	2.82	102.88	-0.13	0.12	
5									
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13									
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24									

Remark; WSP was installed on 13.1.2017 at the depth of 15.00m BGL.



**APPENDIX E:**  
**SPT HAMMER ENERGY MEASUREMENT**



Report No. : SPT16/05/0015-03

## TEST REPORT

Report Date : 28 May 2016

Page 1 of 2

### SPT HAMMER ENERGY MEASUREMENT

**Client** : Kimaro Geotechnical Engineering Pte Ltd  
107 Neythal Road  
Singapore 628595

**Test Location** : ABV Workshop

**Test Date** : 18 May 2015

**SPT Hammer** : KGE/SPT/05

**Test Method** : ASTM D4633 - 10

**Test Equipment** : Pile Driving Analyzer : Model PAX - Serial No. 3862L  
Instrumented Rod : Serial No. 409BW / Length - 0.6 m  
Accelerometers : Serial Nos. K1767 & K1762  
Weighing Scale : OHAUS Model SD75 Serial No. : 0610539JLQ  
Drop Height Device : Scale Rule  
Software : PDA-W Version 2015.123

**Attachments** : 1. Table of Results (1 sheet)  
2. List of Abbreviations (1 sheet)  
3. Selected Graphical Plot of Test Results (1 sheet)



**Report No. : SPT16/05/0015-03**

# TEST REPORT

Report Date : 28 May 2016

Page 2 of 2

## SPT HAMMER ENERGY MEASUREMENT

SPT HAMMER SERIAL NO.: KGE/SPT/05

## **BOREHOLE**

**Ref : ABV-02**      **Dia. : 125 mm**      **Depth : 12.9 m**

## DRILL RIG

Type : B17 Rig Operator : Mani

**ROD / SHOE**

**Drill Rod Type : BW**      **Rod Segments (m) :  $3 + 3 + 3 + 3 + 0.5$  (bottom to top)**

**Shoe Length :** 0.7 m      **Total Length :** 13.8 m (instrumented rod top to shoe base)

**Shoe Type :** Split Spoon Sampler      **Sensor to Shoe Base :** 13.5 m

## **PHYSICAL PROPERTIES**

Ram Mass : 63.40 kg      Anvil Mass : 21.30 kg      Total Mass : 92.30 kg

**Ram Drop Height : 755 mm**      **Theoretical Energy : 0.4696 kN-m**

ENERGY

**No. of Blows : 10**      **Mean Measured Energy (EMX) : 0.3285 kN-m**

**Min. / Max. EMX Value : 0.3074 / 0.3415 kN-m**      **Standard Deviation : 0.0098 kN-m**

$$\text{Energy Ratio, } E_r = \frac{0.3285}{0.4696} = 0.70 \text{ (70\%)}$$

Authorised Signatory  
Cheong Kok Leong  
Director

第二步：选择“插入”→“形状”→“直线”，在绘图区画出一个长方形。

KIMARO - KGE-SPT-05  
OP: TANSPT  
Date: 18-May-2016AR: 11.40 cm<sup>2</sup>

SP: 77.3 kN/m

LE: 13.5 m

EM: 206,843 MPa

WS: 5,123.0 m/s

JC: 0.60 []

EMX: Max Transferred Energy

TSX: Tension Stress Maximum

EF2: Energy of F^2

VMX: Maximum Velocity

DMX: Maximum Displacement

AMX: Maximum Acceleration

FMX: Maximum Force

RX6: Max Case Method Capacity (JC=0.6)

