

SANDBERG

REPORT 66577/G

**TESTING OF
VALENTIA STONE**

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MATERIALS TESTING

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TESTING OF

VALENTIA STONE

Carrig Conservation International Ltd.
Unit 2, Atlantis Building
Cumberland Street South
Dublin
D02 V588

For the attention of Mr Peter Cox

This report comprises
6 pages of text
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Table 9 of 1 sheet

20 March 2020

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TESTING OF

VALENTIA STONE

Reference : Instructions from Mr Peter Cox of Carrig Conservation International Ltd.

1. INTRODUCTION

We were instructed to undertake testing of natural stone, advised to be Valentia stone, in order to establish petrographic, physical, mechanical and durability characteristics.

2. SAMPLES

Test specimens prepared ready for test were received from Carrig Conservation International Ltd. at Sandberg laboratories on 17 January 2020, as follows.

Sandberg Reference	Specimen Size	Test
	Valentia stone	
G49532	1 no. 150 x 150 x 30mm	Petrographic examination
G49533	6 no. 65 x 65 x 30mm } }	Apparent density & open porosity
G49534	6 no. 50 x 50 x 50mm	Water absorption atmospheric pressure
G49535	10 no. 180 x 70 x 30mm *	Water absorption coefficient capillarity
G49536	10 no. 180 x 70 x 30mm	Flexural strength (3-point), dry Frost resistance (56 cycles)
G49537	10 no. 180 x 70 x 30mm *	- flexural strength (3-point), dry
G49539	6 no. 40 x 40 x 40mm	Thermal shock resistance (20 cycles)
G49538	6 no. 200 x 200 x 40mm	- post-cycling flexural strength (3-point), dry Salt crystallisation Breaking load at dowel hole, dry

Note : Received in subsequent second shipment.

3. TEST METHODS AND RESULTS

3.1 Petrographic Examination

A sample was subjected to petrographic examination in accordance with the methods described in BS 5930:2015¹, ISRM² and BS EN 12407:2007³.

The sample was first subjected to macroscopical and low power stereoscopic microscope examination supported by simple physical and chemical tests.

Record photographs of the sample are presented in Table 1.

A representative portion from the sample was used to prepare a large area thin section which was examined using a Leica DM4500P high power petrological microscope employing plane polarised and cross polarised light at magnifications up to x1000.

The detailed petrographic examination results are given in Table 1 and can be summarised as follows:

Valentia stone

Grey to bluish grey, mainly fine to occasionally medium grained, well to very well compacted SLATE, dense, generally hard to moderately hard and apparently robust (subjective assessment). The stone exhibited rough cleavage planes and well closed slaty cleavage. The cleavage was generally parallel to the principal surfaces of the sample and apparently discontinuous and generally irregularly spaced out in the millimetre scale.

Note : We would recommend X-ray diffraction analysis in order to identify the general composition and whether detectable pyrite is present.

3.2 Apparent Density and Open Porosity

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

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

Sandberg Reference	Apparent Density (kg/m ³)		Open Porosity (%)	
	Range	Mean	Range	Mean
G49533	2790 - 2810	2810	0.2 - 0.2	0.2

¹ BS 5930:2015. Code of Practice for Site Investigation, Section 6, Clause 36, Description and Classification of Rocks for engineering Purposes.

² Rock Characterisation Testing and Monitoring. International Society for Rock Mechanics (ISRM) Suggested methods. Petrographic Description of Rocks p.73, 1981 Edition.

³ BS EN 12407:2007. Natural Stone Test Methods - Petrographic Examination.

3.3 Water Absorption at Atmospheric Pressure

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

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

Sandberg Reference	Water Absorption (%)	
	Range	Mean
G49533	0.1 - 0.1	0.1

3.4 Water Absorption Coefficient of Capillarity

Specimens were tested in accordance with BS EN 1925 : 1999.

Detailed test results are given in Table 4 of this report and are summarised as follows:

Sandberg Reference	Water absorption coefficient capillarity (g/m ² .sec ^{0.5})
G49534	0.4

3.5 Flexural Strength (3-point) Under Concentrated Load

Specimens were tested in accordance with the method given in BS EN 12372 : 2006.

