

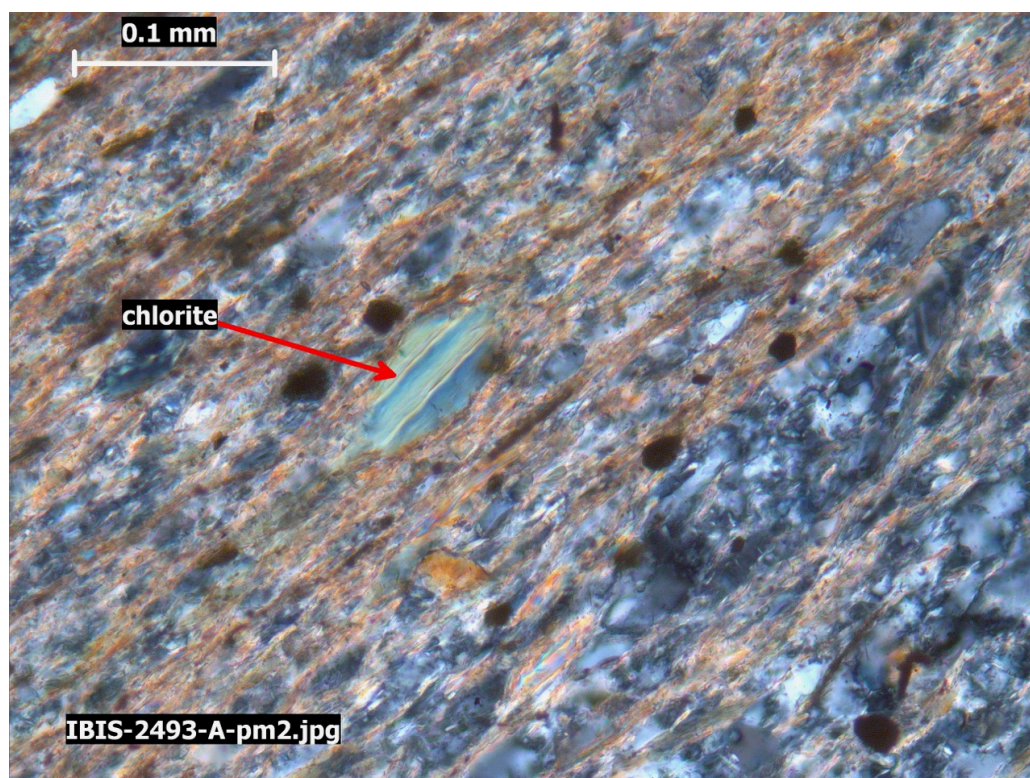
Hilltop Natural Roofing Slate EN 12326 Testing

Report commissioned by
Yates & Co. Ltd
Unit 10b
Salthill Industrial Estate
Lincoln Way
Clitheroe
Lancashire
BB7 1QD

IBIS Report 2493-A, March 2017

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Hilltop Natural Roofing Slate EN 12326 Testing

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IBIS Report 2493-A, March 2017

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For IBIS Limited

Barry J Hunt
BSc MSc MASI MCIQB CGeol EurGeol FGS CSci MRICS FRMS
Director

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Hilltop Natural Roofing Slate

EN 12326 Testing

Executive Summary

Advised Hilltop natural roofing slate has been subjected to the test requirements of the current applicable European Standard. The findings have then been employed to classify the slate, providing an indication of likely performance.

The Hilltop natural roofing slate was confirmed to be true slate in that it comprised very finely crystalline metamorphic rock exhibiting a slaty cleavage. The various tests determined the following information:

- Dimensional requirements all within acceptable tolerances.
- Good flexural strength both transversely and longitudinally.
- No evidence of a grain or secondary splitting plane.
- Exhibited the top Class W1 (≤ 0.6) for water absorption.
- Freeze-thaw cycling not required to be carried out.
- Exhibited the top Class T1 for thermal cycle resistance.
- Exhibited the top Class S1 for sulfur dioxide exposure resistance.
- No requirement for thickness adjustment.
- Acceptable non-carbonate carbon content.
- Unlikely to release dangerous substances in normal use.
- Satisfactory external fire performance.
- Exhibited the top Class A1 for reaction to fire.

Based on the various test results the advised Hilltop natural roofing slate is considered by the European Standard to be suitable for use in traditional slate roofing construction. This assumes the average thickness is greater than the determined minimum thickness for the country within which the Hilltop slate is being deployed.

The European Standard does not provide advice on the life expectancy based on performance in the tests.

The petrographic examination supported by x-ray diffraction analysis did not identify any specific minerals or features that suggest problems could be experienced that would significantly reduce life expectancy.



Hilltop Natural Roofing Slate EN 12326 Testing

1 INTRODUCTION

At the request of the Client, IBIS has conducted an investigation in to the properties of advised Hilltop natural roofing slate. A set of 50 roofing slates were sampled by the Client from their current stock; the details of the samples are provided in **Table 1.1** below. Testing was carried out in accordance with the current British and European Standard. The schedule of the testing is also included in Table 1.1.

This report describes the investigation carried out and then provides and discusses the findings. Conclusions are then provided concerning use of the slate for roofing purposes along with any salient recommendations for further investigation. A number of standard remarks conclude the report.

Table 1.1: Schedule of Samples and Testing

Sample Details	IBIS Reference	Test Carried Out
Advised 'Hilltop' natural roofing slate with nominal dimensions of 508 mm x 254 mm x 6-10 mm	1	Dimensional Properties
	2-21	Flexural Strength
	22-26	Water Absorption
	27-29	Carbonate and Non-carbonate Carbon Contents
	30-35	Sulfur Dioxide Exposure
	36-41	Thermal Cycle Resistance
	42	Petrographic Examination
	43	X-ray Diffraction
	44-50	Spare



2 INVESTIGATION METHODS AND RESULTS

2.1 Introduction

The advised Hilltop natural roofing slate was subjected to testing following the methods given in EN 12326-2:2011¹. Each of the separate facets of the Standard are described in the following sub-sections.