CSX: Max Measured Compr. Stress

BL#	Depth	BLC	EMX	EF2	DMX	FMX	CSX	TSX	VMX	AMX	RX6
	m	bl/m	kN-m	kN-m	mm	kN	MPa	MPa	m/s	g's	kN
9	12.9	0	0.3309	0.2807	13	120	105	24	3.88	1,520	34
10	12.9	0	0.3178	0.2820	12	111	97	25	4.22	1,946	32
11	12.9	0	0.3339	0.1051	13	115	101	26	4.61	1,990	32
12	12.9	0	0.3400	0.2903	13	110	97	27	3.89	1,757	32
13	12.9	0	0.3290	0.2877	12	122	107	27	4.17	1,707	42
14	12.9	0	0.3267	0.0885	13	107	94	22	4.17	2,195	33
15	12.9	0	0.3415	0.3127	13	132	116	29	3.96	1,633	45
16	12.9	0	0.3074	0.2435	11	87	77	22	3.29	1,681	34
17	12.9	0	0.3231	0.2603	12	114	100	20	4.03	1,521	32
18	12.9	0	0.3344	0.2928	12	140	123	23	3.79	1,586	62
Average		0.3285	0.2444	12	116	102	24	4.00	1,754	38	
Std. Dev.		0.0098	0.0760	0	14	12	3	0.33	211	9	
Maximum		0.3415	0.3127	13	140	123	29	4.61	2,195	62	
Minimum		0.3074	0.0885	11	87	77	20	3.29	1,520	32	

Total number of blows analyzed: 10



## SPT HAMMER ENERGY MEASUREMENT

### List of Abbreviations

#### INPUT QUANTITIES

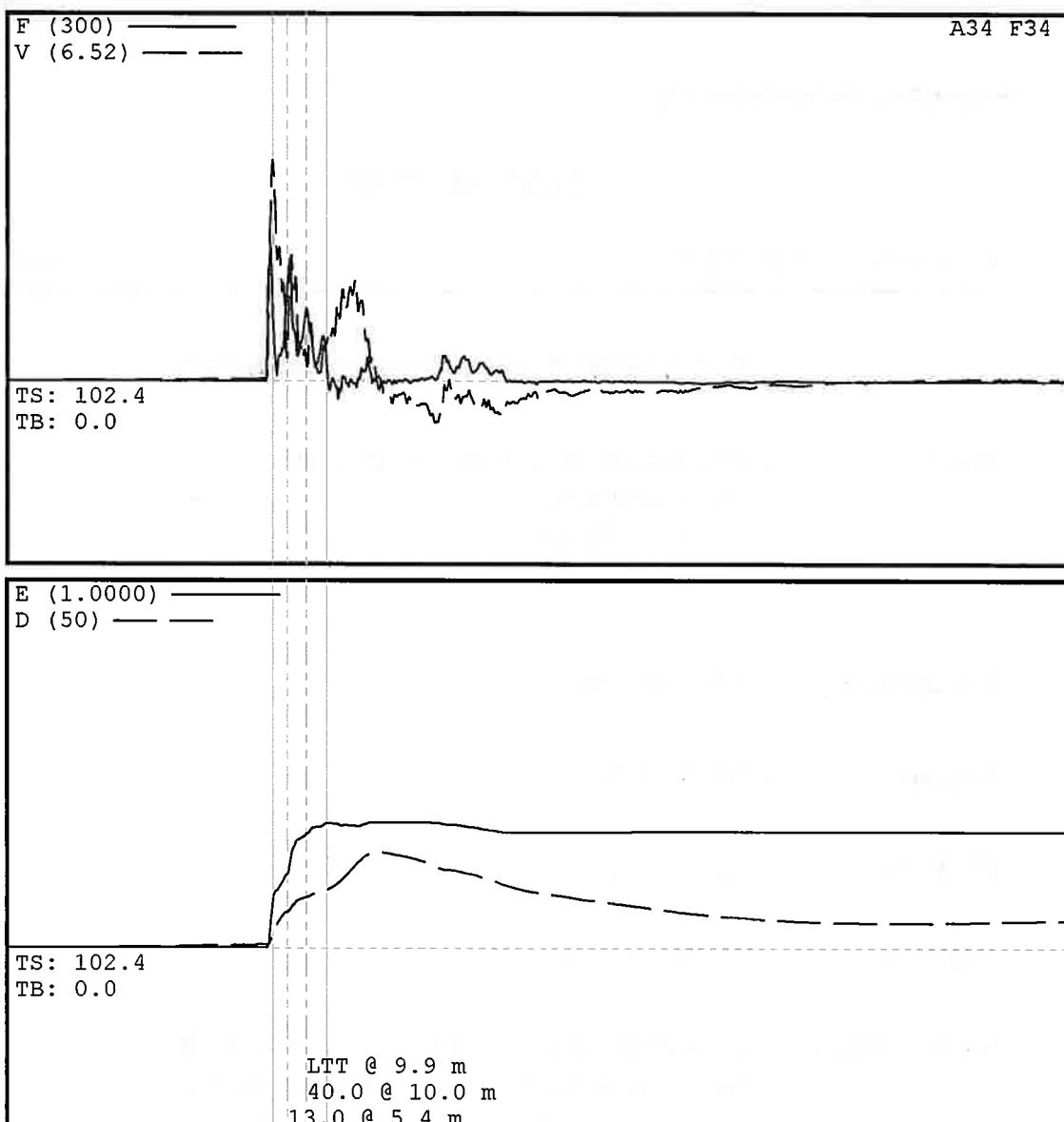
<u>Variable</u>	<u>Description</u>
<b>AR</b>	gross cross-sectional area of the rod at the transducer's location.
<b>EM</b>	elastic modulus of the rod at the transducer's location.
<b>JC</b>	Case damping factor.
<b>LE</b>	rod length below transducers to the sampler bottom.
<b>SP</b>	specific weight density of the rod at the transducer's location.
<b>WS</b>	elastic wave speed of the rod.

