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REPORT 49215/G/3

TESTING OF

PORTLAND LIMESTONE

PERRYFIELD MID TIER WHITBED

**Sandberg LLP
5 Carpenters Place
Clapham High Street
London SW4 7TD**

**Tel: 020 7565 7000
Fax: 020 7565 7101
email: mail@sandberg.co.uk
web: www.sandberg.co.uk**

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CONSULTING ENGINEERS

INVESTIGATION INSPECTION
MATERIALS TESTING

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PERRYFIELD MID TIER WHITBED

Portland Stone Firms Limited
99 Easton Street
Portland
Dorset
DT5 1BP

For the attention of Mr Neil Fuller

This report comprises
6 pages of text
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Table 7 of 1 sheet

12 February 2014

Partners: N C D Sandberg S M Pringle S C Clarke D J Ellis P Tate A A Willmott R A Rogerson M A Eden J D French C Morgan G S Mayers G C S Moor
Senior Associates: Dr R M Harris R D Easthope J Williamson R H Gostomski I M Hudson J Garner J H Dell
Associates: D Hunt S R P Morris M I Ingle R A Lucas
Consultants: T Carbray Prof F M Burdekin Prof M Grantham J J Krancioch

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TESTING OF

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PERRYFIELD MID TIER WHITBED

Reference: Instructions from Mr Neil Fuller of Portland Stone Firms Limited.
Purchase Order no. : M0454 dated 8 July 2013.

1. INTRODUCTION

We were instructed to undertake testing of natural stone, advised to be Portland limestone Perryfield Mid Tier Whitbed, in order to establish physical characteristics.

2. SAMPLES

Test specimens prepared ready for test were received from Portland Stone Firms Limited at Sandberg laboratories on 13 November 2013, as follows.

Sandberg Reference	Specimen Size	Test
	Portland limestone Perryfield Mid Tier Whitbed	
G39881	6 no. 50 x 50 x 50mm	Density & porosity
G39882	6 no. 50 x 50 x 50mm	Water absorption at atmospheric pressure
G39883	6 no. 70 x 70 x 70mm	Water abs. coeff. by capillarity [BS EN 772-11]
G39884	10 no. 50 x 50 x 50mm	Compressive strength [BS EN 772-1]
G39885	10 no. 300 x 100 x 50mm	Flexural strength (4-point)
G39886	10 no. 300 x 50 x 50mm	Frost resistance Identification Test (Test B) (56 cycles) - visual inspection - dynamic modulus of elasticity - apparent volume
G39887	6 no. 200 x 200 x 30mm	Slip resistance - 120 grit

3. TEST METHODS AND RESULTS

3.1 Density and porosity

Specimens were tested in accordance with BS EN 1936 : 2006.

Detailed test results are given in Table 1 of this report and are summarised as follows:

Sandberg Reference	Apparent Density (kg/m ³)		Open Porosity (%)	
	Range	Mean	Range	Mean
G39881	2250 - 2340	2300	12.9 - 16.2	14.6

3.2 Water Absorption at atmospheric pressure

Specimens were tested in accordance with BS EN 13755 : 2008.

Detailed test results are given in Table 2 of this report and are summarised as follows:

Sandberg Reference	Water Absorption (%)	
	Range	Mean
G39882	4.3 - 6.2	5.1

3.3 Water absorption coefficient by capillarity

Specimens were tested in accordance with BS EN 772-11 : 2011.

Detailed test results are given in Table 3 of this report and are summarised as follows:

Sandberg Reference	Water absorption coefficient by capillarity (g/m ² .sec ⁻²)
G39883	24.8

3.4 Compressive strength

Specimens were tested in accordance with the method given in BS EN 772-1 : 2011.

Tests were carried out with the load applied in a perpendicular to bedding orientation and in an oven dried condition.

The detailed test results are given in Table 4 of this report and may be summarised as follows:

Sandberg Reference	Orientation / Condition	Compressive Strength (MPa)	
		Range	Mean
G39884	Perpendicular - dry	39.79 - 61.05	51 *

* To nearest 1.0 MPa

3.5 Flexural strength (4-point) under constant moment

Specimens were tested in accordance with the method given in BS EN 13161 : 2008.

Tests were carried out with the load applied in a perpendicular to bedding orientation and in an oven dried condition.

The detailed test results are given in Table 5 of this report and may be summarised as follows.

