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REPORT 49215/G

**TESTING OF
PORTLAND LIMESTONE
PERRYFIELD WHITBED**

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TESTING OF

PORTLAND LIMESTONE

PERRYFIELD 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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29 January 2014

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TESTING OF

PORTLAND LIMESTONE

PERRYFIELD 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 Whitbed, in order to establish physical characteristics.

2. SAMPLES

Test specimens prepared ready for test were received from Portland Stone Firms Limited Marnhull Stone Limited at Sandberg laboratories on 20 September 2013, as follows.

Sandberg Reference	Specimen Size	Test
	Portland limestone Perryfield Whitbed	
G39714	6 no. 50 x 50 x 50mm	Density & porosity
G39715	6 no. 50 x 50 x 50mm	Water absorption at atmospheric pressure
G39716	6 no. 70 x 70 x 70mm	Water abs. coeff. by capillarity [BS EN 772-11]
G39717	10 no. 50 x 50 x 50mm	Compressive strength [BS EN 772-1]
G39718	10 no. 300 x 100 x 50mm	Flexural strength (4-point)
G39719	13 no. 300 x 50 x 50mm	Frost resistance Identification Test (Test B) (56 cycles) - visual inspection - dynamic modulus of elasticity - apparent volume
G39720	6 no. 200 x 200 x 30mm	Slip resistance - 120 grit
G39721	5 no. 200 x 200 x 50mm	Breaking load at dowel hole

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
G39714	2130 - 2190	2150	18.5 - 20.8	20.0

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
G39715	6.9 - 7.4	7.2

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)
G39716	50.7

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
G39717	Perpendicular - dry	39.86 - 67.95	60 *

* 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
G39718	Perpendicular - dry	5.7 - 6.7	6.2

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

5.4

3.6 Frost resistance Identification Test (Test B)

Specimens were prepared and tested in accordance with BS EN 12371 : 2010 Identification Test (Test B).

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 (%)
G39719 a	0	9.52	0.00
G39719 b	0	8.12	0.00
G39719 c	0	9.64	0.00
G39719 d	0	4.04	0.00
G39719 e	0	5.89	0.00
G39719 f	0	9.17	0.00
G39719 g	0	8.24	0.00
G39719 h	0	10.04	0.00
G39719 j	1	4.79	0.00
G39719 k	0	8.26	0.00
G39719 l	1	8.38	0.00
G39719 m	0	8.96	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
G39720	55 slider - 120 grit	70	65

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.

3.8 Breaking load at dowel hole

Tests were carried out utilising a calibrated loading apparatus in accordance with the method in BS EN 13364 : 2002.

The slabs were tested with the load applied in a parallel to bedding edge orientation (Type IIb), in an oven dried condition and at a specimen thickness of 50mm.

The load was applied evenly until failure occurred and the load at failure recorded.

The results are presented in Table 8 of this report and are summarised as follows.

Sandberg Reference	Orientation / condition	Breaking load at dowel hole (kN)	
		Range	Mean
G39721	50mm Parallel to edge (Type IIb) - dry	1.42 - 2.89	2.18

Statistical evaluation of the test results in accordance with the methods in BS EN 13364: 2002 Annex A (normative) produced the following:-