#### OUTPUT QUANTITIES

<u>Variable</u>	<u>Description</u>
<b>AMX</b>	maximum acceleration at transducer's location.
<b>CSX</b>	maximum compressive stress ( $FMX/Area$ ) at transducer's location.
<b>DMX</b>	maximum downward displacement at the transducer's location.
<b>EF2</b>	maximum energy transmitted past the transducers from integral of force squared.
<b>EMX</b>	maximum energy transmitted past the transducers.
<b>FMX</b>	maximum compressive force at transducer's location.
<b>RMX</b>	computed maximum Case-Goble static resistance with Case damping factor, JC.
<b>TSX</b>	maximum tensile stress along length of rod.
<b>VMX</b>	maximum velocity at the transducer's location.

KIMARO

KGE-SPT-05

Project Information

PROJECT: KIMARO  
 PILE NAME: KGE-SPT-05  
 DESCRI: SPT  
 OPERATOR: TAN  
 FILE: KGE-SPT-05  
 18-May-16 11:05:07 AM  
 Blow Number 12

Quantity Results

EMX 0.3400 kN-m  
 EF2 0.2903 kN-m  
 DMX 13 mm  
 FMX 110 kN  
 CSX 96.7 MPa  
 TSX 27.0 MPa  
 VMX 3.89 m/s  
 AMX 1757 g's  
 RX6 32 kN

Pile Properties

LE 13.5 m  
 AR 11.40 cm<sup>2</sup>  
 EM 206843 MPa  
 SP 77.3 kN/m<sup>3</sup>  
 WS 5123.0 m/s  
 EA/C 46 kN-s/m  
 2L/C 5.28 ms  
 JC 0.60 []  
 LP 12.9 m

Sensors

F3: [277BW-1] 220.08 (1)  
 F4: [277BW-2] 220.6 (1)  
 A3: [K1767] 415 mv/5000g's (1)  
 A4: [K1762] 375 mv/5000g's (1)  
 CLIP: OK

ABV Technology Pte Ltd

**Report No. : SPT16/05/0015-04**

## TEST REPORT

Report Date : 28 May 2016

Page 1 of 2

### SPT HAMMER ENERGY MEASUREMENT

**Client** : Kimaro Geotechnical Engineering Pte Ltd  
107 Neythal Road  
Singapore 628595

**Test Location** : ABV Workshop

**Test Date** : 18 May 2015

**SPT Hammer** : KGE/SPT/13

**Test Method** : ASTM D4633 - 10

**Test Equipment** : Pile Driving Analyzer : Model PAX - Serial No. 3862L  
Instrumented Rod : Serial No. 409BW / Length - 0.6 m  
Accelerometers : Serial Nos. K1767 & K1762  
Weighing Scale : OHAUS Model SD75 Serial No. : 0610539JLQ  
Drop Height Device : Scale Rule  
Software : PDA-W Version 2015.123

**Attachments** : 1. Table of Results (1 sheet)  
2. List of Abbreviations (1 sheet)  
3. Selected Graphical Plot of Test Results (1 sheet)