Tests were carried out with the load applied in a perpendicular to cleavage 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
G49535	Perpendicular - dry	31.0 - 90.5	49.9

Statistical evaluation of the test results in accordance with the methods in BS EN 12372 : 2006 Annex A (normative) produced the following:-

Lowest Expected Value (MPa)

Perpendicular - dry

24.1

3.6 Frost Resistance - Flexural Strength (3-point) Under Concentrated Load

Specimens were tested in accordance with BS EN 12371 : 2010 Technology Test (Test A) to 56 no. cycles.

On completion of the cycling period specimens were tested for flexural strength in accordance with BS EN 12372 : 2006.

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

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

Sandberg Reference	Orientation / Condition	Flexural Strength (3-pt) (MPa)	
		Range	Mean
G49536	Post-cycling Perpendicular - dry	59.0 - 77.6	67.6

Visual inspection of the test specimens (post-56 cycles) indicated a classification of '0' (intact).

Statistical evaluation of the test results in accordance with the method in BS EN 12372 : 2006 Annex A (normative) produced the following:-

	Lowest Expected Value (MPa)
Post-cycling Perpendicular - dry	56.3

3.7 Thermal Shock Resistance - Flexural Strength (3-point) Under Concentrated Load

Specimens were tested in accordance with BS EN 14066 : 2013.

One set of specimens were tested for flexural strength in accordance with the method given in BS EN 12372 : 2006 post-cycling.

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

The detailed test results are given in Table 7 of this report and may be summarised as follows:

Sandberg Reference	Orientation / Condition	Flexural Strength (3-pt) (MPa)	
		Range	Mean
G49537	Post-cycling Perpendicular - dry	21.0 - 76.8	41.5

Statistical evaluation of the test results in accordance with the methods in BS EN 12372 : 2006 Annex A (normative) produced the following:

Lowest Expected Value (MPa)

Post-cycling Perpendicular - dry 16.2

Sandberg Reference	Visual observations post-20 cycles	Mean change in mass (%)	Mean change in dynamic elastic modulus (%)
G49537	No changes in visual appearance or material loss	0.00	0.25

3.8 Salt Crystallisation

Specimens were tested in accordance with BS EN 12370 : 1999.

The test comprised 15 no. cycles of immersion in a 14% solution of sodium sulphate and oven drying, and a final post cycling rinse in water to dissolve any salts away.

The detailed test results are given in Table 8 of this report and may be summarised as follows.

Sandberg Ref.	Weight Loss (15 cycles) %	
	Range	Mean
G45939	0.00 - 0.01	0.00

3.9 Breaking Load At Dowel Hole

Specimens were tested utilising a calibrated loading apparatus in accordance with the method in BS EN 13364 : 2002.

The dowels were tested with the load applied in a perpendicular to cleavage orientation (Type I) and in an oven dried condition.

Test specimens were drilled and had dowels installed by Sandberg.

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

The results are presented in Table 9 of this report and are summarised as follows.

Sandberg Reference	Orientation / condition	Breaking load at dowel hole (kN)	
		Range	Mean
G49538	Perpendicular (Type I), dry	3.30 - 7.76	4.80

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)

Perpendicular (Type I), dry 2.84

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.

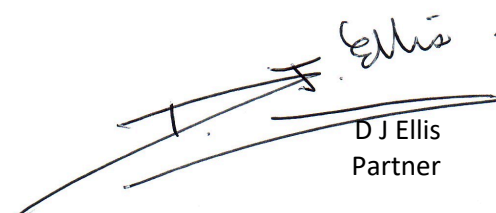
Carrig Conservation International Ltd.
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For the attention of Mr Peter Cox