Sandberg Reference	Orientation / Condition	Flexural Strength (3-pt) (MPa)	
		Range	Mean
G39885	Perpendicular - dry	4.6 - 10.0	6.6

Statistical evaluation of the test results in accordance with the methods in BS EN 13161 : 2008 Annex A (normative) produced the following:-

Lowest Expected Value (MPa)

Perpendicular - dry

3.6

3.6 Frost resistance Identification Test (Test B)

Specimens were prepared and tested in accordance with BS EN 12371 : 2010 Identification Test (Test B), except that only ten specimens were tested.

It was instructed to continue the test to 56 cycles.

Specimens were visually inspected and tested for dynamic modulus of elasticity (fundamental resonance frequency) in an unknown bedding orientation and change in apparent volume in accordance with BS EN 14156 : 2004 at specified intervals (0, 14 and 56 cycles).

The detailed test results are given in Table 6 of this report and may be summarised as follows:

Sandberg Reference	Visual inspection score at 56 cycles (Nc)	Decrease in dynamic elastic modulus at 56 cycles (%)	Change in apparent volume at 56 cycles (%)
G39886 a	0	2.88	0.00
G39886 b	0	0.21	0.00
G39886 c	0	0.73	0.00
G39886 d	0	0.84	0.00
G39886 e	0	3.47	0.00
G39886 f	0	0.83	0.00
G39886 g	0	1.76	0.00
G39886 h	0	1.08	0.00
G39886 j	0	0.00	0.00
G39886 k	0	1.64	0.00

Note : A test set is defined as having failed when two or more samples show a visual score of 3 and/or a decrease in dynamic elastic modulus of 30%.

3.7 Slip resistance

Specimens with a 120 grit surface finish were tested for slip resistance in accordance with BS EN 14231 : 2003 using a portable skid resistance tester (pendulum tester).

Testing was carried out in dry and wet conditions.

Surface roughness measurements were also carried out using a Surtronic Duo R_z roughness meter whilst the slip resistance measurements were being made.

Detailed results of the slip resistance test are given in Table 7 and are summarised below.

Sandberg Reference		Average Slip Resistance Value (SRV) (55 rubber)	
		Dry	Wet
G39887	55 slider - 120 grit	66	75

The TRL pendulum tester has a range of readings from 0 to 150, high values indicate good slip resistance. Guidance on the interpretation of results is suggested by the UK Slip Resistance Group¹. These are generally accepted limits and are given below.

<u>Pendulum Test Value</u>	<u>Slip Potential</u>
0 - 24	High
25 - 35	Moderate
36+	Low

The surface roughness measurements are a guide to slip resistance particularly in borderline regions. It is recognised that increased roughness of the floor surface can give an improvement in slip resistance in wet conditions.

Surfaces contaminated with pure water generally require a surface roughness of at least 10µm R_z to provide a moderate level of slip resistance and at least 20µm R_z to indicate low slip potential. More viscous contaminants require higher surface roughness².

The slip resistance results relate to the samples in their as-received condition. It should be noted that the slip resistance of surfaces in service can be altered by various factors such as abrasion, polishing and contamination. Overall assessment of the potential for slip should take into account conditions of use and the environment, in addition to test results.

¹ The assessment of Floor Slip Resistance. The UK Slip Resistance Group, Issue 4, 2011.

² Roughness measurements should not be solely relied upon to evaluate the potential slip resistance of a floor.

4. REMARKS

These results conclude the requested programme of testing. Please do not hesitate to contact us if we can be of any further assistance in this matter.

Portland Stone Firms Limited
99 Easton Street
Portland
Dorset
DT5 1BP

for Sandberg LLP

For the attention of Mr Neil Fuller

D J Ellis
Partner

DJE/Geoman/ws

12 February 2014

File:49215/G/3.rep

Materials, samples and test specimens are retained for a period of 2 months from the issue of the final report.

Tests reported on sheets not bearing the UKAS mark in this report/certificate are not included in the UKAS accreditation schedule for this laboratory.