Lowest Expected Value (kN)	
50mm Parallel to edge (Type IIb) - dry	1.36

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

29 January 2014

File:49215/G.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

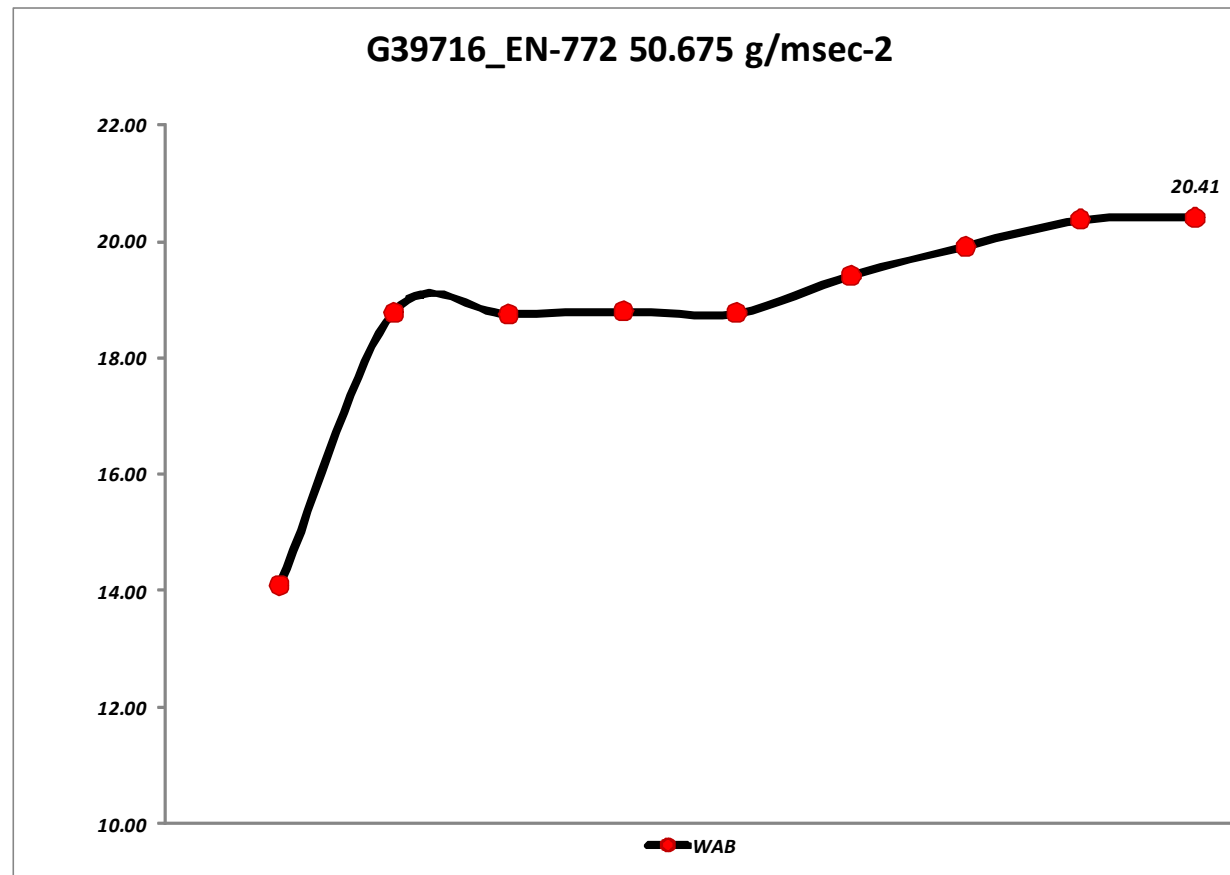
BS EN 1936 : 2006

Rock Name	Perryfield Whitbed			Test By/Date	MB / 31.10.13	
Rock Type	Portland limestone			Checked/Date	LN / 31.10.13	
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)
G39714 a	289.67	998	317.25	181.93	20.4	2140
G39714 b	293.67	998	318.46	184.51	18.5	2190
G39714 c	290.34	998	318.03	182.69	20.5	2140
G39714 d	291.42	998	319.72	183.33	20.8	2130
G39714 e	288.71	998	316.87	181.62	20.8	2130
G39714 f	293.42	998	319.27	184.71	19.2	2180
Mean					20.0	2150

WATER ABSORPTION AT ATMOSPHERIC PRESSURE

BS EN 13755 : 2008

Rock Name	Perryfield Whitbed	Test By / Date	MB / 01.11.13
Rock Type	Portland limestone	Checked / Date	MG / 04.11.13
Sandberg Sample Ref.	Oven Dried Mass (g)	Saturated Surface Dried Mass (g)	Water Absorption (%)
G39715 a	292.88	313.10	6.9
G39715 b	290.64	311.54	7.2
G39715 c	289.91	310.56	7.1
G39715 d	289.48	310.86	7.4
G39715 e	292.27	313.37	7.2
G39715 f	290.95	311.66	7.1
Average			7.2