**Report No. : SPT16/05/0015-04**

## TEST REPORT

Report Date : 28 May 2016

Page 2 of 2

### SPT HAMMER ENERGY MEASUREMENT

**SPT HAMMER SERIAL NO.: KGE/SPT/13**

**BOREHOLE**

Ref: ABV-02                    Dia. : 125 mm                    Depth : 13.1 m

**DRILL RIG**

Type : B17                    Rig Operator : Mani

**ROD / SHOE**

Drill Rod Type : BW                    Rod Segments (m) : 3 + 3 + 3 + 3 + 0.5 (bottom to top)

Shoe Length : 0.7 m                    Total Length : 13.8 m (instrumented rod top to shoe base)

Shoe Type : Split Spoon Sampler                    Sensor to Shoe Base : 13.5 m

**PHYSICAL PROPERTIES**

Ram Mass : 63.45 kg                    Anvil Mass : 21.00 kg                    Total Mass : 91.95 kg

Ram Drop Height : 755 mm                    Theoretical Energy : 0.4699 kN-m

**ENERGY**

No. of Blows : 10                    Mean Measured Energy (EMX) : 0.3302 kN-m

Min. / Max. EMX Value : 0.2901 / 0.3587 kN-m                    Standard Deviation : 0.0212 kN-m

$$\text{Energy Ratio, } E_r = \frac{0.3302}{0.4699} = 0.70 \text{ (70\%)}$$



Authorised Signatory  
Cheong Kok Leong  
Director

The test report shall not be reproduced, except in full, without the written approval of ABV.

ABV (Singapore)  
Case Method & iCAP® Results

Page 1  
PDIPILOT2 2016.1.56.2 - Printed 28-May-2016

KIMARO - KGE-SPT-13  
OP: TAN

SPT

Date: 18-May-2016

AR: 11.40 cm<sup>2</sup>SP: 77.3 kN/m<sup>3</sup>

LE: 13.5 m

EM: 206,843 MPa

WS: 5,123.0 m/s

JC: 0.60 [1]

EMX: Max Transferred Energy

TSX: Tension Stress Maximum

EF2: Energy of F^2

VMX: Maximum Velocity

DMX: Maximum Displacement

AMX: Maximum Acceleration

FMX: Maximum Force

RX6: Max Case Method Capacity (JC=0.6)

CSX: Max Measured Compr. Stress

BL#	Depth	BLC	EMX	EF2	DMX	FMX	CSX	TSX	VMX	AMX	RX6
	m	bl/m	kN-m	kN-m	mm	kN	MPa	MPa	m/s	g's	kN
15	13.1	0	0.3360	0.0907	12	113	99	22	4.14	2,114	39
16	13.1	0	0.3423	0.2741	12	99	86	27	4.05	2,239	34
17	13.1	0	0.2944	0.2413	11	95	83	17	3.48	2,180	40
18	13.1	0	0.3319	0.2680	12	113	99	24	4.00	1,993	43
19	13.1	0	0.3587	0.1948	12	133	116	25	3.89	2,237	37
20	13.1	0	0.3364	0.1039	12	143	125	25	4.04	2,636	63
21	13.1	0	0.3315	0.2694	11	103	90	22	4.06	2,364	34
22	13.1	0	0.3541	0.1069	11	130	114	20	3.78	2,334	57
23	13.1	0	0.3265	0.1007	11	109	95	26	4.03	2,299	40
24	13.1	0	0.2901	0.0852	10	96	85	20	4.30	2,202	41
Average		0.3302	0.1735	11	113	99	23	3.98	2,260	43	
Std. Dev.		0.0212	0.0791	1	16	14	3	0.21	162	9	
Maximum		0.3587	0.2741	12	143	125	27	4.30	2,636	63	
Minimum		0.2901	0.0852	10	95	83	17	3.48	1,993	34	