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

APPARENT DENSITY AND OPEN POROSITY

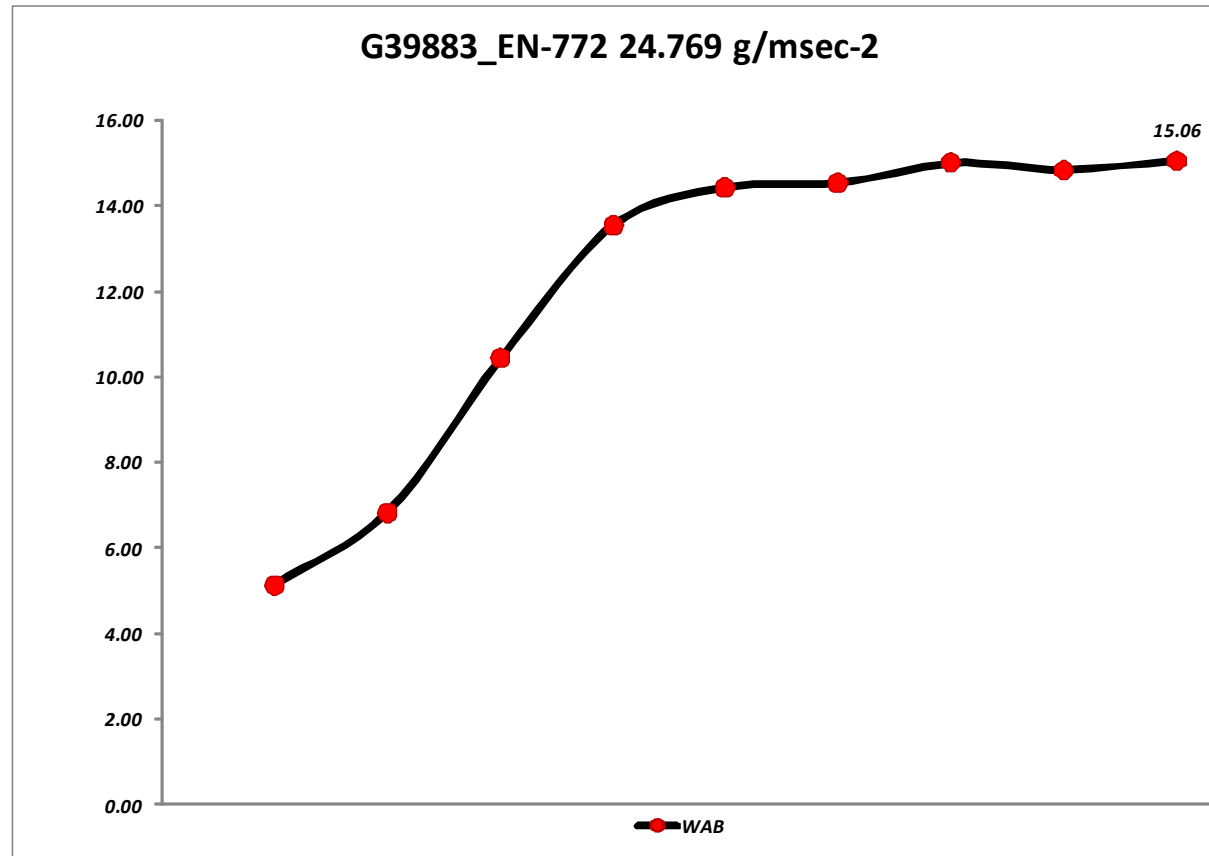
BS EN 1936 : 2006

Rock Name	Perryfield Mid Tier Whitbed			Test By/Date	MB / 27.11.13	
Rock Type	Portland limestone			Checked/Date	LN / 27.11.13	
Sandberg Sample Ref.	Oven Dried Mass in Air (g)	Density of Water (kg/m ³)	Vacuum Saturated Mass in Air (g)	Vacuum Saturated Mass in Water (g)	Open Porosity (%)	Apparent Density (kg/m ³)
G39881 a	295.83	998	316.43	185.87	15.8	2260
G39881 b	300.15	998	319.74	188.81	15.0	2290
G39881 c	297.68	998	319.14	187.03	16.2	2250
G39881 d	308.27	998	325.16	193.93	12.9	2340
G39881 e	306.84	998	324.44	193.18	13.4	2330
G39881 f	300.28	998	318.77	188.63	14.2	2300
Mean					14.6	2300

WATER ABSORPTION AT ATMOSPHERIC PRESSURE

BS EN 13755 : 2008

Rock Name	Perryfield Mid Tier Whitbed	Test By / Date	MB / 26.11.13
Rock Type	Portland limestone	Checked / Date	LN / 26.11.13
Sandberg Sample Ref.	Oven Dried Mass (g)	Saturated Surface Dried Mass (g)	Water Absorption (%)
G39882 a	304.18	317.68	4.4
G39882 b	307.24	320.44	4.3
G39882 c	300.85	316.02	5.0
G39882 d	301.74	316.40	4.9
G39882 e	293.41	310.73	5.9
G39882 f	295.76	313.97	6.2
Average			5.1