Coefficient of water absorption by capillarity : 50.68 g/m².Sec⁻²

Table
3

Job No.
49215/G

COMPRESSIVE STRENGTH

BS EN 772-1 : 2011

Load Orientation¹ : Perpendicular
Test Condition : Oven dried

Rock Name	Perryfield Whitbed				Test By/Date	MB / 30.10.13	
Rock Type	Portland limestone				Checked/Date	LN / 30.10.13 + DJE/ 13.11.13	
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
G39717 a	102400	51.7	51.7	49.7	2569	39.86	Normal failure
G39717 b	155100	52.2	52.2	50.2	2620	59.20	Normal failure
G39717 c	162200	52.1	52.1	49.9	2600	62.38	Normal failure
G39717 d	170300	51.9	51.6	50.0	2580	66.01	Normal failure
G39717 e	156400	51.8	51.7	49.9	2580	60.62	Normal failure
G39717 f	156500	52.3	52.2	50.2	2620	59.73	Normal failure
G39717 g	168700	51.8	51.5	50.1	2580	65.39	Normal failure
G39717 h	152500	52.1	52.2	49.9	2605	58.54	Normal failure
G39717 j	176000	51.4	51.7	50.1	2590	67.95	Normal failure
G39717 k	150600	52.4	52.2	50.1	2615	57.59	Normal failure
Mean						60 *	
Std. Dev.						8 *	
Var. Coef.						0.1	

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 Whitbed			Test By/Date	MB / 30.09.13	
Rock Type	Portland limestone			Checked/Date	LN / 30.09.13	
Sandberg Sample Reference	Breaking Load (N)	Specimen Span (mm)	Specimen Width (mm)	Specimen Thickness (mm)	Flexural Strength (MPa)	Observations
G39718 a	5750	250	100.6	50.1	5.7	Normal Failure
G39718 b	5930	250	100.7	49.7	6.0	Normal Failure
G39718 c	5700	250	100.7	49.9	5.7	Normal Failure
G39718 d	5550	250	100.4	48.6	5.9	Normal Failure
G39718 e	6060	250	100.4	50.4	5.9	Normal Failure
G39718 f	5870	250	100.7	49.4	6.0	Normal Failure
G39718 g	6590	250	100.6	49.5	6.7	Normal Failure
G39718 h	6640	250	100.6	49.8	6.7	Normal Failure
G39718 j	6500	250	100.4	50.4	6.4	Normal Failure
G39718 k	6450	250	100.3	49.0	6.7	Normal Failure
Mean					6.2	
Std. Dev.					0.4	
Var. Coef.					0.1	

¹ With respect to bedding

Lowest Expected Value (MPa) : 5.4

FROST RESISTANCE

BS EN 12371 : 2010
Identification test (Test B)

Rock Name	Perryfield Whitbed											Test by/Date	HO / 03.12.13				
Rock Type	Portland limestone											Checked by/ Date	MB / 03.12.13				
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 (%)
G39719 a	0	0	0	-	-	-	23254	22074	5.08	21040	9.52	-	-	-	-	-	-
G39719 b	0	0	0	-	-	-	22841	21670	5.13	20987	8.12	-	-	-	-	-	-
G39719 c	0	0	0	-	-	-	22770	21582	5.22	20575	9.64	-	-	-	-	-	-
G39719 d	0	0	0	-	-	-	21940	20707	5.62	21054	4.04	-	-	-	-	-	-
G39719 e	0	0	0	-	-	-	22102	21403	3.16	20800	5.89	-	-	-	-	-	-
G39719 f	0	0	0	-	-	-	22184	26851	0.00	20149	9.17	-	-	-	-	-	-
G39719 g	0	0	0	-	-	-	23479	22294	5.05	21545	8.24	-	-	-	-	-	-
G39719 h	0	0	0	-	-	-	22175	21257	4.14	19948	10.04	-	-	-	-	-	-
G39719 j	0	0	1	-	-	-	21960	21203	3.45	20909	4.79	-	-	-	-	-	-
G39719 k	0	0	0	-	-	-	21403	25293	0.00	19636	8.26	-	-	-	-	-	-
G39719 l	0	0	1	-	-	-	22832	26296	0.00	20918	8.38	-	-	-	-	-	-
G39719 m	0	0	0	-	-	-	22833	25948	0.00	20786	8.96	-	-	-	-	-	-