Total number of blows analyzed: 10



## SPT HAMMER ENERGY MEASUREMENT

### List of Abbreviations

#### INPUT QUANTITIES

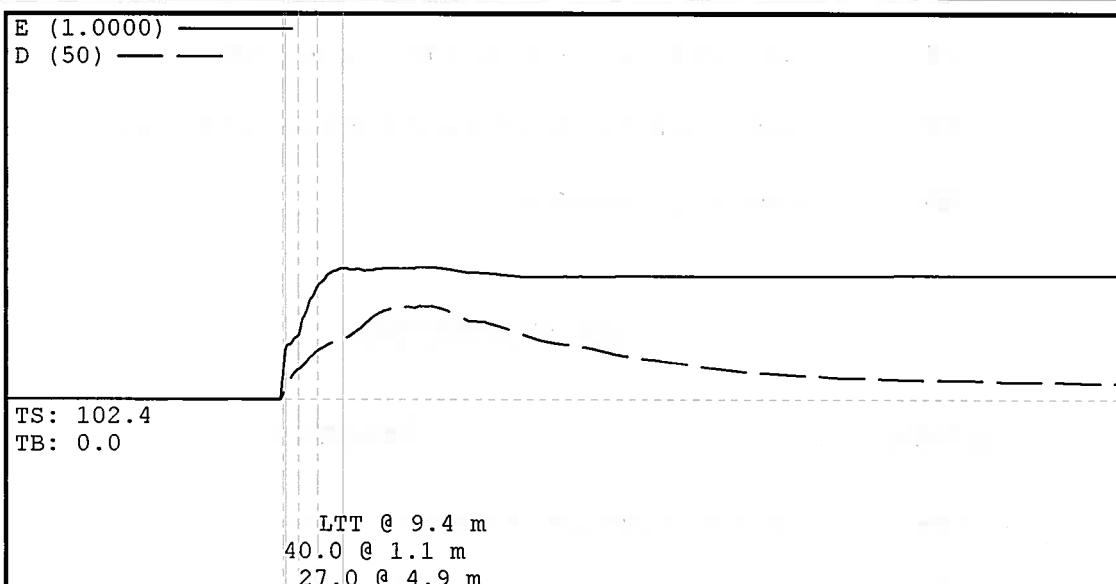
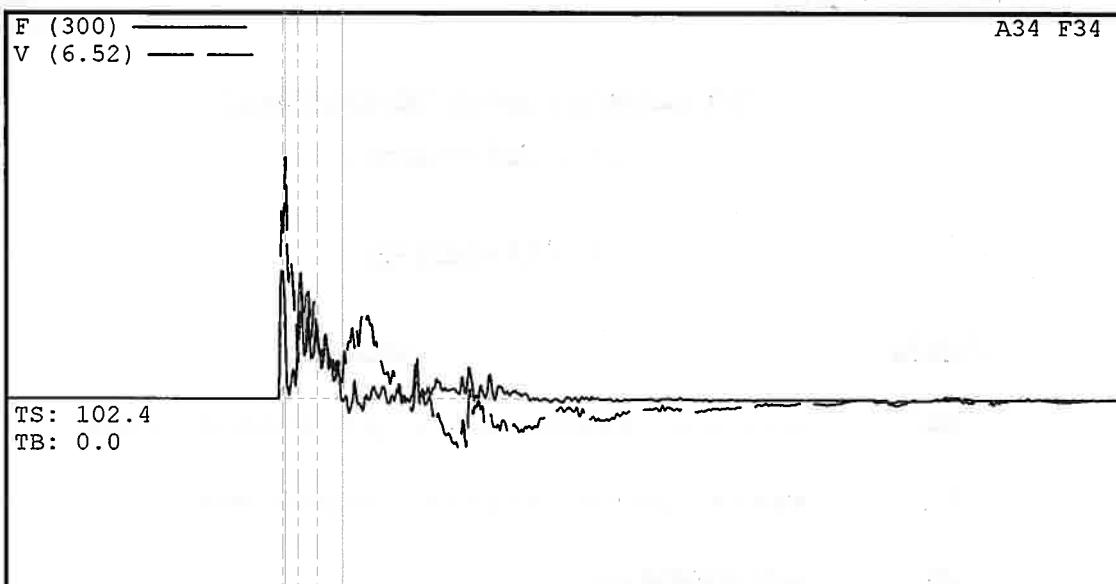
<u>Variable</u>	<u>Description</u>
AR	gross cross-sectional area of the rod at the transducer's location.
EM	elastic modulus of the rod at the transducer's location.
JC	Case damping factor.
LE	rod length below transducers to the sampler bottom.
SP	specific weight density of the rod at the transducer's location.
WS	elastic wave speed of the rod.