DJE/Geoman/pd

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for Sandberg LLP

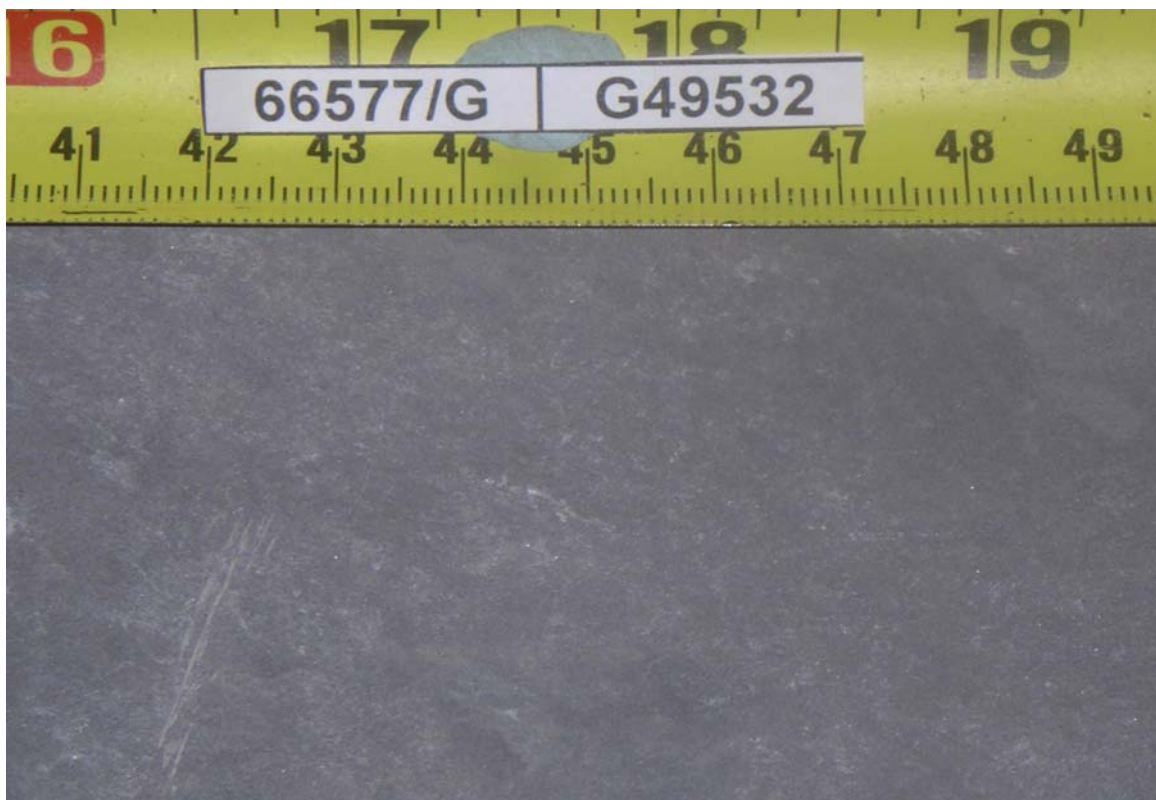

D J Ellis
Partner

20 March 2020

SAMPLE PHOTOGRAPHS



G49532: General view of a principal surface of Valentia sample.



G49532: Close-up of a principal surface of Valentia sample.

PETROGRAPHICAL EXAMINATION OF ROCK

BS EN ISO 14689:2018, BS 5930:2015, ISRM Method, BS EN 12407:2007, BS EN 12326-2:2011

SAMPLE DETAILS			
Sample Reference	G49532	Client Reference/Site Mark	-
Sample Type, Source and Sampling Location Details:	Valentia		
Condition on Receipt:	Dry	Sample Dimensions, mm:	200 x 200 x 40
Methods of Preparation of Specimens and Examination Procedures:	The sample was first subjected to macroscopical and low power stereomicroscopical examination supported by simple physical and chemical tests. A representative specimen from the sample was diamond-sawn and used to prepare a large area thin section which was examined under a Leica DM4500P high power petrological microscope employing magnifications up to x1000.		
Any Other Details:	A slice specimen was taken perpendicular to a principal surface and across the cleavage and the thickness of the sample. Thin section dimensions, mm: 67 x 40. Thin section completion date: 16 March 2020.		

