Southern Testing
Environmental & Geotechnical

Factual Site Investigation Report

Desk Studies | Risk Assessments | Site Investigations | Geotechnical | Contamination Investigations | Remediation Design and Validation

Site: Shaftesbury Theatre, 210 Shaftesbury Ave, City of London, WC2H 8DP

Client: Theatre of Comedy Company Ltd

Report Date: 25th January 2013

Project Reference: J11265

AGS ace ISO 9001 ISO 14001 BS18001

ST Consult
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SUMMARY

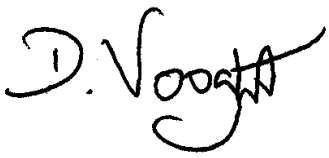
The site comprises the stage area of the Shaftesbury Theatre, including rooms and space below the stage. It is proposed to install piling in order to increase the loading capacity of the stage.

Geological records indicate the site to be underlain by Terrace Gravels over London Clay.

A single borehole was drilled from stage level to 25.2 m below basement floor level.

The soils encountered comprised London Clay to a depth of approximately 25 m below the level of the stage, overlying mottled clays of the Lambeth Group.

Groundwater was not encountered in this investigation.



D. Vooght MSc
(Countersigned)

T. Lees MSc
(Signed)

For and on behalf of Southern Testing Laboratories Limited

STL: J11265
25 January 2013

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A INTRODUCTION

1 Authority

Our authority for carrying out this work is contained in a project order from Theatre of Comedy Company Ltd, dated 19th November 2012.

2 Location

The site is located on Shaftesbury Avenue, approximately 0.6 km east of Tottenham Court Road underground station, London. The approximate National Grid Reference of the site is TQ 301 813.

3 Proposed Construction

We understand that it is proposed to install a series of piles beneath the stage.

4 Object

This is a Phase II geotechnical investigation (Tier 1).

The object of the investigation was to assess foundation bearing conditions and other soil parameters relevant to the proposed development and to aid pile design

5 Scope

This factual report presents our exploratory hole logs and test results. As with any site there may be differences in soil conditions between exploratory hole positions.

This factual report is not an engineering design and the figures and calculations contained in the report should be used by the Engineer, taking note that variations will apply, according to variations in design loading, in techniques used, and in site conditions. Our figures therefore should not supersede the Engineer's design.

Contamination issues are not considered in this report.

The findings conveyed via this Factual Site Investigation Report are based on information obtained from a variety of sources as detailed within this report, and which Southern Testing Laboratories Limited believes are reliable. Nevertheless, Southern Testing Laboratories Limited cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

The site investigation was conducted and this report has been prepared for the sole internal use and reliance of Theatre of Comedy Company Ltd and their appointed Engineers. This report shall not be relied upon or transferred to any other parties without the express written authorization of Southern Testing Laboratories Limited. If an unauthorised third party comes into possession of this report they rely on it at their peril and the authors owe them no duty of care and skill.

6 Geology

The indicated geology is London Clay over Lambeth Group.

London Clay

London Clay is a well-known stiff (high strength) blue-grey, fissured clay, which weathers to a brown colour near the surface. It contains thin layers of nodular calcareous mudstone - "claystone" - from place to place, and crystals of water clear calcium sulphate (selenite) are common. Although slopes will stand in the clay at steep angles in the short term, the long-term stable slope angle is about 7^{o} for grassed, or cleared slopes, and a few degrees more for wooded slopes.

Lambeth Group (Woolwich and Reading Beds)

The Woolwich Beds, part of the Lambeth Formation, consist largely of grey to grey-brown interlaminated fine-grained sands silts and clays. Shelly beds have been identified in both the top and bottom of the formation, with the basal shelly beds being of greater thickness and more readily identifiable. Interlaminated sands and silts and pockets of striped loams may occur in southeastern areas of the London basin. Rock strength bands of weakly cemented shells and limestone can be encountered, particularly in the area between Lewisham and Bermondsey. (Ref: Engineering in the Lambeth Group, CIRIA C583, 2004)

B SITE INVESTIGATION

7 Method

The strategy adopted for the intrusive investigation comprised the following:

- 1 No borehole was drilled to a depth of 25.2 m below the basement floor using a light percussion, 150mm diameter, shell and auger boring rig. Due to restrictions regarding access to the borehole location an electric breakdown cable percussive rig was utilised. In this investigation ground level is taken as the stage level. The floor of the basement from which intrusive drilling commenced is 2.8 m below this level. In total the basement level is approximately 6 m below street level.

