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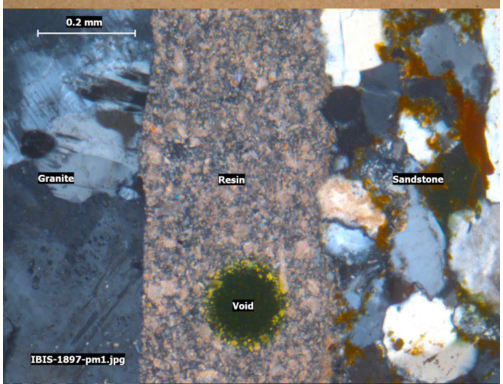
Investigation of Aerolite Cladding Panels

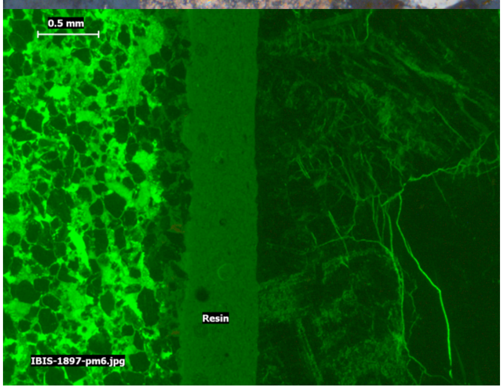
Report commissioned by
Mr Phil Harwood
TI Tiles International Ltd
Westview House
Devro Campus
Gartferry Road
Moodiesburn
Glasgow
G69 0JE

IBIS Report 1897-01, July 2011

Pull-off tested Aerolite cladding panel specimen post weatherometer testing. Failure occurred within the sandstone facing material.



The resin glue flanked by the granite backing and sandstone facing materials.



No evidence of separation at the contact between the two stones and the resin glue.

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Investigation of Aerolite Cladding Panels

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For IBIS Limited

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

Status of report: Final
Issue number: 1
Date of issue: 12 July 2011

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Investigation of Aerolite Cladding Panels

Executive Summary

An assessment has been carried out to determine the properties of advised Aerolite Cladding Panels. These panels are a composite material comprising sheets or slabs of two different stones bonded together with resinous glue.

Testing was carried out in order to determine the potential long-term effects of weathering upon the resinous glue. The effects of weather conditioning were assessed using comparative flexural strength and pull-off testing. Petrographic examination was also undertaken to assess the bonding.

The findings indicate that the bonding between the two stone materials was greater than the strength of the weaker sandstone that formed the facing. The bonding also appeared to be resistant to the weather conditioning.

Current indications are that the Aerolite Cladding Panels may be suitable for use as external cladding in a variety of circumstances. However, comment on this aspect is beyond the scope of this report.

NOTE: This executive summary is provided for initial briefing purposes only and should not be substituted for the main body of the report and the detailed conclusions and recommendations provided therein.

Investigation of Aerolite Cladding Panels

1 INTRODUCTION

Aerolite Cladding Panels are a product supplied by the Client within the UK. These panels are a composite material comprising a natural stone backing slab on to which a veneer of natural stone facing material is bonded. The idea is that the panel obtains its strength and durability properties from the backing material whilst the veneer provides purely aesthetic properties.

The use of veneered finishes is an attempt to allow stone types to be deployed that would not normally be able to be used for thin cladding purposes. The physical and mechanical properties of the Aerolite Cladding Panels have been assessed by various means, and these suggest that the panels possess sufficient strength to resist the different loading influences they could be subjected to.

The potential long-term durability of the bond between the backing and veneer had not been assessed, though this must be considered a vital performance requirement for any composite panel of this type. Therefore the current investigation was designed to investigate the durability of the bond in addition to the actual performance characteristics.

This report describes the laboratory investigation procedures and the detailed findings are presented in a number of Appendices given at the end of the report. The investigation findings are summarised within the body of the report as a prelude to a discussion of the findings where a number of conclusions and recommendations are also provided. The report is completed by a number of standard remarks.