MATERIAL DESCRIPTION:	Grey to bluish grey, mainly fine to occasionally medium grained, well to very well compacted SLATE, dense, generally hard to moderately hard and apparently robust (subjective assessment). The stone exhibited rough cleavage planes and well closed slaty cleavage. The cleavage was generally parallel to the principal surfaces of the sample and apparently discontinuous and generally irregularly spaced out in the millimetre scale. All the surfaces of the slab sample were smooth and diamond sawn.
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MATERIAL COMPOSITION:		PETROGRAPHICAL DETAILS ⁿ
COMPONENT	Volume % (estimated)	<p>The stone was a generally well to very well compacted slate comprising mainly mica, chlorite and quartz, which formed the background, and minor amounts of calcite, opaque grains and extremely fine carbonaceous dust. The stone was mainly fine grained (i.e. 10µm to 150µm across and up to 200µm long and most common size range below 50µm across).</p> <p>Occasionally discontinuous laminations and lenses, up to 200µm long and 100µm across, were rich in chlorite and some quartz, and exhibited overall coarser grain size (i.e. 100µm across) than the surrounding groundmass.</p> <p>Quartz, mica and chlorite were generally evenly distributed along cleavage planes. Opaque grains and possible carbonaceous dust were generally evenly distributed within the cleavage planes.