The detailed methods and results for each test are provided in **Appendix A** whilst a summary of the findings is provided in **Section 3** of this report.

In **Section 4** of this report the pass/fail criteria given in EN 12326-1:2014² are provided and the level of compliance with them is indicated.

2.2 Dimensional Properties

A single slate was selected at random and subjected to testing to determine the deviations from its assigned length and width, edge straightness, rectangularity and flatness. The thickness and deviation of this thickness were also determined.

The detailed dimensional properties results are provided in Appendix A as Certificate of Testing & Analysis No. 5090-2493.

2.3 Three Point Flexural Strength

A set of 20 slates was randomly selected for three point flexural strength testing. Each slate was sufficiently large to allow the preparation of two test specimens of nominal 200 mm by 125 mm size, one parallel the other perpendicular to the long dimension.

Each slate from the two sets of 20 test specimens was rapidly loaded via an upper bar centrally located between two lower bars set 180mm apart. The applied load was increased at a rate of 1.00 ± 0.25 MPa/s until failure occurred and the maximum load achieved was recorded. The thickness of each test specimen was recorded at three locations and the average value used to calculate the flexural strength. The characteristic modulus of rupture was determined by applying environmental factors given in the Standard for the UK environment.

The detailed three point flexural strength results are provided in Appendix A as Certificate of Testing & Analysis No. 5091-2493.

2.4 Water Absorption

A set of five slates was randomly selected for the determination of water absorption. From each slate a nominal 100 mm square test specimen was prepared. Each test specimen was first dried to constant mass and then immersed in water for 48 hours. The increase in mass due to absorbed moisture was used to calculate the water absorption.

The thickness of the five test specimens was determined at four locations and the results averaged to provide the basic individual thickness value.

The detailed water absorption results are provided in Appendix A as Certificate of Testing & Analysis No. 5092-2493.

¹ EN 12326-2:2011, Slate and stone for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate. Published by the British Standards Institution (BSI), London, England.

² BS EN 12326-1:2014, Slate and stone for discontinuous roofing and external cladding – Part 1: Specifications for slate and carbonate slate. Published by the British Standards Institution, London, England.



2.5 Freeze-Thaw Resistance

This test is only carried out if the results of the water absorption test determine the slate to have an absorption of $> 0.6\%$. In this instance the slate was Class W1 (≤ 0.6) and thus the test was not required.

2.6 Carbonate and Non-Carbonate Carbon Content

A set of three slates was randomly selected for the determination of the carbonate and non-carbonate carbon contents. A representative portion was removed from each slate and then ground to a fine powder for chemical analysis. A direct estimation of carbon content was made by the LECO method.

The detailed carbonate and non-carbonate carbon content results are provided in Appendix A as Certificate of Testing & Analysis No. 5093-2493.

2.7 Sulfur Dioxide Exposure Resistance

A set of six slates was randomly selected to determine their resistance when exposed to sulfur dioxide vapour. The test method was determined by the content of calcium carbonate, which in this case was less than 20 %.

From each slate a pair of test specimens with nominal dimensions of 150 mm by 100 mm was prepared and any defects visible to the unaided eye were removed. The two sets of six test specimens were each sealed for 21 days inside separate containers that each contained a tray with a different solution of sulfuric acid.

The detailed sulphur dioxide exposure resistance results are provided in Appendix A as Certificate of Testing & Analysis No. 5094-2493.

2.8 Thermal Cycle Resistance

A set of six slates was randomly selected to determine their resistance when exposed to cyclic wetting and drying. A test specimen with nominal dimensions of 300 mm by 200 mm was prepared from each slate and any defects visible using a low power magnifying or hand lens were removed.

The six test specimens were repeatedly immersed in water for six hours and then dried at 110 °C for 17 hours. Before placing back into the water the samples were allowed to cool for one hour. A total of 21 cycles of wetting and drying were carried out. After each cycle the specimens were inspected for evidence of deterioration, this repeated using a hand lens after every fifth cycle.

The detailed thermal cycle resistance results are provided in Appendix A as Certificate of Testing & Analysis No. 5095-2493.

2.9 Petrographic Examination

A visual and low-power microscopic examination was carried out assisted by a Leica MZ16 binocular zoom microscope employing magnifications up to x160. This examination was supported by a variety of simple physical and chemical tests. The examination was used to select specimens for the preparation of thin-sections for high-power microscopical examination. The thin-sections were prepared after impregnation with an epoxy resin containing an ultraviolet light sensitive fluorescent dye.

High-power microscopical examination was carried out using both the polarising binocular zoom function of the Leica MZ16 microscope and also a Leica DM RXP petrological microscope at different magnifications up to x3000. The thin-sections were examined in both transmitted plain and cross-polarised



light and reflected ultraviolet light. High-power photomicrographs (photographs taken down the microscope) were prepared to illustrate microscopical features of importance.

The detailed petrographic examination results are provided in Appendix A as Certificate of Examination No. 5096-2493.

2.10 X-ray Diffraction (XRD) Analysis

A representative specimen taken from a sample of the natural roofing slate was subjected to qualitative XRD analysis to help confirm the principal minerals present and provide a very basic semi-quantitative assessment.

A portion of the sample was ground to a powder in a McCrone micronising mill with the addition of acetone to minimise structural damage to the minerals present. The resulting sample was dried and lightly ground so that the powder could be side-packed into a XRD powder holder and scanned at a rate of 5 seconds per 0.02° step width, using 0.3 mm slits from 5 to $70^\circ 2\theta$.

The detailed XRD analysis results are provided in Appendix A as Certificate of Testing & Analysis No. 5097-2493.