Coefficient of water absorption by capillarity : 24.77 g/m².Sec⁻²

COMPRESSIVE STRENGTH

BS EN 772-1 : 2011

Load Orientation¹ : Perpendicular
Test Condition : Oven dried

Rock Name	Perryfield Mid Tier Whitbed				Test By/Date	MB / 03.12.13	
Rock Type	Portland limestone				Checked/Date	HO / 03.12.13	
Sandberg Sample Reference	Breaking Load (N)	Specimen Height (mm)	Mean Lateral Dimension (mm)	Mean Lateral Dimension (mm)	Cross Section Area (mm ²)	Compressive Strength ^a (MPa)	Observations
G39884 a	159700	50.3	51.2	51.1	2616	61.05	Normal failure
G39884 b	124900	50.5	51.1	51.1	2611	47.84	Normal failure
G39884 c	141800	50.7	51.1	51.2	2616	54.20	Normal failure
G39884 d	128200	50.9	51.0	51.2	2611	49.10	Normal failure
G39884 e	128700	50.6	51.2	51.0	2611	49.29	Normal failure
G39884 f	152300	50.7	51.0	51.5	2627	57.97	Normal failure
G39884 g	104400	50.7	51.1	51.1	2611	39.98	Normal failure
G39884 h	133100	50.4	51.0	51.1	2606	51.07	Normal failure
G39884 j	103700	50.1	50.9	51.2	2606	39.79	Normal failure
G39884 k	160000	49.8	51.5	51.0	2627	60.91	Normal failure
Mean						51 *	
Std. Dev.						8 *	
Var. Coef.						0.2	

¹ Relative to bedding

* To nearest 1.0 MPa

FLEXURAL STRENGTH (UNDER CONSTANT MOMENT)

BS EN 13161 : 2008

Load Orientation¹ : Perpendicular
Finish : Sawn
Test Condition : Oven dried

Rock Name	Perryfield Mid Tier Whitbed			Test By/Date	MB / 19.11.13	
Rock Type	Portland limestone			Checked/Date	LN / 19.11.13	
Sandberg Sample Reference	Breaking Load (N)	Specimen Span (mm)	Specimen Width (mm)	Specimen Thickness (mm)	Flexural Strength (MPa)	Observations
G39885 a	9460	250	99.7	48.7	10.0	Normal Failure
G39885 b	5860	250	99.4	49.1	6.1	Normal Failure
G39885 c	4480	250	98.9	49.8	4.6 *	Normal Failure
G39885 d	6020	250	99.1	49.4	6.2	Normal Failure
G39885 e	6040	250	99.3	49.3	6.3	Normal Failure
G39885 f	4410	250	98.8	49.2	4.6 *	Normal Failure
G39885 g	5430	250	99.1	48.9	5.7	Normal Failure
G39885 h	8580	250	98.8	48.6	9.2	Normal Failure
G39885 j	7870	250	98.8	48.7	8.4	Normal Failure
G39885 k	4690	250	99.0	48.3	5.1	Normal Failure
Mean					6.6	
Std. Dev.					1.9	
Var. Coef.					0.3	

¹ With respect to bedding

Lowest Expected Value (MPa) : 3.6

* Failure plane contained traces of manganese

FROST RESISTANCE

BS EN 12371 : 2010
Identification test (Test B)

Rock Name	Perryfield Mid Tier Whitbed						Test by/Date		HO / 27.01.14									
Rock Type	Portland limestone						Checked by/ Date		MB / 29.01.14									
Sandberg Sample Ref.	Visual inspection score						Dynamic elastic modulus (% decrease)											
	0	14	56	84	140	168	0 (MPa)	14 (MPa)	14 (%)	56 (MPa)	56 (%)	84 (MPa)	84 (%)	140 (MPa)	140 (%)	168 (MPa)	168 (%)	
G39986 a	0	0	0	-	-	-	33422	33422	0.00	32458	2.88	-	-	-	-	-	-	
G39986 b	0	0	0	-	-	-	33870	33860	0.03	33799	0.21	-	-	-	-	-	-	
G39986 c	0	0	0	-	-	-	33147	32816	1.00	32906	0.73	-	-	-	-	-	-	
G39986 d	0	0	0	-	-	-	30590	29718	2.85	30333	0.84	-	-	-	-	-	-	
G39986 e	0	0	0	-	-	-	34183	34030	0.45	32998	3.47	-	-	-	-	-	-	
G39986 f	0	0	0	-	-	-	32317	32317	0.00	32049	0.83	-	-	-	-	-	-	
G39986 g	0	0	0	-	-	-	27126	36693	1.60	26649	1.76	-	-	-	-	-	-	
G39986 h	0	0	0	-	-	-	28663	28197	1.62	28353	1.08	-	-	-	-	-	-	
G39986 j	0	0	0	-	-	-	28161	27935	0.80	28161	0.00	-	-	-	-	-	-	
G39986 k	0	0	0	-	-	-	26810	26837	0.00	26369	0.64	-	-	-	-	-	-	