The location of the exploratory hole is shown in Figure 1 in Appendix A.

The fieldwork was carried out between the 14th and 16th of January 2013.

8 Soils as Found

The soils encountered are described in detail in the attached exploratory hole logs (Appendix A), but in general comprised a stiff to very stiff London Clay over the Lambeth Group (previously the Woolwich and Reading Beds). A summary is given below.

Depth	Thickness	Soil Type	Description
GL – 2.8 m	-	VOID	Open space between stage and basement floor.
2.8 – 2.9 m	0.1 m	CONCRETE	Concrete slab.
2.9 – 3.2 m	0.3 m	MADE GROUND	Sub base consisting of brick and concrete fragments in a clay matrix.
3.2 – 24.5 m	21.3 m	CLAY (LONDON CLAY)	Stiff to very stiff, high strength, dark grey brown clay. With possible selenite crystals.
24.5 m +	Base not reached	CLAY (LAMBETH GROUP)	Very stiff, very high strength blue grey mottled red brown clays.

C FIELD TESTING AND SAMPLING

The following in-situ test and sampling methods were employed. Descriptions are given in Appendix B together with the test results.

- Standard Penetration Tests
- Disturbed samples
- U100 undisturbed samples

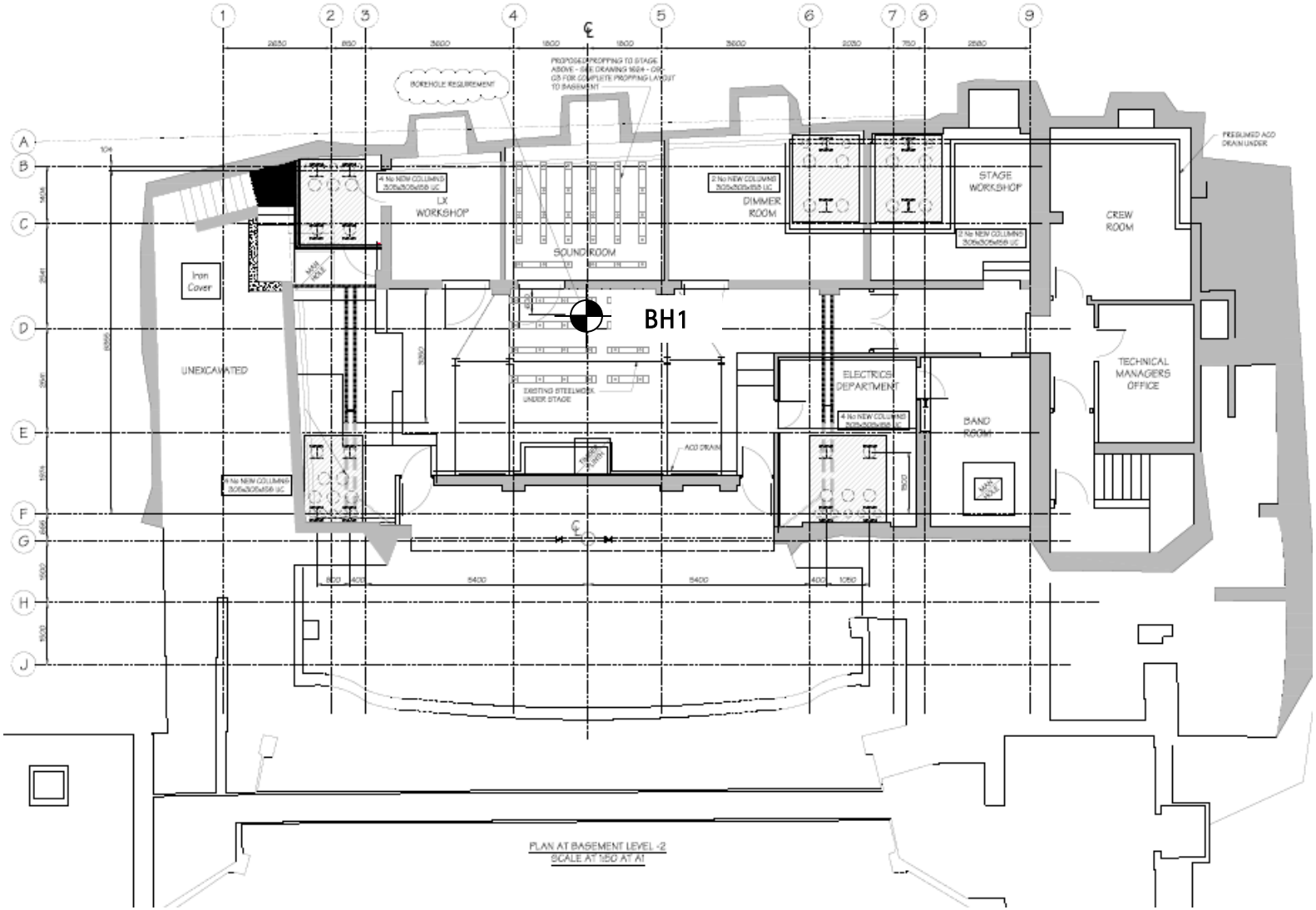
D GEOTECHNICAL LABORATORY TESTS

The following tests were carried out on selected samples. Test method references and results are given in Appendix C.

- pH value;
- Natural moisture content;
- Atterberg limits;
- Water soluble sulphate content;
- Undrained 100 mm diameter Triaxial tests.

APPENDIX A

Site Plans and Exploratory Hole Logs



NB: Positions of Boreholes and/or Trial Pits are only indicative unless dimensioned

Site: Shaftesbury Theatre, London	STL: J11265	Fig No: 1
Date: 25 January 2013	Borehole location	

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Job No: **J11265** Hole No: **BH1**