#### OUTPUT QUANTITIES

<u>Variable</u>	<u>Description</u>
AMX	maximum acceleration at transducer's location.
CSX	maximum compressive stress (FMX/Area) at transducer's location.
DMX	maximum downward displacement at the transducer's location.
EF2	maximum energy transmitted past the transducers from integral of force squared.
EMX	maximum energy transmitted past the transducers.
FMX	maximum compressive force at transducer's location.
RMX	computed maximum Case-Goble static resistance with Case damping factor, JC.
TSX	maximum tensile stress along length of rod.
VMX	maximum velocity at the transducer's location.

KIMARO

KGE-SPT-13

Project Information

PROJECT: KIMARO  
PILE NAME: KGE-SPT-13  
DESCR: SPT  
OPERATOR: TAN  
FILE: KGE-SPT-13  
18-May-16 11:32:22 AM  
Blow Number 16

Quantity Results

EMX 0.3423 kN-m  
EF2 0.2741 kN-m  
DMX 12 mm  
FMX 99 kN  
CSX 86.4 MPa  
TSX 26.7 MPa  
VMX 4.05 m/s  
AMX 2239 g's  
RX6 34 kN

Pile Properties

LE 13.5 m  
AR 11.40 cm<sup>2</sup>  
EM 206843 MPa  
SP 77.3 kN/m<sup>3</sup>  
WS 5123.0 m/s  
EA/C 46 kN-s/m  
2L/C 5.28 ms  
JC 0.60 []  
LP 13.1 m

Sensors

F3: [277BW-1] 220.08 (1)  
F4: [277BW-2] 220.6 (1)  
A3: [K1767] 415 mv/5000g's (1)  
A4: [K1762] 375 mv/5000g's (1)  
CLIP: OK



**APPENDIX F:**  
**CERTIFICATE OF ACCREDITATIONS**

**ACCREDITATION SCHEME  
FOR INSPECTION BODIES**



# Schedule

Kimaro Geotechnical Engineering Pte Ltd  
107 Neythal Road  
Singapore 628595

Certificate No. : IB-2014-100-F

Issue No. : 3

Date : 16 September 2015

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Inspection Field : Site Investigation

## Type A Inspection Body

TYPE OF PRODUCT	TYPE AND RANGE OF INSPECTION	INSPECTION METHOD, CODES OR STANDARDS USED
1. Soil	Site Investigation  Under Undisturbed Sampling <ul style="list-style-type: none"> <li>a) Stationary Piston Sampler</li> <li>b) Open Thin Wall Sampler</li> <li>c) Mazier Sampler</li> </ul> Under Functional Testing <ul style="list-style-type: none"> <li>a) Standard Penetration Test</li> <li>b) Vane Shear Test</li> <li>c) Plate Load Test</li> <li>d) Field Permeability Test</li> </ul>	BS5930:1999 BS EN ISO 22475-1:2006  BS 5930:1999 BS EN ISO 22475-1:2006  BS 5930:1999 BS EN ISO 22475-1:2006  BS 5930:1999 BS EN ISO 22475-1:2006  BS 1377:1990 BS EN ISO 22476-3:2005  BS 1377: 1990 BS EN ISO 22476-9 (draft 2014)  BS 1377: 1990, Part 9  BS 5930: 1999, section 25.4



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TYPE OF PRODUCT	TYPE AND RANGE OF INSPECTION	INSPECTION METHOD, CODES OR STANDARDS USED
2. Rock	<p>Site Investigation</p> <p>Under Undisturbed Sampling</p> <p>a) Rock Core Barrel</p> <p>Under Functional Testing</p> <p>a) Field Permeability Test (Packer Test)</p>	<p>BS5930:1999 BS EN ISO 22475-1:2006</p> <p>BS 5930: 1999 BS EN ISO 22475-1:2006</p> <p>BS 5930: 1999, section 25.5</p>

Approved signatory

Er. Cheang Yew Kee

} For item 1 and 2

## Note:

An inspection body's fulfilment of the requirements of ISO/IEC 17020:2012 means the Inspection body meets both the technical competence requirements and **management system requirements** that are necessary for it to consistently deliver technically valid inspection results. The **management system requirements** in ISO/IEC 17020:2012 (Section 8) are written in language relevant to inspection body operations and are aligned with the pertinent requirements of ISO 9001.