3 SUMMARY OF FINDINGS

Table 3.1: Summary of EN 12326 Test Results

Slate Type	Hilltop
IBIS Reference	2493-A / 1-50
Commercial Definition	Slate
Source	Hilltop from Wells Quarry, Vermont, USA
Nominal Size, mm	508 x 254
Nominal Thickness, mm	6-10
Slate Finish Type	Normal
Test Description	Result
Basic Individual Thickness, mm	4.3
Deviation from Length / Width, %	0.1 / 0.4
Deviation from Edge Straightness, %	0.3 / 0.2
Deviation from Rectangularity, %	0.4
Deviation from Flatness, %	0.6
Defects	None observed
Mean MoR, MPa, Longitudinal	54
Mean Thickness, mm	7.7
Standard Deviation, Longitudinal	11.5
Characteristic MoR, MPa, Longitudinal	34
Mean MoR, MPa, Transverse	44
Mean Thickness, mm	7.7
Standard Deviation, Transverse	8.8
Characteristic MoR, MPa, Transverse	29
Grain Direction	None indicated
Water Absorption, %	0.3
Freeze-Thaw Resistance	Not required
Thermal Cycle Results	No changes
Carbonate Carbon Content, %	0.1
Carbonate Content, %	0.8
Sulfur Dioxide Exposure Results	No changes
Non-Carbonate Carbon Content, %	0.1



4 SUMMARY OF PERFORMANCE

Table 4.1: Performance Based on Requirements of EN 12326

Slate Type	Hilltop
IBIS Reference	2493-A / 1-50
Commercial Definition	Slate
Source	Hilltop from Wells Quarry, Vermont, USA
Nominal Size, mm	508 x 254
Nominal Thickness, mm	6-10
Slate Finish Type	Normal
Criteria	Performance
Individual Thickness of Slates shall not be less than 2.0 mm	Pass
Manufacturers Declared Nominal Thickness, mm	6-10
Minimum Individual Thickness, mm	4.3 (UK)
Individual Thickness within ± 35 % of Nominal Thickness	Pass
Slates not to Deviate by more than 5 mm from Declared Length/Width	Pass
Edge Straightness Deviation shall not exceed 5 mm	Pass
Edge Straightness Deviation shall not exceed 1 % of the length	Pass
Rectangularity shall not deviate by more than ± 1 % of the length	Pass
Flatness shall not deviate by more than 1.5 %	Pass
Absorption Class	W1 (≤ 0.6)
Declared Characteristic Modulus of Rupture, MPa	29
Thermal Cycle Class	T1
Carbonate Content, %	< 5
Sulfur Dioxide Exposure Class	S1
Thickness Adjustment	None
Non-Carbonate Carbon Content < 2 %	Pass
Release of Dangerous Substances	None in normal use
External Fire Performance	Deemed to satisfy
Reaction to Fire	Class A1



5 DISCUSSION OF FINDINGS

5.1 Classification

The Hilltop natural roofing slate was confirmed to be true slate in accordance with EN 12326 in that it comprised extremely finely crystalline metamorphic rock that exhibited a well developed slaty cleavage. The mineral components included chiefly chlorite, white micas (illite/muscovite), quartz and feldspar with minor carbonates (calcite and siderite) and pyrite, and traces of rutile and graphite.

The phyllosilicate minerals (chlorite and micas) exhibited a preferred orientation sub-parallel to the cleavage. The micas were perfectly connected to one another and the layers of micas were continuous, oblique to the cleavage and tied together. Relict bedding laminations were visible at an angle of approximately 20° to the cleavage plane.

5.2 Fitness for Purpose

The slate passed the various physical, chemical and dimensional criteria given in EN 12326, achieving the top classifications for water absorption, thermal cycling and acid resistance. In accordance with the standard it is considered that the slate is acceptable for roofing purposes.

The petrographic examination did not identify any obvious features suggesting that the slate could suffer premature failure. Specifically, the opaque material was not found to exhibit any signs of oxidation such as the release of coloured oxide and hydroxide compounds.

The flexural strength results are used to determine the minimum thickness of slate required. The thickness determined is then increased based on the results of the various carbonate determinations and acid exposure test results. In this instance no increase in the determined minimum thickness was found to be necessary.

Table 5.1 below provides a summary of the calculations of minimum thickness for the different countries that so far have declared national values for a constant that is applied to the thickness result based on local climate conditions and traditional construction techniques. The calculations have been made for a nominal 508 mm by 254 mm slate and include any adjustment required based on the sulfur dioxide exposure test.

Table 5.1: Minimum Slate Thickness Based on National Factors for a Nominal 508 mm by 254 mm Slate

Country	National Factors		Minimum Thickness, mm		SO ₂ Adjust.
	Transverse	Longitudinal	Transverse	Longitudinal	
Belgium	1.35	1.35	4.00	5.22	None
Czech R.	1.2	1.2	3.55	4.64	None
France	1.25	1.4	3.70	5.41	None
Germany	1.2	1.2	3.55	4.64	None
Ireland	0.9	1.1	2.66	4.25	None
Italy	1.2	1.2	3.55	4.64	None
Spain	1.2	1.2	3.55	4.64	None
UK	0.9	1.1	2.66	4.25	None

The actual calculated minimum thickness value is taken to be the higher of the two values determined for each country, plus any adjustment. Therefore, when



used in the UK, the Hilltop natural roofing slate should have a minimum thickness of 4.3 mm, whilst in France this should be increased to 5.4 mm. Calculated minimum thickness values for differently sized slates advised to be used within the UK are given in **Table 5.2**; this includes both metric and imperial sizes.

Table 5.2: Minimum Slate Thickness for Differently Sized Slates Using the United Kingdom National factor

Length	Width	Transverse	Longitudinal	SO ₂ Adjustment
457	254	2.66	4.03	None
406	254	2.66	3.80	None
356	254	2.66	3.56	None
305	254	2.66	3.29	None
406	203	2.38	3.80	None
356	203	2.38	3.56	None
305	203	2.38	3.29	None
254	203	2.38	3.01	None

Note: all values are in millimetres

From Table 5.2 it is apparent that the minimum thickness requirement for the slate reduces for smaller sizes of slate.

EN 12326 does not provide guidance concerning the potential service life of the slate.

5.3 Recommendations

The packed thickness of slate should be determined for every crate or pallet. This should be undertaken before the slates are removed.