</p> <p>Mica was mainly white muscovite, up to 200µm and commonly less than 100µm long, and were intermixed with chlorite and exhibited alignment along the cleavage planes. The mica trains were well packed and generally irregular, disconnected and separated. The cleavage was predominantly delineated by mica which was generally parallel to the cleavage and generally continuously aligned along the cleavage planes.</p> <p>Calcite fine to very fine (<30µm across) was unevenly distributed along the cleavage planes.</p> <p>Opaque irregular fine grains, up to 50µm and commonly less than 30µm across, were unevenly distributed along the mica layers. Extremely fine carbonaceous dust was also unevenly distributed, occasionally was concentrated along some cleavage planes.</p> <p>Cleavage planes were tightly compacted and were delineated by the parallel alignment of mica, chlorite and quartz.</p> <p>We would recommend X-ray diffraction analysis in order to identify the general composition and whether detectable pyrite is present.</p>
Quartz, Mica, Chlorite	Major	
Opakes & Calcite	Minor	
TOTAL:	100	
	0.2	

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Table/Sheet 1/3
Plate 1

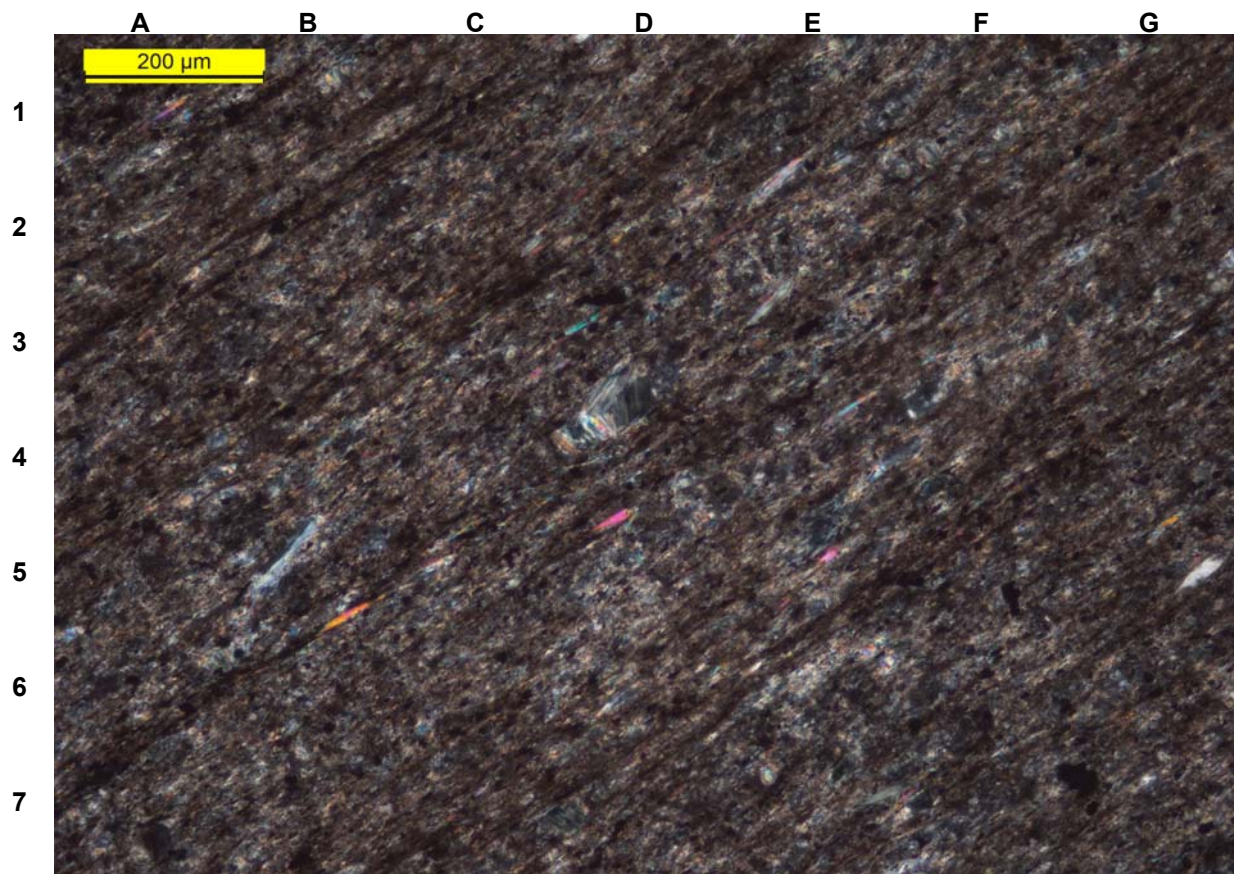
PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G49532 (perpendicular to cleavage)	Client Ref/Site Mark:	Valentia
Microscope Light:	Plane polarised	Objective Magnification:	x10
Photomicrograph Description			
<p>General view of stone structure under plane polarised light. The stone is generally fine grained. The background consists of quartz, mica layers which are orientated south west to north east and are also intermixed with calcite and chlorite (green, C-D/3-4). The black fine material is iron oxide and possibly some pyrite.</p>			