National Grid Reference		TQ 301 813	
Start date	14/01/2013	End date	15/01/2013
Ground level		Backfill date	16/01/2013
Logged by	TL	Engineer	DV
Final depth	28.00	Page	1 of 2

Site : **Shaftesbury Theatre**

Client : **MJ Consulting**

Drilling Method : Shell and Auger (150mm)

Piezometer or Monitoring well	Testing		Samples		Strata					
	Depth	Penetration Test (N value) U(blows)	Depth	Type	Thickness	Level	Legend	Depth		Strata Descriptions
										Void space between stage and basement floor
					2.80					
			2.90	B	0.10			2.80	CONCRETE	CONCRETE slab
					0.30			2.90	MADE GROUND	MADE GROUND comprising fine to coarse GRAVEL consisting of crushed bick and concrete in a dark brown clay matrix
	3.50	U (23)	3.50	U				3.20	CLAY	Stiff to very stiff, high strength, dark greyish brown, thinly to thickly laminated CLAY with occasional extremely to very closely spaced fissuring in random orientation. With rare very fine clear crystals (possibly selenite).
	3.60	ucs (300)								
	4.00	ucs (360)	4.00	D						
	5.00	SPT (17)								
	5.00	ucs (350)								
			5.50	D						
	6.00	ucs (350)								
	6.50	U (25)	6.50	U						
	7.00	ucs (360)	7.00	D						
	8.00	SPT (22)								
	8.00	ucs (490)								
	8.50	ucs (500)	8.50	D						
	9.50	ucs (490)	9.50	U						
	9.50	U (25)								
			10.00	D						
	11.00	SPT (26)								
	11.50	ucs (590)	11.50	D						
	12.50	U (34)	12.50	U						
			13.00	D						
					21.30					
	14.00	SPT (29)								
	14.50	ucs (600)	14.50	D						

Hole Diameters		
Depth (m)	Hole (mm)	Casing (mm)
3.50	150	150

Water Strikes					
Date	Water (m)	Casing (m)	Time (mins)	Rose to (m)	Sealed (m)

Chiselling Time		
From (m)	To (m)	Time (hrs)

General Remarks

Ground level taken as stage surface. Stage surface is 3 m below street level. Basement floor level is 2.8 m below stage level.