The investigation of bending strength, grain orientation, water absorption, thermal cycle resistance, carbonate content, sulfur dioxide exposure resistance, carbon content and petrography must be carried out at least once a year or every 25,000 tonnes of finished product, whichever is the sooner.

Where different geological horizons or veins are worked, the frequency of testing should be applied to each situation.

The investigation of thickness of the product should be set on the basis of the test results, primarily to avoid supplying materials below the minimum individual thickness requirement

The deviation from the declared length, width, rectangularity, flatness and edge straightness, and the individual thickness should be carried out more regularly with an acceptable quality level of 4% using the sampling schemes described in ISO 2859-1:1999³, Clause 10, using inspection level S-3.

³

ISO 2859-1:1999. Sampling procedures for inspection by attributes. Part 1 - Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection. Published by the BSI, London, England.



6 REMARKS

An assessment has been carried out to determine the properties of advised Hilltop natural roofing slate. The slate was confirmed to be true slate and passed the various physical, chemical and dimensional criteria given in EN 12326, achieving the top classifications for water absorption, thermal cycling and acid resistance. In accordance with the standard it is considered that the slate is acceptable for roofing purposes when compliant with the determined minimum thickness requirements.

EN 12326 does not provide guidance concerning the potential service life of the slate.

These remarks conclude the work so far requested and should be taken as being applicable only to materials properly represented by the samples supplied. Natural roofing slate resources may be expected to exhibit both lateral and vertical variations in composition and properties and single or small samples may not necessarily be reliably representative of a resource or even specific locations within that resource.

To maintain compliance, EN 12326 recommends testing is repeated at regular intervals based on either time or volume of material produced.

Any samples taken for laboratory investigation will be retained for a period of one month from the date of this report. After this time the samples will be disposed of unless otherwise instructed. On request the samples may be either returned or stored, either action incurring a small administration charge.

If you require any further assistance with this or any other matter please do not hesitate to contact IBIS.



Hilltop Natural Roofing Slate EN 12326 Testing

Appendix A EN 12326 Test Results

Contents

Certificate No. 5090-2493: Determination of Dimensional Properties
Certificate No. 5091-2493: Determination of 3-Point Flexural Strength
Certificate No. 5092-2493: Water Absorption of Roofing Slate
Certificate No. 5093-2493: Carbonate and Non-carbonate Carbon Contents
Certificate No. 5094-2493: Sulfur Dioxide Exposure Test
Certificate No. 5095-2493: Thermal Cycle Test
Certificate No. 5096-2493: Petrographic Examination of Natural Roofing Slate
Certificate No. 5097-2493: XRD Analysis of Natural Roofing Slate



Certificate of Testing & Analysis

Determination of Dimensional Properties

BS EN 12326-2:2011

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Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	1
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	BJH-IBIS	Date Tested	19.12.16

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stocks.
Accreditation	All equipment employed was traceable to National standards and within calibration.

Results	
The detailed test results are provided in Page 2 of this certificate of testing and analysis. Below the pass/fail criteria have been applied based on the results.	
Minimum Individual Thickness of Slates shall not be less than 2.0 mm	Pass
Manufacturers Declared Nominal Thickness, mm	6 – 10
Individual Thickness within ± 35 % of Nominal Thickness	Pass
Slates not to Deviate by more than 5 mm from Declared Length/Width	Pass
Edge Straightness Deviation shall not exceed 5 mm	Pass
Edge Straightness Deviation shall not exceed 1 % of the length	Pass
Rectangularity shall not deviate by more than ± 1 % of their length	Pass
Manufacturers declared slate finish type	Normal
Flatness shall not deviate by more than 1.5 %	Pass

Remarks

The slate samples tested passed all the dimensional requirements. Slate is a natural product and is expected to vary in consistency and properties. Therefore it is recommended that testing is carried out in accordance with the frequencies suggested by Table 6 of BS EN 12326-1:2014.

Issue Date: 01.03.17

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Director, IBIS Limited

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Certificate of Testing & Analysis
Determination of Dimensional Properties
BS EN 12326-2:2011

Results			
Determination of Length, Width and Deviation			
Length, mm	508.5	Width, mm	255
Length Deviation, %	0.1	Width Deviation, %	0.4
Determination of Edge Deviation from a Straight Edge			
Edge Deviation 1, mm	1.5	Edge Deviation 2, mm	1.0
Edge Deviation 1, %	0.3	Edge Deviation 2, %	0.2
Determination of Rectangularity			
Corner 1 Deviation, mm	0.5	Corner 2 Deviation, mm	1.0
Corner 3 Deviation, mm	2.0	Corner 4 Deviation, mm	1.0
Maximum Deviation from a Rectangle, %			0.4
Determination of Thickness of Individual Slates			
Location 1 Depth, mm	7.35	Location 2 Depth, mm	8.02
Location 3 Depth, mm	7.56	Location 4 Depth, mm	7.16
Mean Thickness, mm	7.52	Maximum Deviation, %	6.65
Determination of the Deviation from Flatness			
Thickness 1, mm	8.33	Thickness 2, mm	8.61
Thickness 3, mm	8.27	Mean Value A, mm	8.40
Thickness 4, mm	10.68	Thickness 5, mm	11.42
Thickness 6, mm	11.59	Mean Value B, mm	11.23
Flatness Deviation, mm	2.83	Flatness Deviation, %	0.56

Certificate of Testing & Analysis

Determination of 3-Point Flexural Strength

BS EN 12326-2:2011

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Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	2-21
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	PS / TTRL	Date Tested	8-19.12.16

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stock. The loading rate was 1.0 MPa/s $\pm$ 0.1 MPa.
Accreditation	The test was carried out by a UKAS accredited laboratory that holds specific accreditation for the test.