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Table/Sheet 1/4
Plate 2

PETROGRAPHICAL EXAMINATION OF STONE - PHOTOMICROGRAPH



Photomicrograph Details			
Sandberg Sample Ref:	G49532 (perpendicular to cleavage)	Client Ref/Site Mark:	Valentia
Microscope Light:	Cross polarised	Objective Magnification:	x10
Photomicrograph Description			
<p>General view of stone structure under cross polarised light. The stone is generally fine grained. The background consists of quartz, mica layers which are orientated south west to north east and are also intermixed with calcite and chlorite (green, C-D/3-4). The black fine material is iron oxide and possibly some pyrite.</p>			

APPARENT DENSITY AND OPEN POROSITY

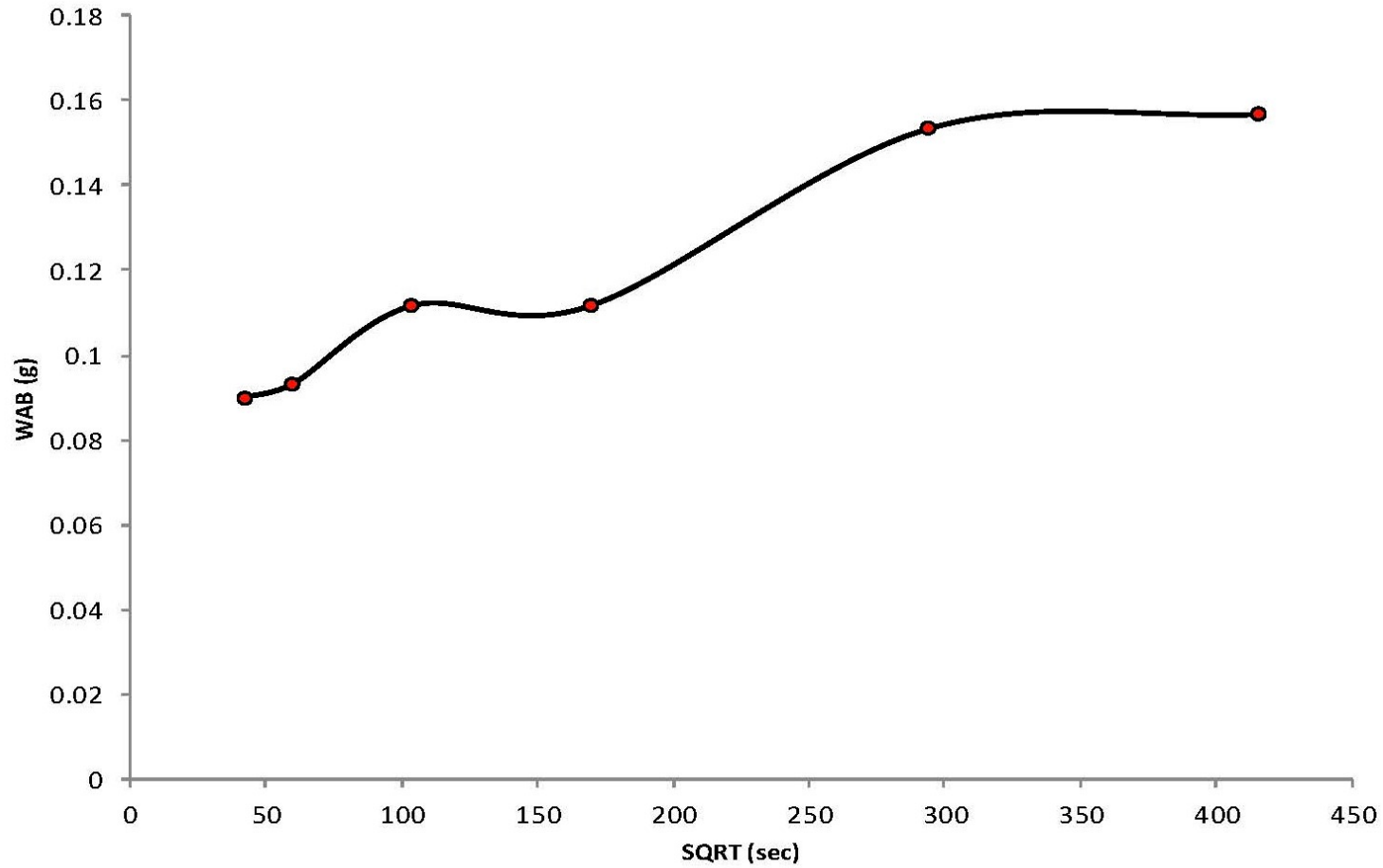
BS EN 1936 : 2006

Rock Name	Valentia			Test By/Date	MB/31-1-20	
Rock Type	Slate			Checked/Date	MMc/31-1-20	
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)
G49533 a	368.81	998	369.10	238.11	0.2	2810
G49533 b	370.03	998	370.27	238.63	0.2	2810
G49533 c	367.71	998	368.02	237.60	0.2	2810
G49533 d	368.38	998	368.60	236.63	0.2	2790
G49533 e	370.70	998	371.00	239.20	0.2	2810
G49533 f	368.96	998	369.27	237.93	0.2	2800
Mean					0.2	2810

WATER ABSORPTION AT ATMOSPHERIC PRESSURE

BS EN 13755 : 2008

Rock Name	Valentia	Test By / Date	MB/28-1-20
Rock Type	Slate	Checked / Date	MMc/28-1-20
Sandberg Sample Ref.	Oven Dried Mass (g)	Saturated Surface Dried Mass (g)	Water Absorption (%)
G49533 a	368.77	369.13	0.1
G49533 b	370.01	370.33	0.1
G49533 c	367.66	368.07	0.1
G49533 d	368.34	368.65	0.1
G49533 e	370.65	371.03	0.1
G49533 f	368.90	369.28	0.1
Average			0.1



G49534

Coefficient of water absorption by capillarity : $0.4 \text{ g/m}^2\text{s}^{0.5}$

DETERMINATION OF WATER ABSORPTION COEFFICIENT CAPILLARITY
BS EN 1925:1999

Table
4

Job No.
66577/G

FLEXURAL STRENGTH (UNDER CONCENTRATED LOAD)

BS EN 12372 : 2006

Load Orientation¹ : Perpendicular
Finish : Honed held in flexural tension
Test Condition : Oven dried