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Job No: **J11265** Hole No: **BH1**

National Grid Reference		TQ 301 813	
Start date	14/01/2013	End date	15/01/2013
Ground level		Backfill date	16/01/2013
Logged by	TL	Engineer	DV
Final depth	28.00	Page	2 of 2

Site : **Shaftesbury Theatre**

Client : **MJ Consulting**

Drilling Method : Shell and Auger (150mm)

Piezometer or Monitoring well	Testing		Samples		Strata					
	Depth	Penetration Test (N value) U(blows)	Depth	Type	Thickness	Level	Legend	Depth	Strata Descriptions	
	15.50	U (35)	15.50	U						
			16.00	D						
	17.00	SPT (29)								
			17.50	D						
	18.95	U (35)	18.95	U						
			19.00	D						
	20.00	SPT (50 for 75mm)								
			20.50	D						
	21.50	U (38)	21.50	U						
			22.00	D						
	23.00	SPT (40)								
			23.50	D						
								24.50	CLAY	Very stiff, very high strength blue grey mottled red brown fissured CLAY. Fissures are extremely closely to closely spaced and randomly orientated.
	24.95	U (50)	24.95	U						
			25.00	D						
	26.00	SPT (51)								
	26.00	ucs (600)			3.50					
			26.50	D						
	27.50	U (50)	27.50	U						
	28.00	ucs (600)	28.00	D				**28.00**		End of Borehole

Hole Diameters		
Depth (m)	Hole (mm)	Casing (mm)
3.50	150	150

Water Strikes					
Date	Water (m)	Casing (m)	Time (mins)	Rose to (m)	Sealed (m)

Chiselling Time		
From (m)	To (m)	Time (hrs)

General Remarks

Ground level taken as stage surface. Stage surface is 3 m below street level. Basement floor level is 2.8 m below stage level.

APPENDIX B

Field Sampling and in-situ Test Methods & Results

Field Sampling and in-situ Test Methods

Disturbed Samples

Disturbed samples were taken from the trial holes intervals and stored in sealed glass jars and polythene bags, as appropriate.

Undisturbed U100 Samples

Undisturbed U100 samples were taken in the clay soils at appropriate intervals. These samples are taken in a 100 mm diameter, 450 mm long, thin-walled steel tube, and are sealed with paraffin wax and tightly fitting end caps for transporting to the laboratory.

Standard Penetration Test

The Standard Penetration (SPT) Test is specified in BS EN ISO 22476-3 : 2005. In this test, a 51mm diameter open-ended tube is driven into the ground by a 63.5 kg hammer falling freely through 760 mm. The tube is seated by driving to a penetration of 150mm, or by 25 standard blows, whichever occurs first. It is then driven for a maximum of a further 300mm and the number of blows is termed the penetration resistance (N). If 300mm penetration cannot be achieved in 50 blows (100 blows in soft rock), the test drive is terminated.

When testing in gravels, a conical end piece is attached to the tube. The test is then called an SPT(C).