Results	
Mean Thickness, mm	7.7
Transverse Orientation	
Mean Thickness, mm	7.7
Mean Modulus of Rupture, MPa	44
Standard Deviation, MPa	8.81
Characteristic Modulus of Rupture, MPa	29
Longitudinal Orientation	
Mean Thickness, mm	7.7
Mean Modulus of Rupture, MPa	54
Standard Deviation, MPa	11.49
Characteristic Modulus of Rupture, MPa	34

Remarks

BS EN 12326-1:2014 includes a calculation of the minimum individual thickness of slate based on the characteristic modulus of rupture and mean thickness. On the basis of the test values obtained and using the UK national factors, the minimum individual thickness was calculated to be 4.25 mm.

Issue Date: 01.03.17

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Certificate of Testing & Analysis

Water Absorption of Roofing Slate

BS EN 12326-2:2011

Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	22-26
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	PS-TTRL	Date Tested	12-22.12.16

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stock.
Accreditation	The test was carried out by a UKAS accredited laboratory that holds specific accreditation for the test.

Results	
Thickness, mm	5.6, 8.4, 8.9, 7.1, 7.4
Mean Thickness, mm	7.5
Absorption, %	0.31, 0.27, 0.26, 0.28, 0.33
Mean Absorption, %	0.29
Classification	W1 (≤ 0.6)

Remarks

BS EN 12326-1:2014 classifies the slate as W1 (≤ 0.6), which is considered acceptable, and means that frost testing is not required.

Issue Date: 01.03.17



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Certificate of Testing & Analysis

Carbonate and Non-carbonate Carbon Contents

BS EN 12326-2:2011

Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	27-29
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	FE / QED	Date Tested	13.12.16-11.01.17

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stock. Analyses carried out in triplicate and a direct estimation of carbon was made using the LECO method.
Accreditation	The test was carried out by a UKAS accredited laboratory.

Results	
Carbonate Carbon Content, %	0.13, 0.03, 0.11
Mean Carbonate Carbon Content, %	0.09
Determined Calcium Carbonate Content, %	0.75
Non-carbonate Carbon Content, %	0.05, 0.04, 0.05
Mean Non-carbonate Carbon Content, %	0.05
Non-carbonate Carbon Content Classification (≤ 2.0 %)	Pass

Remarks

BS EN 12326-1:2014 classifies that the slate, when subjected to the sulphur dioxide exposure test, should be tested to one of the methods described in Section 14.

Issue Date: 01.03.17

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Certificate of Testing & Analysis

Sulfur Dioxide Exposure Test

BS EN 12326-2:2011

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Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	30-35
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	PS-TTRL	Date Tested	19.12.16-20.01.17

Methods of Testing and Analysis	
Carbonate, %	< 20% (as determined by Section 14 of the Standard)
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stock.
Accreditation	The test was carried out by a UKAS accredited laboratory that holds specific accreditation for the test.

Results	
Splitting or cracking of the edges	None observed
Swelling, softening or flaking of the surface	None observed
Colour changes	None observed
Classification (Test Code)	S1

Remarks

BS EN 12326-1:2014 classifies that the slate as Test Code S1, when subjected to the sulphur dioxide exposure test. Therefore, the slate is considered acceptable for use in all conditions.

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Certificate of Testing & Analysis

Thermal Cycle Test

BS EN 12326-2:2011

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Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	36-41
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	PS-TTRL	Date Tested	12.12.16-17.01.17

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate.
Comments	Samples for test taken from a batch of 50 sampled by the Client from their current stock.
Accreditation	The test was carried out by a UKAS accredited laboratory that holds specific accreditation for the test.

Results	
Splitting or cracking of the edges	None observed
Swelling, flaking or exfoliation of the surface	None observed
Colour changes	None observed
Classification (Test Code)	T1

Remarks

BS EN 12326-1:2014 classifies that the slate as Test Code T1, when subjected to the thermal cycle test. Therefore, the slate is considered acceptable for use in all conditions.

Issue Date: 01.03.17

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Certificate of Examination

Petrographic Examination of Natural Roofing Slate

BS EN 12326-2:2011

Client and Sample Details

Client	Yates and Co. Ltd
IBIS Sample No	2493-A
Client Sample No	S42
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate
Sampled by / Date	Client / Not advised
Condition / Date Received	Dry / 06.12.16
Examined by / Date	BJH / 06.12.16-02.02.17

Methods of Examination and Results

The detailed methods of examination, including guidance for some of the terms used in the description, are given in Page 6 of this Certificate of Examination. The detailed petrographic examination results are given in Page 2 with a summary given below. Some photomicrographs illustrating features of importance are given in Pages 3 to 5.

Summary Overview

BS EN 12326 Classification	Slate
BS EN 12440 Denomination	Not applicable
Major Minerals	Illite/muscovite, quartz, chlorite, plagioclase feldspar
Minor Minerals	Pyrite, carbonates, rutile, graphite
Potentially Deleterious Materials	Pyrite No evidence of any material reactions
Phyllosilicate Connection	Perfectly connected to others
Bedding and Cleavage	At an angle to each other, approximately 20°
Phyllosilicate Spacing	Continuous
Phyllosilicate layers	Oblique to the cleavage and tied together
Other Textural Features	Relict microstructures associated with opaque materials
Other Details	Carbonates included siderite and calcite A trace of tourmaline identified

Issue Date: 01.03.17

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Petrographic Examination of Natural Roofing Slate

BS EN 12326-2:2011

A full description of the examination methods is given in Page 6

Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	S42
Thin-Section Details	Orthogonal set of slices prepared.		