2 LABORATORY INVESTIGATION

2.1 General

Aerolite Cladding Panels comprise a two-layer system whereby a thin layer of stone is stuck on to a more competent layer of stone using a resin-based product. The idea is that the thin layer of stone is the aesthetic finish whilst the thicker layer provides the greater majority of the performance characteristics. Therefore the principal concern is the competency of the resin and the bond created between the two stone materials.

Therefore it was decided to conduct weatherometer testing to simulate natural weathering that may attack organic materials such as resins. Before and after comparative testing was also to be conducted in order to assess any changes in the flexural strength and pull-off resistance. Petrographic examination was also undertaken to provide a more direct view of the bonding.

2.2 Flexural Strength

Twenty Aerolite Cladding Panel samples with dimensions of 300mm by 50mm by the thickness of the panel were received for four point flexural strength testing in accordance with the procedures given in BS EN 13161[1].

It was advised that the samples were cut from ten different panels, two from each panel, so that each pair of specimens could be used for the comparative testing: one untested, the other subjected to weatherometer testing. Testing of both sets of samples was undertaken at the same time after completion of the weatherometer testing in order to minimize potential anomalies created by testing at different times.

Each sample was loaded under constant moment using a four-point set-up until failure was achieved. The highest load achieved was used to calculate the flexural strength.

The detailed flexural strength results are given in **Appendix A** as Certificates of Test Nos. 3578 and 3579. A summary of the results is provided in **Section 3** of this report.

2.3 Pull-Off Resistance

Ten Aerolite Cladding panel samples with nominal 200mm square dimensions by the thickness of the panel were received for pull-off resistance testing following procedures given in BS 1542[2]. All of the samples selected included the kerf slot along one of the edges as this is an important feature of the panels.

As for the flexural strength testing, it was advised that the samples were cut from five different panels, two from each panel, so that each pair of specimens could be used for the comparative testing: one untested, the other subjected to weatherometer testing. Testing of both sets of samples was undertaken at the same time after completion of the weatherometer testing in order to minimize potential anomalies created by testing at different times.

Each sample had two core holes partially drilled from the facing through to the start of the backing. A test dolly was adhered to the facing surface that was then pulled until failure occurred. The highest load achieved was used to calculate the pull-off resistance.

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1 BS EN 13161: 2001. Natural stone test methods – Determination of flexural strength under constant moment. Published by the British Standards Institution (BSI), London, England.

2 BS EN 1542: 1999. Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off. Published by the British Standards Institution (BSI), London, England.

The detailed pull-off resistance results are given in **Appendix B** as Certificates of Test Nos. 3580 and 3581. A summary of the results is provided in **Section 3** of this report.

2.4 Weatherometer Testing

Weathering conditioning of fifteen Aerolite Cladding Panel samples was carried out in accordance with ASTM G154[3]. The fifteen samples comprised a set of ten samples of flexural strength size and a set of five samples of pull-off test size as described above in Sections 2.2 and 2.3 of this report respectively.

The weathering conditioning was carried out under the following conditions:

- Exposure to UV-A radiation for four hours at 60°C.
- Four hours of condensation at 50°C without light.

This cycle was repeated until a total test time of 2000 hours was completed.

There are no results for the weatherometer testing as the performance was determined by the before and after comparative flexural strength and pull-off resistance testing.

In **Figure 2.1** below are record colour photographs of some of the pull-off test specimens post weatherometer and pull-off testing.

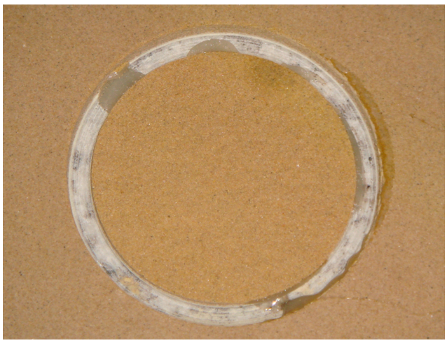

Figure 2.1a

Close view of one of the test specimens and the clean split or delamination that occurred within the sandstone veneer when subjected to pull-off testing.