This test provides an indirect method of assessing the properties of cohesionless soils, and the following table (after Terzaghi and Peck) gives the approximate condition:-

Number Blows (N)	Density
0 - 4	Very Loose
4 – 10	Loose
10 – 30	Medium Dense
30 – 50	Dense
Over 50	Very Dense

Clay

An approximate value for the shear strength of clay may be obtained using Stroud (1974), which paper indicates that the cohesive strength is a function of plasticity and SPT 'N' value. The relation is:

C_u = f_i x N kPa

C_u = undrained shear strength

f_i = factor related to plasticity index and ranging from 4 to more than 6

The SPT test is not generally accepted as giving a reliable indication of the strength of cohesive soils but it does give a guide; often the following table:-

Number Blows (N)	Soil Strength
Less than 2	Very Soft (Very Low Strength)
2 – 5	Soft (Low Strength)
5 – 10	Firm (Medium Strength)
10 – 15	Stiff (High Strength)
15 – 30	Very Stiff (Very High Strength)

APPENDIX C

Geotechnical Laboratory Test Methods & Results

Determination of pH value

The pH value is a measure of acidity or alkalinity. It is measured using an electrometric meter, directly in the case of water, or in a soil suspension in distilled water.

Moisture Content

A sample of soil is dried to constant dry weight at a temperature of 105 degrees centigrade and the moisture content determined.

Atterberg Limit Tests

This is a valuable classification test, which is used to determine the moisture contents at which a soil changes from a liquid through a plastic to a solid state and gives an indication of the clay quantities present in the soil.

2 : 1 Water Extract Sulphate Test

When the water soluble sulphate content, as described above, is classified as Class III or over a 2 : 1 water : soil extract is prepared and the sulphate content determined gravimetrically.

This ensures that only the more readily soluble sulphates - those most likely to attack concrete - are determined.

Triaxial Compression Test

Shear characteristics of the soil are obtained by the undrained triaxial test. In this test, 38mm diameter or 100mm diameter samples were tested in compression under a series of varied lateral pressures, and the angle of shearing resistance and apparent cohesion obtained.

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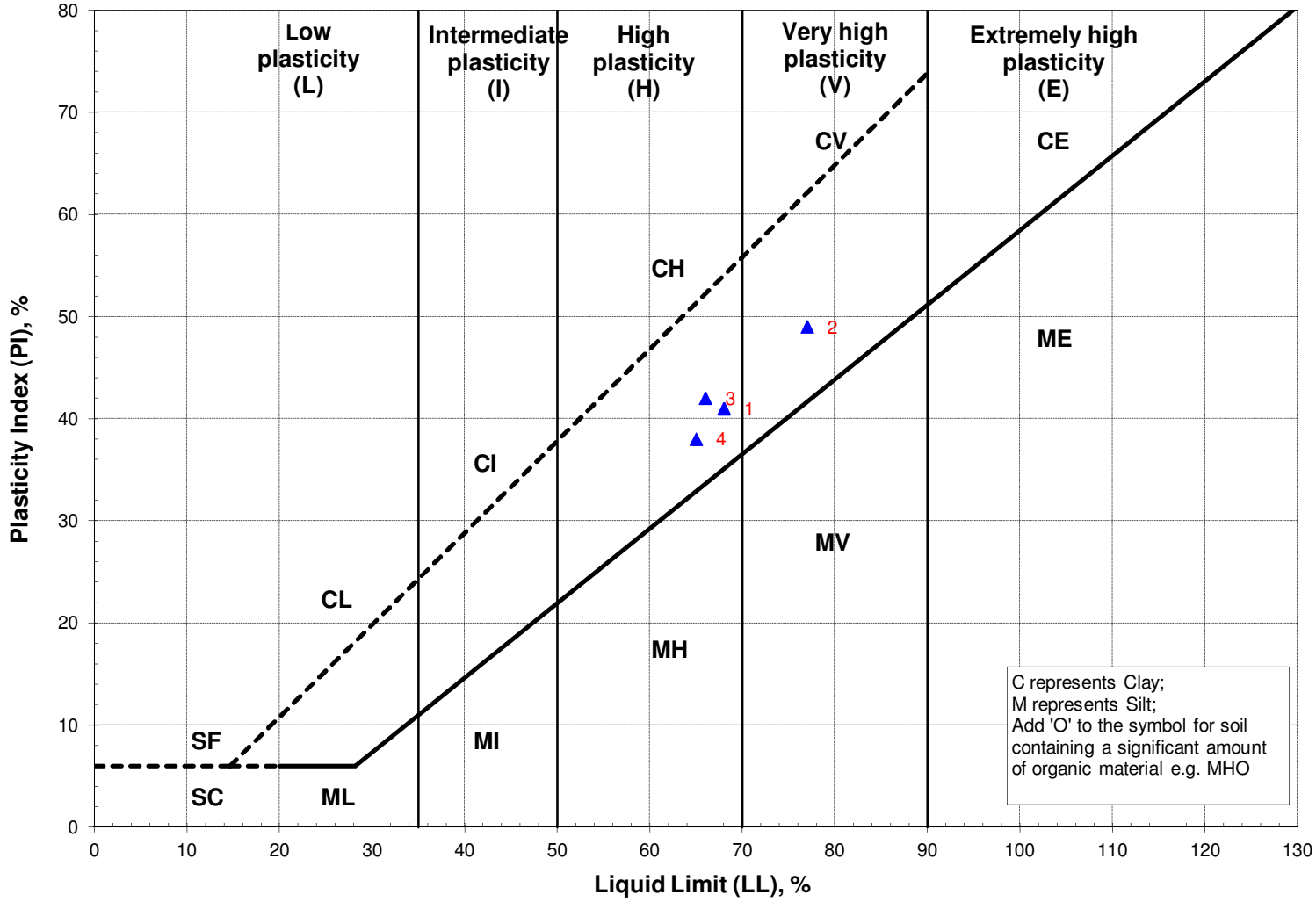
Plasticity Chart for Atterberg Limit Test Results