Material Description <i>(incl. strength, weathering, crystal/ grain size, structure, alteration, name, secondary structure)</i>	Very strong, fresh, green, very finely crystalline SLATE exhibiting a tight, very closely spaced, slightly wavy, slaty cleavage. Pyrite inclusions were present.
---	--

Material Component	Point Count ¹	Volume %	Crystal/Grain Size	Origin ²
Chlorite	Not Determined	35	1 µm – 150 µm	Primary
Quartz	Not Determined	30	2 µm – 60 µm	Primary
Illite/Muscovite	Not Determined	15	1 µm – 15 µm	Primary
Feldspar	Not Determined	15	5 µm – 60 µm	Primary
Carbonates	Not Determined	4	2 µm – 100 µm	Primary
Pyrite	Not Determined	1	10 µm – 200 µm	Primary
Rutile	Not Determined	Trace	< 1 µm	Primary
Graphite	Not Determined	Trace	< 1 µm	Primary

1 Point count normally only carried out when requested.

2 Primary - originally part of the rock/stone; Secondary - an alteration/weathering product.

Material Component	Petrographic Details ³
Chlorite	Discretely present amongst the rock fabric but most noticeable in small lenses scattered throughout the rock fabric.
Quartz	Mostly discretely present within the rock fabric forming the cement but also noticeable as larger crystal concentrations reflecting former sedimentary bedding variations.
Illite/Muscovite	Flaky crystals of white mica forming the bulk of the rock fabric. The X-ray diffraction found that this comprised illite and/or muscovite, which are difficult to distinguish because there is a transitional series between these two minerals.
Feldspar	The XRD identified mostly plagioclase but also some alkali feldspar to be present. Only obvious plagioclase fragments were observed due to the presence of multiple twinning.
Carbonates	Scattered crystal grains visible throughout the rock fabric and sometimes more concentrated within some of the quartz-rich former sedimentary structures. The XRD identified siderite as a minor mineral, though this was not observed as obvious crystals in thin-section.
Pyrite	Opaque particles scattered throughout the rock fabric but sometimes gathered in to large concentrations or agglomerations. There was no evidence of reaction effects.
Rutile	Very fine needles of titanium oxide with high birefringence scattered throughout the rock fabric with random orientation. There were visible variations in concentration.
Graphite	Extremely fine opaque matter of variable concentration visible throughout the rock fabric. This appeared to be associated with relict structures of unknown type.
Other Details	The minerals exhibited a preferred orientation parallel to the cleavage, which was slaty but not perfectly planar because of various features interrupting it. The phyllosilicates were perfectly connected to one another. The bedding and cleavage intersected at an angle and the phyllosilicates parallel to the cleavage were continuous, whilst the phyllosilicate layers were oblique to the cleavage and tied together. The number of mica layers per millimetre was measured to be 100. A trace of tourmaline was identified.

3 Details mainly relate to components or features of possible engineering significance.

Petrographic Examination of Natural Roofing Slate

BS EN 12326-2:2011

A full description of the examination methods is given in Page 6

Photographs and Photomicrographs

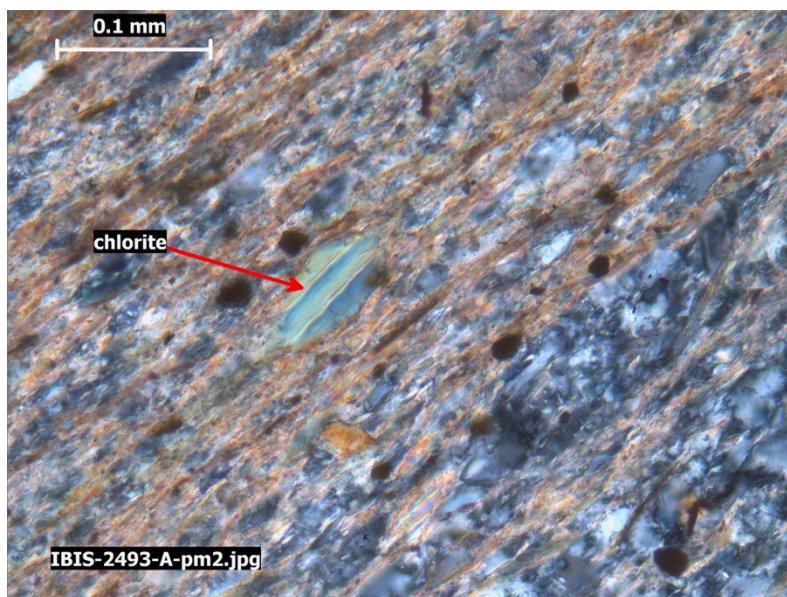


Photomicrograph 1

The cleavage plane runs left-right in this view. The light coloured feature is rich in quartz and other minerals and likely reflects former bedding structures, these at an angle of around 20°.

Opaque material has concentrated along the cleavage plane, which thus must have developed as part of the slate formation process.

Plane Polarised Light



Photomicrograph 2

Typical view of the slate fabric with the cleavage running from bottom left to top right and the phyllosilicates oriented sub-parallel to this.

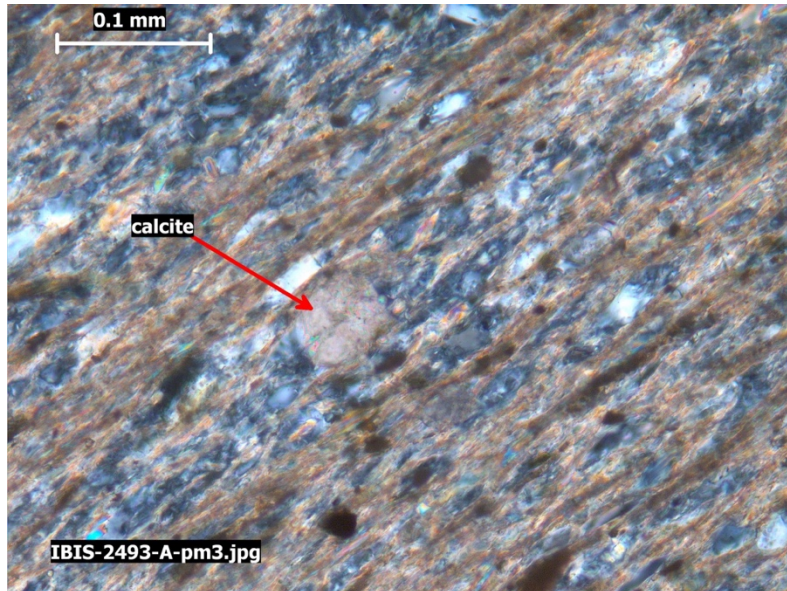
A small lense of chlorite has been indicated, these relatively infrequent. Most chlorite was mixed with the darker materials visible here that otherwise comprised finely divided quartz.