Rock Name	Valentia			Test By/Date	MB/3-2-20	
Rock Type	Slate			Checked/Date	CW/4-2-20	
Sandberg Sample Reference	Breaking Load (N)	Specimen Span (mm)	Specimen Width (mm)	Specimen Thickness (mm)	Flexural Strength (MPa)	Observations
G49535 a	11040	150	71.4	29.6	39.7	Normal Failure
G49535 b	11310	150	71.7	29.7	40.2	Normal Failure
G49535 c	8720	150	71.2	29.8	31.0 *	Normal Failure
G49535 d	25200	150	71.0	29.7	90.5	Normal Failure
G49535 e	10910	150	71.5	29.6	39.2	Normal Failure
G49535 f	13190	150	71.2	30.5	44.8	Normal Failure
G49535 g	11940	150	71.4	30.1	41.5	Normal Failure
G49535 h	21600	150	71.6	30.0	75.4	Normal Failure
G49535 j	14090	150	71.7	29.9	49.5	Normal Failure
G49535 k	13490	150	71.4	30.0	47.2	Normal Failure
Mean					49.9	
Std. Dev.					18.5	
Var. Coef.					0.4	

¹ With respect to bedding

* Failure along vein material

Lowest Expected Value (MPa) : 24.1

FLEXURAL STRENGTH (UNDER CONCENTRATED LOAD)

BS EN 12372 : 2006

After 56 Cycles of Freeze-Thaw to BS EN 12371 : 2010

Load Orientation¹ : Perpendicular

Finish : Honed held in flexural tension

Test Condition : Oven dried

Rock Name	Valentia			Test By/Date	MB/21-2-201	
Rock Type	Slate			Checked/Date	MMc/24-2-20	
Sandberg Sample Reference	Breaking Load (N)	Specimen Span (mm)	Specimen Width (mm)	Specimen Thickness (mm)	Flexural Strength (MPa)	Observations
G49536 a	18650	150	70.8	30.0	65.9	Normal Failure
G49536 b	19240	150	70.5	29.3	71.5	Normal Failure
G49536 c	19360	150	70.6	30.0	68.6	Normal Failure
G49536 d	18010	150	70.7	29.8	64.5	Normal Failure
G49536 e	20400	150	70.7	29.6	74.1	Normal Failure
G49536 f	18200	150	70.6	29.8	65.3	Normal Failure
G49536 g	19150	150	70.6	29.8	68.7	Normal Failure
G49536 h	22000	150	70.4	30.1	77.6	Normal Failure
G49536 j	15640	150	70.4	29.1	59.0	Normal Failure
G49536 k	15930	150	70.3	29.0	60.6	Normal Failure
Mean					67.6	
Std. Dev.					5.8	
Var. Coef.					0.1	

¹ With respect to bedding

Lowest Expected Value (MPa) : 56.3

Visual Code 0 - no cracks or loss of material

FLEXURAL STRENGTH (UNDER CONCENTRATED LOAD)

BS EN 12372 : 2006

Post-20 thermal cycles to BS EN 14066 : 2013

Load Orientation¹ : Perpendicular
Finish : Honed held in flexural tension
Test Condition : Oven dried

Rock Name	Valentia			Test By/Date	MB/10-3-20	
Rock Type	Slate			Checked/Date	MMc/10-3-20	
Sandberg Sample Reference	Breaking Load (N)	Specimen Span (mm)	Specimen Width (mm)	Specimen Thickness (mm)	Flexural Strength (MPa)	Observations
G49537 a	8870	150	71.4	30.3	30.4	Normal Failure
G49537 b	14880	150	71.4	30.4	50.7	Normal Failure
G49537 c	6830	150	71.1	29.8	24.3	Normal Failure
G49537 d	21700	150	71.1	29.9	76.8	Normal Failure
G49537 e	10890	150	71.4	29.5	39.4	Normal Failure
G49537 f	11100	150	71.3	29.5	40.3	Normal Failure
G49537 g	11110	150	70.9	29.9	39.4	Normal Failure
G49537 h	5840	150	71.1	29.7	21.0	Normal Failure
G49537 j	8150	150	71.3	29.8	29.0	Normal Failure
G49537 k	18020	150	71.6	29.8	63.8	Normal Failure
Mean					41.5	
Std. Dev.					17.7	
Var. Coef.					0.4	