Sample List

1	BH1@5.5m
2	BH1@12m
3	BH1@16m
4	BH1@26.5m

Statistics

Liquid Limit	
Max	77
Min	65
Average	69
Plastic Limit	
Max	28
Min	24
Average	27
Plasticity Index	
Max	49
Min	38
Average	43

Project Name:	*Shaftesbury Theatre*	**Project No:**	*J11265*	**Project Engineer:**	*DV*
Client:	*MJ Consulting*	**Date:**	*23/01/2013*	*Figure No. 2*	

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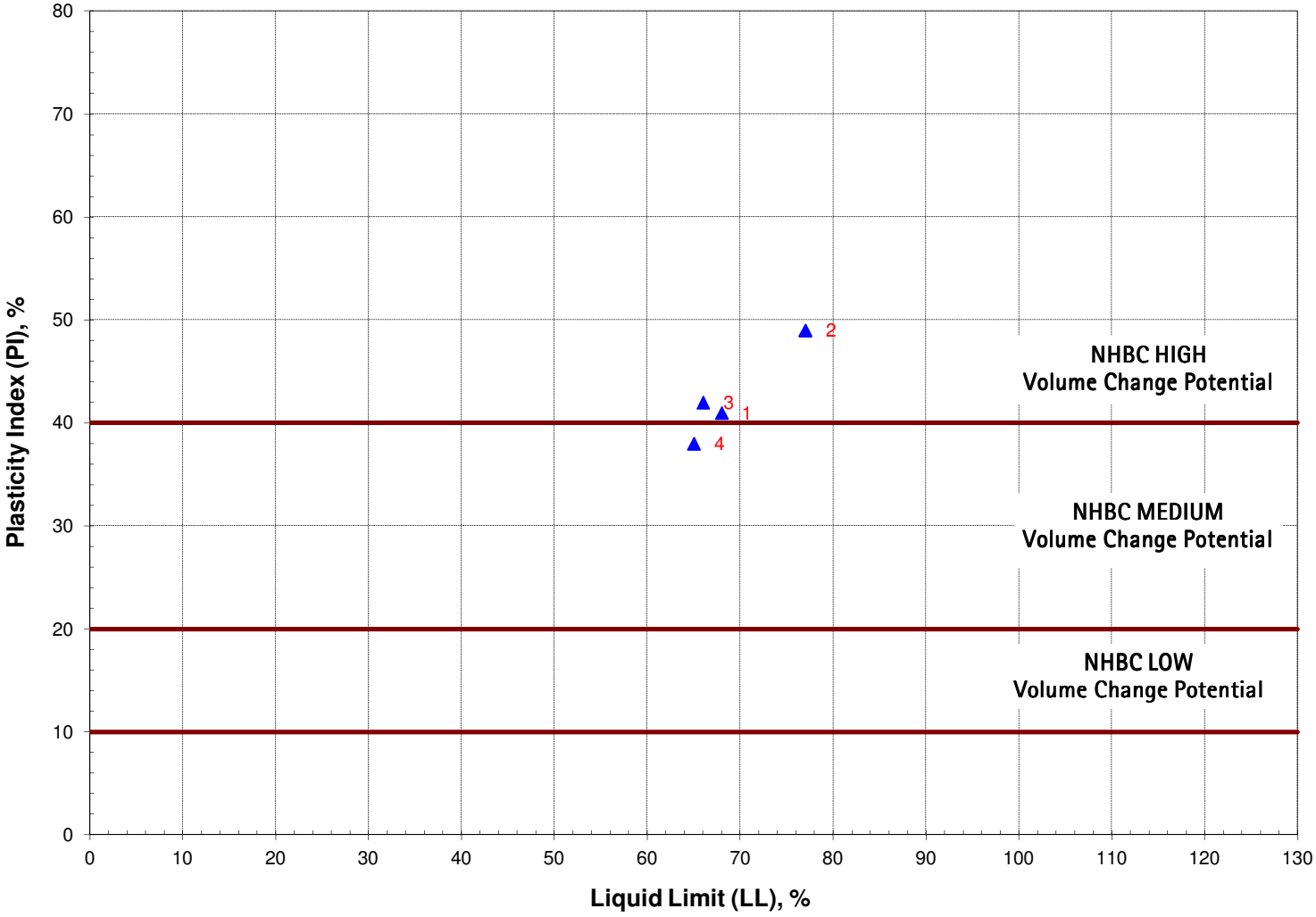
Plot Relating Soil Plasticity to NHBC Classification for Volume Change Potential



Sample List

1	BH1@5.5m
2	BH1@12m
3	BH1@16m
4	BH1@26.5m

Statistics

Liquid Limit	
Max	77
Min	65
Average	69
Plastic Limit	
Max	28
Min	24
Average	27
Plasticity Index	
Max	49
Min	38
Average	43

Project Name:	*Shaftesbury Theatre*	**Project No:**	*J11265*	**Project Engineer:**	*DV*
Client:	*MJ Consulting*	**Date:**	*23/01/2013*	*Figure No. 3*	

Atterberg Limits Test Result Summary Sheet

Test carried out in accordance with BS 1377-2:1990(2003) cl. 3.2, 4.2, 4.3, 5.3 & 5.4

Project No : *J11265* **Checked By :** *AS* **Date:** *23-Jan-2013*

Project Name : *Shaftesbury Theatre*

Client : *MJ Consulting*

Plot No	TH No.	Depth (m)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Class-ification	% Passing 425µm (%)	Visual Description
1	*BH1*	*5.50*	*27.5*	*68*	*27*	*41*	*CH*	*100*	*Very stiff very high strenght dark grey CLAY.*
2	*BH1*	*12.00*	*27.2*	*77*	*28*	*49*	*CV*	*100*	*Hard extremely high strength dark grey CLAY.*
3	*BH1*	*16.00*	*23.7*	*66*	*24*	*42*	*CH*	*100*	*Very stiff very high strength dark grey slightly sandy CLAY.*
4	*BH1*	*26.50*	*24.7*	*65*	*27*	*38*	*CH*	*100*	*Very stiff very high strength red brown mottled light grey CLAY.*

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ST Consult

Soil / Groundwater Sulphate Content Test Results

Test carried out in accordance with BS 1377-3:1990 (2003) cl. 5.3, 5.4, 5.6 & 9.5