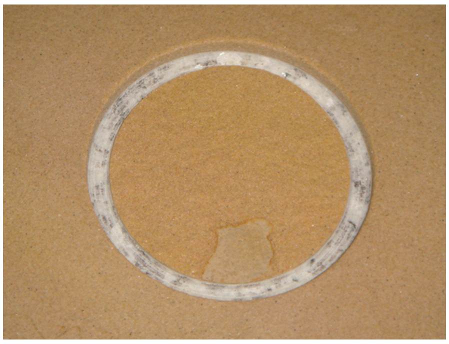

Figure 2.1b

Similar situation to Figure 2.1a but with the split partially passing through another lamination.

2.5 Petrographic Examination

Four samples representing the highest and lowest pull-off strength test results before and after the weatherometer testing were subjected to comparative petrographic examination following the procedures given in BS EN 12407[4].

Each sample was first subjected to a visual and low-power microscopic examination 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 is used to select a specimen for the preparation of a thin-section for high-power microscopical examination. Each thin-section was prepared after impregnation of the sample with an epoxy resin containing an ultraviolet light sensitive fluorescent dye.

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3 ASTM G154-06. Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. Published by ASTM International, West Conshohocken, USA.

4 BS EN 12407: 2000. Natural stone test methods – Petrographic examination. Published by the BSI, London, England.

High-power microscopical examination was carried out using a Leica DM RXP petrological microscope with magnifications up to x3000. The thin-section examination was carried out in both plain and cross-polarised light, and reflected ultraviolet light creating secondary fluorescence. A number of high-power photomicrographs were prepared to illustrate microscopical features of importance.

The detailed petrographic examination results are given in **Appendix C** as Certificate of Examination No. 3582. A summary of the results is provided in **Section 3** of this report.

3 SUMMARY OF RESULTS

Material	Aerolite Cladding Panel	
Value	Mean	Lower Expected
Flexural Strength, MPa	10.2	9.2
Flexural Strength after Weatherometer testing, MPa	10.7	8.8
Change in Strength, %	+ 5	- 4
Flexural Strength Test Comments	One unweathered sample failed at zero loading suggesting it was already cracked. A weathered sample failed outside of the loading platens at a very low value also suggesting that this may also have been damaged prior to testing. Both results have been excluded from the mean calculations.	
Value	Mean	Lower Expected
Pull-Off Resistance, MPa	1.15	0.60
Pull-Off Resistance after Weatherometer testing, MPa	1.00	0.56
Change in Resistance, %	- 13	- 7
Pull-Off Resistance Test Comments	All failures occurred within the sandstone layer, suggesting that the bond was as strong as or stronger than the sandstone.	
Weatherometer Test Comments	No obvious visual evidence of distress or deterioration affecting the test samples.	
Petrographic Details	The backing stone was confirmed to be a type of granite that appeared to be fresh with no obvious issues. The facing stone was confirmed to be a type of sandstone that might be further classified as a type of arenite due to the dominance of quartz grains over minor chert and rock fragments and traces of feldspar and micas. The cement was mostly siliceous with some iron-based compounds. The resin glue appeared to be organic in composition with a carbonate dust filler. The resin apparently had entered the sandstone to a depth of a few hundred microns. There was no visible evidence of separations affecting any of the test specimens.	

4 DISCUSSION

4.1 Advised Information

Various test reports were received that provided information about the Aerolite Cladding Panels. Testing that was carried out to CWCT guidelines[5] provided the following information:

- Wind serviceability: +/- 2400 Pascals.
- Wind safety: +/- 3600 Pascals.
- Cyclic or Fatigue: +/- 600 to 2400 Pascals over a 24-hour period.