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 Whitbed					Test by/Date	HO / 03.12.13		
Rock Type	Portland limestone					Checked by/ Date	MB / 03.12.13		
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 (%)
G39719 a	1681	1794	949	1680	1794	949	845	845	0.00
G39719 b	1649	1762	924	1648	1762	924	838	838	0.00
G39719 c	1661	1773	934	1660	1773	934	839	839	0.00
G39719 d	1664	1778	942	1664	1778	942	836	836	0.00
G39719 e	1677	1787	937	1677	1787	937	850	850	0.00
G39719 f	1675	1789	941	1674	1789	941	848	848	0.00
G39719 g	1695	1803	980	1695	1803	980	823	823	0.00
G39719 h	1670	1784	937	1670	1784	937	847	847	0.00
G39719 j	1685	1793	942	1684	1793	942	851	851	0.00
G39719 k	1663	1776	930	1661	1776	930	846	846	0.00
G39719 l	1703	1806	965	1702	1806	965	841	841	0.00
G39719 m	1676	1786	948	1675	1786	948	838	838	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
G39720 a	Perryfield Whitbed	120 grit	A	51.6	21	22	87	88	63	64
			180° to A	-	21	22	89		64	
G39720 b	Perryfield Whitbed	120 grit	A	46.3	21	22	83	84	66	66
			180° to A	-	21	22	85		66	
G39720 c	Perryfield Whitbed	120 grit	A	52.6	21	22	65	66	66	68
			180° to A	-	21	22	67		70	
G39720 d	Perryfield Whitbed	120 grit	A	47.4	21	22	65	64	63	61
			180° to A	-	21	22	62		58	
G39720 e	Perryfield Whitbed	120 grit	A	50.1	21	22	60	60	65	64
			180° to A	-	21	22	59		62	
G39720 f	Perryfield Whitbed	120 grit	A	54.4	21	22	57	59	62	64
			180° to A	-	21	22	60		65	

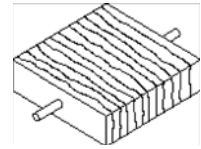
SRV dry (6 no. specimens) : 70

SRV wet (6 no. specimens) : 65

DETERMINATION OF BREAKING LOAD AT DOWEL HOLE

BS EN 13364 : 2002

Fixing Type : Dowel (ss 6mm dia.) With standard cement
Fixing Location : Centre of edge
Load Orientation : Parallel to edge (Type IIb)
Test Condition : Oven dried



Rock Name	Perryfield Whitbed - 50mm thickness			Tested By/Date	MB / 01.10.13
Rock Type	Portland limestone			Checked By/Date	HO / 01.10.13
Specimen Reference (with dowel)	Simulated Wind Loading ¹	Failure Load (kN)	Max. distance from hole centre to fracture edge (mm) b_A	Distance from hole to fracture face (mm) d_1	Observations
G39721 a	Negative	1.42	69.39	20.67	Half-cone failure
G39721 b	Negative	2.21	57.38	18.38	Half-cone failure
G39721 c	Negative	1.92	75.39	20.90	Half-cone failure
G39721 d	Negative	1.64	48.42	19.21	Half-cone failure
G39721 e	Negative	2.32	39.22	19.70	Half-cone failure
G39721 f	Negative	2.73	48.04	19.92	Half-cone failure
G39721 g	Negative	2.17	83.23	23.94	Half-cone failure
G39721 h	Negative	2.89	72.17	23.33	Half-cone failure
G39721 j	Negative	2.30	57.03	20.26	Half-cone failure
G39721 k	Negative	2.23	48.77	19.81	Half-cone failure
Mean		2.18			
Std. Dev.		0.44			
Var. Coef.		0.20			

¹ Relative to finished face

n/a = not applicable

Lowest Expected Value (kN) : 1.36

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