Plane Cross Polarised Light

Petrographic Examination of Natural Roofing Slate BS EN 12326-2:2011

A full description of the examination methods is given in Page 6

Photographs and Photomicrographs

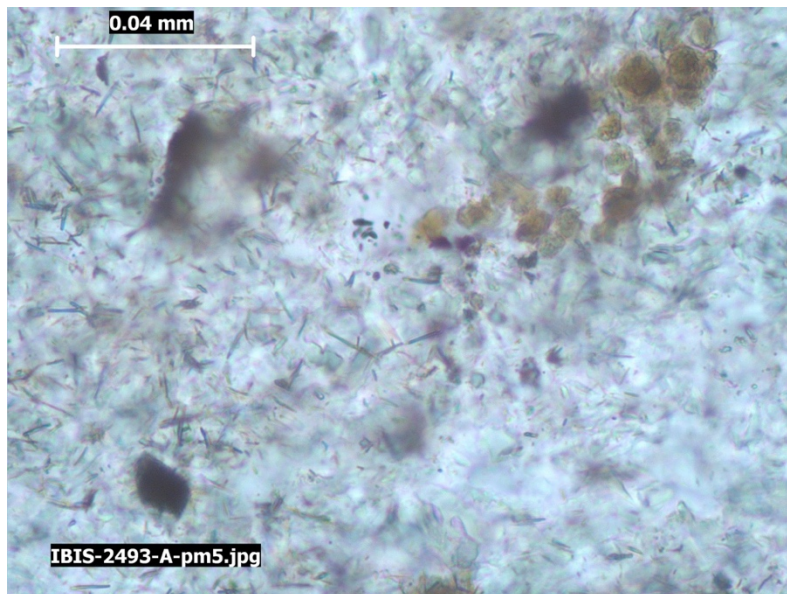


Photomicrograph 3

Another typical view of the slate fabric with the cleavage running from bottom left to top right and the phyllosilicates oriented sub-parallel to this.

A small and relatively rare larger crystal of calcite has been indicated, this not in combination with other minerals.

Cross Polarised Light



Photomicrograph 4

At the highest power of magnification the small needles of apparent rutile present throughout the slate are just visible, these a fraction of a micron in width.

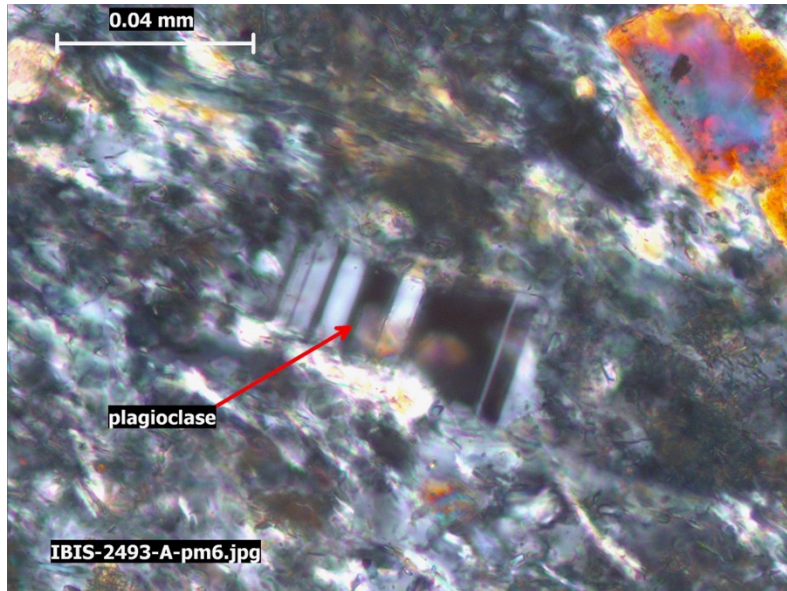
The patchy greenish background colour is due to the presence of chlorite, which was otherwise difficult to distinguish in cross polarised light amongst the quartz and other minerals.

Plane Polarised Light

Petrographic Examination of Natural Roofing Slate BS EN 12326-2:2011

A full description of the examination methods is given in Page 6

Photographs and Photomicrographs

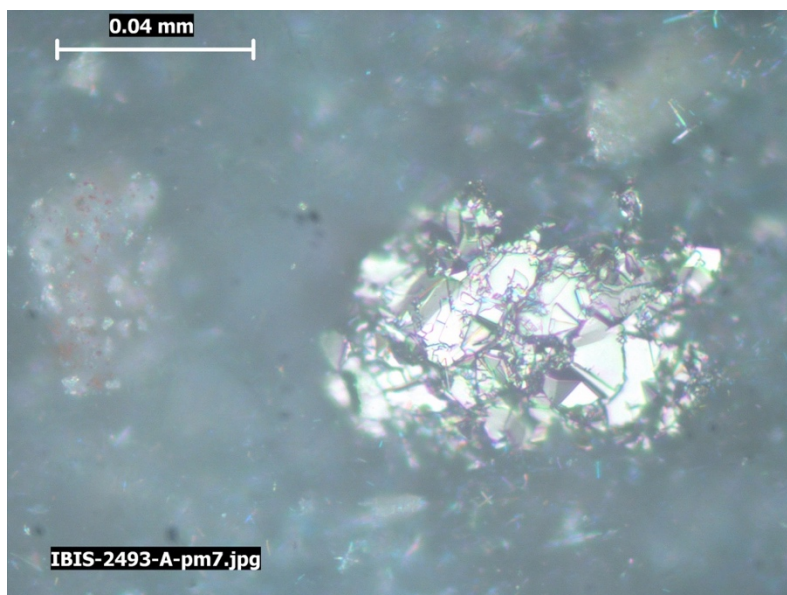


Photomicrograph 5

Visible amongst the background mineral assemblage were frequent multiple twinned crystals typical of plagioclase feldspar. These were considered to be relics of the former mineral assemblage.