Impact resistance testing to BS 8200[6] revealed that the Aerolite Cladding Panels passed all hard and soft body impacts.

The Warrington Fire Group tested the Aerolite Cladding Panels and found that they exhibited a fire propagation index of 0.0 in accordance with BS 476-6[7] and a Class 1 rating in accordance with BS 476-7[8].

4.2 Description of the Product

The Aerolite Cladding Panels comprise a 15mm thick granite slab on to which a 4mm veneer of sandstone had been bonded. A continuous kerf slot is cut along the outer edges of the panel where it is to be fixed, this being 3mm wide and beginning 7mm from the rear of the panel. Thus the slot finishes around 5mm from the sandstone veneer.

The granite backing has not always been employed, a variety of materials having been used over time. The veneer can be varied as it is not expected to exhibit properties that would affect the performance of the panels. However, it is considered that a more crystalline and/or lighter coloured veneer might be able to transmit a higher degree of ultraviolet radiation through to the bonding resin.

It is noted that any variance in the cutting and finishing tolerances could lead to the kerf slot being very close to the veneer. Therefore, it is possible that the performance of the veneer could be significant. The use of an organic resinous material for bonding the veneer is thus potentially significant, as such materials may be susceptible to breakdown under ultraviolet radiation and other external weathering influences.

4.3 Investigation Findings

The Aerolite Cladding Panels did not lose significant flexural strength or pull-off resistance as a consequence of the weather conditioning testing. It was also apparent that the bond between the sandstone and resin was as strong if not stronger than the sandstone itself. It is possible that laminar weaknesses within the sandstone were the controlling factor for the pull-off failure planes.

It was apparent that the bonding resin had entered the sandstone and also possibly some of the granite cleavages and crystal grain boundaries at or close to the contact. There was no evidence of any separations in any of the samples examined. Occasional small voids were apparent but these occurred within the resin.

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5 CWCT Standard Test Methods for Building Envelopes. Published by the Centre for Window and Cladding technology (CWCT), Bath, England, 2005.

6 BS 8200: 1985. Code of practice for design of non-loadbearing external vertical enclosures of buildings. Published by the BSI, London, England.

7 BS 476-6: 1989. Fire tests on building materials and structures. Method for fire propagation for products. Published by the BSI, London, England.

8 BS 476-7: 1997. Fire tests on building materials and structures. Method for classification of the surface spread of flame of products. Published by the BSI, London, England.

The granite appeared to be a fresh stone material and likely to provide the bulk of the performance properties of the Aerolite Cladding Panels as a whole. However, the strong bonding achieved suggests that the veneer will add to these properties, most notably the performance of the kerf slot. Given that there is at most only 5mm of the backing stone between the kerf slot and the veneer, any additional resistance to breaking provided by a sound veneer must be welcomed.

The findings suggest that the resin material used as the bonding medium is a strong product with potentially excellent resistance to ultraviolet radiation. It would appear that the resin should provide excellent long-term performance and may serve to significantly enhance the physical performance of the panels.

5 REMARKS

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 stone products 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.

The observations and comments provided must be regarded as very general given the limitations of the brief. However, it is hoped that the investigation findings provide a sufficiently accurate and usable picture of the conditions presented.

The Author would like to take this opportunity to confirm that any opinions provided are given independently and to the best of his ability. It is acknowledged that these opinions are partly based on potentially incomplete information. Thus the Author reserves the right to alter these opinions should new information arise that requires their reconsideration.

Samples taken for laboratory investigation are normally retained for a period of one month from the date of the report. Samples are then disposed of unless otherwise instructed. Samples may be either returned or stored, which would incur further charges.