Project No : ***J11265*** **Client :** ***MJ Consulting***

Project Name : ***Shaftesbury Theatre***

Tested By : ***STL*** **Checked :** ***AS*** **Date :** ***24-Jan-13***

TH No.	Depth (m)	Sample Type	Soil Sulphate in 2:1 Water Extract		Groundwater Sulphate		Total Potential Sulphate		pH Value	Percentage Passing 2mm Sieve	Visual Description
			g /l SO_3	BRE mg /l SO_4	g /l SO_3	BRE mg /l SO_4	% SO_3	BRE % SO_4			
BH1	**4.00**	Soil	***0.21***	***252***					***7.9***	*100.0*	Very stiff very high strength grey sandy CLAY.
BH1	**8.00**	Soil	***0.16***	***192***					***8.0***	*100.0*	Hard extremely high strength dark grey CLAY.
BH1	**16.00**	Soil	***0.40***	***480***					***8.0***	*100.0*	Very stiff very high strength dark grey slightly sandy CLAY.
BH1	**21.50**	Soil	***0.22***	***264***					***8.5***	*100.0*	Hard fissured extremely high strength dark grey sandy CLAY.
BH1	**28.00**	Soil	***0.05***	***60***					***9.1***	*100.0*	Hard fissured extremely high strength blue grey mottled red brown CLAY.

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Summary Sheet Triaxial Compression Test Results (BS1377-7:1990(1994)

Proj No: ***J11265*** **Project Name:** ***Shaftesbury Theatre*** **Checked By:** **AS** **Date:** ***23/01/2013***

TH No	Depth (m)	Moisture Content (%)	Bulk Density (Mg/m^3)	Dry Density (Mg/m^3)	Cell Pressure (kPa)	Deviator Stress (kPa)	Apparent Cohesion; C_u (kPa)	Visual Description	Sample Type	UCS by Hand Pen (kN/m^2)
BH1	**3.5**	*26.1*	*1.90*	*1.50*	*20*	*256.5*	*128.2*	*Very stiff fissured very high strength grey brown slightly sandy CLAY.*	*U100*	*460*
BH1	**6.5**	*27.9*	*1.88*	*1.47*	*75*	*244.6*	*122.3*	*Very stiff fissured very high strength grey brown slightly sandy CLAY.*	*U100*	*560*
BH1	**9.5**	*28.1*	*1.87*	*1.46*	*135*	*280.2*	*140.1*	*Very stiff extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*
BH1	**12.5**	*29.1*	*1.84*	*1.43*	*195*	*335.7*	*167.9*	*Very stiff fissured extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*
BH1	**15.5**	*26.9*	*1.91*	*1.51*	*255*	*468.4*	*234.2*	*Very stiff fissured extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*
BH1	**18.5**	*25.9*	*1.92*	*1.53*	*315*	*567.4*	*283.7*	*Very stiff fissured extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*
BH1	**21.5**	*25.5*	*1.88*	*1.50*	*375*	*488.2*	*244.1*	*Very stiff fissured extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*
BH1	**24.5**	*19.7*	*2.03*	*1.69*	*435*	*767.5*	*383.7*	*Very stiff fissured extremely high strength grey brown slightly sandy CLAY.*	*U100*	*>600*

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ST Consult

Summary Sheet Triaxial Compression Test Results (BS1377-7:1990(1994)

Proj No: ***J11265*** **Project Name:** ***Shaftesbury Theatre*** **Checked By:** **AS** **Date:** ***23/01/2013***

TH No	Depth (m)	Moisture Content (%)	Bulk Density (Mg/m^3)	Dry Density (Mg/m^3)	Cell Pressure (kPa)	Deviator Stress (kPa)	Apparent Cohesion; C_u (kPa)	Visual Description	Sample Type	UCS by Hand Pen (kN/m^2)
BH1	**27.5**	*14.0*	*2.07*	*1.81*	*495*	*1482.5*	*741.3*	*Very stiff extremely high strength light grey mottled orange brown sandy CLAY.*	*U100*	*>600*