The bright crystal at the top right corner appears to be a trace of tourmaline.

Cross Polarised Light



Photomicrograph 6

This opaque crystal grain exhibited light yellow metallic bireflectance that was considered to be typical of pyrite. There was no evidence of any reaction effects.

Reflected Polarised Light

Petrographic Examination of Natural Roofing Slate

BS EN 12326-2:2011

Investigation Methods

The submitted sample was subjected to a petrographic examination following the methods given in BS EN 12326-2:2011, Slate and stone for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate, Section 16: Petrographic examination, Annex A: Petrographic interpretation, and Annex B: Petrographic examination of origin and identification of slate.

A visual and low-power microscopic examination was carried out assisted by a Leica MZ16 binocular zoom microscope employing magnifications up to x160. This examination was supported by a variety of simple physical and chemical tests. Low-power photomicrographs (photographs taken through the microscope) may be prepared to illustrate general character. The examination is used to select specimens for the preparation of a thin-section and, where applicable, a highly polished specimen, for high-power microscopical examination.

Thin-sections are typically prepared after impregnation of the sample with an epoxy resin containing an ultraviolet light sensitive fluorescent dye. Highly polished specimens are prepared by grinding with successively finer abrasives finishing with a ¼µm diamond paste.

The high-power microscopical examinations are carried out using a Leica DM RXP petrological microscope with magnifications up to x3000. Thin-section examination may be carried out in both plain and cross-polarised light, and reflected ultraviolet light creating secondary fluorescence. Highly polished specimens may be examined in reflected polarised and brightfield illuminations. High-power photomicrographs may be prepared to illustrate microscopical features of importance.

Glossary of Common Terms Used in the Description

Proportions	Major: constituent present at 10% level and above; Minor: constituent present at 2% to 10% level; Trace: constituent present at below the 2% level		
Frequency	Increasing Frequency ▼	Rare - only found by thorough searching Sporadic - only occasionally observed during normal examination Common - easily observed during normal examination Frequent - easily observed with minimal examination Abundant - immediately apparent to initial examination	
Size	Mega: >60mm; Macro: 2-60mm; Meso: 60µm-2mm; Micro: 2-60µm; Crypto: <2µm; Glassy: without visible crystallinity		
Hardness	Very soft: can be penetrated easily by a finger; Soft: scores with a fingernail; Moderately soft: scores using a copper coin; Moderately hard: scores easily with a penknife; Hard: not easily scored with a penknife; Very hard: cannot be scored with a steel point or knife.		
Strength	Very weak: indented by thumbnail; Weak: can be peeled with a pocket knife; Moderately weak: shallow indentations made by firm blow with the point of a geological hammer; Moderately strong: specimen fracture by single firm blow of geological hammer, cannot be peeled with a pocket knife; Strong: specimen requires more than one blow to fracture it; Very strong: specimen requires several blows to fracture it; Extremely strong: specimen can only be chipped with a geological hammer.		
Alteration	Faintly: traces of oxidation along crystal grain boundaries and mineral decay; Slightly: discoloration noticeable, common alteration of some minerals; Moderately: many minerals exhibit partial alteration and discoloration may be considerable; Disintegrated/Decomposed: loss of crystal bonds, most minerals heavily altered. Note: beyond moderate alteration the rock may be reclassified.		
Bedding/Layering	Thick: <600mm; Medium: 200-600mm; Thin: 60-200mm; Very thin: 20-60mm		
Lamination	Thick: 6-20mm; Thin: 2-6mm; Very thin: 600µm-2mm; Extremely thin: <600µm		
Cleavage	Extremely wide: >2mm; Very wide: 600µm-2mm; Wide: 200-600µm; Medium: 60-200µm; Close: 20-60µm; Very close: 6-20µm; Extremely close: <6µm.		
Voids	Sporadic: <1%; Occasional: 1-5%; Frequent: 5-10%; Abundant: 10-25%; Honeycombed: >25%		

Certificate of Testing & Analysis

Qualitative X-Ray Diffraction Analysis

BS EN 12326-2:2011

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Client and Sample Details			
Client	Yates & Co. Ltd, Unit 10b, Salthill Industrial Estate, Lincoln Way, Clitheroe, Lancashire, BB7 1QD		
IBIS Ref. No	2493-A	Sample No	43
Source	Hilltop Slate Inc, Wells Quarry, 59 Hilltop Road, Wells, Vermont, USA		
Sample Details	Nominal 20" by 10" (508 mm by 254 mm) slate		
Sampled by	Client	Date Sampled	Not advised
Tested by	JH / PL	Date Tested	03.01.17

Methods of Testing and Analysis	
Method	BS EN 12326-2:2011. Slate and stone products for discontinuous roofing and external cladding – Part 2: Methods of test for slate and carbonate slate. A representative portion of the sample was ground to a powder in a McCrone micronising mill with the addition of acetone to minimise structural damage to the minerals present. The resulting sample was dried and lightly ground so that the powder could be side-packed into a XRD powder holder and scanned at a rate of 5 seconds per 0.02° step width, using 0.3 mm slits from 5 to 70° 2θ.
Comments	Sample for test taken from a batch of 50 sampled by the Client from their current stock. The semi-quantitative proportions should be regarded as having a potential error of 10%.
Accreditation	This is a specialised test undertaken by an expert in the field. There is no accreditation held for this test method. The machinery is calibrated regularly using known reference samples.

Results	
Trace	A copy of the XRD output is given in Page 2 of this certificate.
Major Minerals	Chlorite (35%) Quartz (29%) Illite & Micas (16%) Plagioclase (13%)
Minor Minerals	Alkali Feldspar (3%) Siderite (3%) Pyrite (1%)
Other Details	Traces of calcite were identified by the traces. Graphite could not be determined by this method.

Issue Date: 01.03.17

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Page 2 of 2

Certificate of Testing & Analysis
Qualitative X-Ray Diffraction Analysis
BS EN 12326-2:2011

XRD Output