¹ With respect to bedding

Lowest Expected Value (MPa) : 16.2

THERMAL SHOCK RESISTANCE

BS EN 14066 : 2013

Rock Name	Valentia			Test By/Date			HO/10-3-20	
Rock Type	Slate			Checked/Date			MB/10-3-20	
Sandberg Sample Ref.	Visual observations post 20 cycles	Initial mass (g)	Final mass (g)	Change in mass (%)	Initial dynamic elastic modulus (MPa)	Final dynamic elastic modulus (MPa)	Change in dynamic elastic modulus (%)	
G49537 a	No changes in visual appearance or material loss	1096.50	1096.50	0.00	22055.46	22015.72	0.18	
G49537 b	No changes in visual appearance or material loss	1105.00	1104.90	0.01	20649.90	20565.36	0.41	
G49537 c	No changes in visual appearance or material loss	1076.70	1076.70	0.00	20662.69	20585.70	0.37	
G49537 d	No changes in visual appearance or material loss	1083.30	1083.20	0.01	23212.97	23111.51	0.44	
G49537 e	No changes in visual appearance or material loss	1081.30	1081.30	0.00	22278.43	22278.43	0.00	
G49537 f	No changes in visual appearance or material loss	1069.50	1069.50	0.00	22028.33	21948.76	0.36	
G49537 g	No changes in visual appearance or material loss	1081.60	1081.60	0.00	22162.00	22127.91	0.15	
G49537 h	No changes in visual appearance or material loss	1072.70	1072.70	0.00	21792.56	21775.63	0.08	
G49537 j	No changes in visual appearance or material loss	1083.10	1083.10	0.00	22578.18	22514.84	0.28	
G49537 k	No changes in visual appearance or material loss	1085.20	1085.20	0.00	21837.91	21792.45	0.21	
Mean				0.00			0.25	

Bedding direction : Unknown

Surface finish : Sawn

RESISTANCE TO SALT CRYSTALLISATION

BS EN 12370:1999

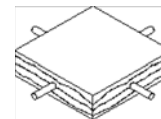
Rock Name	Valentia		Test by/Date	MB/17-2-20	Cycles Start	23-1-20
Rock Type	Slate		Checked/Date	MMc/17-2-20	Cycles End	12-2-20
Sandberg Sample Reference	Initial Oven Weight (g)	Final Oven Weight (g)	Weight Loss (15 Cycles) (g)	Weight Loss (15 Cycles) (%)		
G49539 a	189.43	189.43	0.00	0.00		
G49539 b	187.44	187.44	0.00	0.00		
G49539 c	188.13	188.13	0.00	0.00		
G49539 d	187.48	187.48	0.00	0.00		
G49539 e	189.89	189.87	0.02	0.01		
G49539 f	188.75	188.73	0.02	0.01		
Average				0.00		

PHOTOGRAPH OF SPECIMENS ON COMPLETION OF TEST



DETERMINATION OF BREAKING LOAD AT DOWEL HOLE

BS EN 13364 : 2002



Fixing Type : Dowel (6mm dia.) in standard cement, drilled and installed by Sandberg
Fixing Location : Centre of edge
Load Orientation : Perpendicular (Type I)
Finish : Natural
Test Condition : Oven dried

Rock Name	Valentia			Tested By/Date	MB/24-1-20
Rock Type	Slate			Checked By/Date	MMc/27-1-20
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
G49538 a	Negative	5.27	103.14	15.35	Failure across whole width of sample along the cleavage
G49538 b	Negative	4.91	101.43	15.09	Failure across whole width of sample along the cleavage
G49538 c	Negative	3.84	102.33	12.19	Failure across whole width of sample along the cleavage
G49538 d	Negative	3.34	99.31	11.80	Failure across whole width of sample along the cleavage
G49538 e	Negative	5.99	100.20	14.60	Failure across whole width of sample along the cleavage
G49538 f	Negative	6.25	100.87	15.87	Failure across whole width of sample along the cleavage
G49538 g	Negative	4.30	99.23	15.30	Failure across whole width of sample along the cleavage
G49538 h	Negative	7.76	102.32	14.08	Failure across whole width of sample along the cleavage
G49538 j	Negative	3.30	51.69	11.73	Normal half cone failure
G49538 k	Negative	6.03	100.22	13.86	Failure across whole width of sample along the cleavage
Mean		4.80			
Std. Dev.		1.10			
Var. Coef.		0.23			

¹ Relative to natural cleavage face

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Where test results are given, the results and our conclusions relate only to the samples tested and apply to the sample(s) as received, except where sampling has been conducted by Sandberg LLP.

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 accredited schedule for this laboratory.

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

End of report.