Bedding direction : Unknown
Surface finish : Sawn

FROST RESISTANCE

BS EN 12371 : 2010

Identification test (Test B)

Note : Failure is defined in BS EN 12371 : 2010 clause 7.3.2.5 as when two or more specimens show either ; - a visual inspection score of 3
- decrease in dynamic elastic modulus of 30%

Visual inspection score :	0	Specimen intact
	1	Very minor damage (minor rounding of corners and edges) which does not compromise the integrity of the specimen
	2	One or several minor cracks (≤ 0.1 mm width) or detachment of small fragments (≤ 10 mm ² per fragment)
	3	One or several cracks, holes or detachment of fragments larger than those defined for the '2' rating, or alteration of material in veins.
	4	Specimen broken in two or with major cracks.
	5	Specimen in pieces or disintegrated.

FROST RESISTANCE

BS EN 12371 : 2010
Identification test (Test B)

Rock Name	Perryfield Mid Tier Whitbed					Test by/Date	HO / 27.01.14		
Rock Type	Portland limestone					Checked by/ Date	MB / 29.01.14		
Sandberg Sample Ref.	Measurement of apparent volume (% decrease)								
	Initial dry mass (g)	Initial saturated mass (g)	Apparent mass in water (g)	Dry mass at 56 cycles (g)	Saturated mass at 56 cycles (g)	Apparent mass at 56 cycles (g)	Initial apparent volume (ml)	Apparent volume at 56 cycles (ml)	Change in apparent volume 56 cycles (%)
G39886 a	1792	1875	1029	1792	1875	1029	846	846	0.00
G39886 b	1780	1860	1023	1780	1860	1023	837	837	0.00
G39886 c	1623	1699	932	1623	1699	932	767	767	0.00
G39886 d	1607	1689	913	1607	1689	913	776	776	0.00
G39886 e	1657	1732	953	1657	1732	953	779	779	0.00
G39886 f	1779	1861	1021	1779	1861	1021	840	840	0.00
G39886 g	1724	1825	972	1724	1825	972	853	853	0.00
G39886 h	1741	1837	984	1741	1837	984	853	853	0.00
G39886 j	1594	1684	899	1594	1684	899	785	785	0.00
G39886 k	1589	1678	896	1589	1678	896	782	782	0.00

Nc : Maximum number of cycles (56) or number of cycles completed to failure

Sandberg Reference	Material	Surface Finish	Orientation	Surface Roughness ¹ R _z , μm	Temperature °C		Slip Resistance Value (SRV)			
					Surface	Ambient	Dry		Wet	
							Mean [5 readings]	Mean	Mean [5 readings]	Mean
G39887 a	Perryfield Mid Tier Whitbed	120 grit	A	52.1	21	21	66	67	77	77
			180° to A	-	21	21	67		77	
G39887 b	Perryfield Mid Tier Whitbed	120 grit	A	47.2	21	21	62	63	75	75
			180° to A	-	21	21	63		74	
G39887 c	Perryfield Mid Tier Whitbed	120 grit	A	57.4	21	21	64	65	75	76
			180° to A	-	21	21	65		77	
G39887 d	Perryfield Mid Tier Whitbed	120 grit	A	47.5	21	21	70	69	68	70
			180° to A	-	21	21	68		72	
G39887 e	Perryfield Mid Tier Whitbed	120 grit	A	56.6	21	21	67	66	77	77
			180° to A	-	21	21	65		77	
G39887 f	Perryfield Mid Tier Whitbed	120 grit	A	46.4	21	21	64	65	70	73
			180° to A	-	21	21	65		76	

SRV dry (6 no. specimens) : 66
SRV wet (6 no. specimens) : 75

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Where our involvement consists exclusively of testing samples, the results and our conclusions relate only to the samples tested.