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

Investigation of Aerolite Cladding Panels

Appendix A
Flexural Strength Test Results

Certificate of Testing & Analysis
4-Point Flexural Strength of Dimension Stone
BS EN 13161:2001

Client and Sample Details			
Client	TI Tiles International Ltd, Westview House, Devro Campus, Gartferry Road, Moodiesburn, Glasgow, G69 0JE		
IBIS Ref. No	1897-A	**Sample No**	1a to 10a
Source	Advised Aerolite cladding panel.		
Sample Details	Granite with a sandstone facing adhering using resin.		
Sampled by	Client	**Date Sampled**	Not advised
Tested by	PS-TTR	**Date Tested**	31.05.11

Methods of Testing and Analysis	
Method	BS EN 13161: 2001. Natural stone test methods – Determination of flexural strength under constant moment.
Comments	Ten nominal 300mm by 50mm specimens were tested in the recommended dry condition. The loading rate was 200N/s.
Accreditation	The test was carried out by a newly set up laboratory currently seeking UKAS accreditation. IBIS has audited the laboratory and considers that it is carrying out the test in accordance with the European Standard requirements and that all equipment was within calibration.

Flexural Strength Results	
Condition	Dry
Orientation	Facing positioned in tension
Flexural Strength Values , MPa	10.7, 9.7, 10.1, 9.6, 10.9, 10.2, 9.6, 10.7, 10.1
Mean Flexural Strength, MPa	10.2
Standard Deviation, MPa	0.5
Coefficient of Variation	0.05
Quantile Factor	2.14
Lower Expected Value, MPa	9.16

Remarks

All fractures took place within the two line loads and no existing planes of anisotropy were determined. One sample failed at zero loading and was excluded from results due to suspected pre-existing cracking.

The results relate only to the samples tested and materials properly represented by them.

Issue Date: 12.07.11

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Director, IBIS Limited

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Certificate of Testing & Analysis
4-Point Flexural Strength of Dimension Stone
BS EN 13161:2001

Client and Sample Details			
Client	TI Tiles International Ltd, Westview House, Devro Campus, Gartferry Road, Moodiesburn, Glasgow, G69 0JE		
IBIS Ref. No	1897-A	**Sample No**	1b to 10b
Source	Advised Aerolite cladding panel.		
Sample Details	Granite with a sandstone facing adhering using resin. Samples had been subjected to 2,000 hours of weather conditioning testing in accordance with ASTM G154-06.		
Sampled by	Client	**Date Sampled**	Not advised
Tested by	PS-TTR	**Date Tested**	31.05.11

Methods of Testing and Analysis	
Method	BS EN 13161: 2001. Natural stone test methods – Determination of flexural strength under constant moment.
Comments	Ten nominal 300mm by 50mm specimens were tested in the recommended dry condition. The loading rate was 200N/s.
Accreditation	The test was carried out by a newly set up laboratory currently seeking UKAS accreditation. IBIS has audited the laboratory and considers that it is carrying out the test in accordance with the European Standard requirements and that all equipment was within calibration.

Flexural Strength Results	
Condition	Dry
Orientation	Facing positioned in tension
Flexural Strength Values , MPa	9.4, 11.2, 9.0, 12.1, 10.8, 10.7, 10.9, 11.1, 11.0, 1.3
Mean Flexural Strength, MPa	10.7
Standard Deviation, MPa	0.94
Coefficient of Variation	0.09
Quantile Factor	2.14
Lower Expected Value, MPa	8.77

Remarks

All fractures took place within the two line loads except for one sample whose result was excluded from the mean calculation. No existing planes of anisotropy were determined.

The results relate only to the samples tested and materials properly represented by them.

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Investigation of Aerolite Cladding Panels

Appendix B
Pull-Off Resistance Test Results

Certificate of Testing & Analysis

Pull-Off Resistance of Material

BS 1542

Client and Sample Details			
Client	TI Tiles International Ltd, Westview House, Devro Campus, Gartferry Road, Moodiesburn, Glasgow, G69 0JE		
IBIS Ref. No	1897-A	**Sample No**	11a to 15a
Source	Advised Aerolite cladding panel.		
Sample Details	Granite with a sandstone facing adhering using resin.		
Sampled by	Client	**Date Sampled**	Not advised
Tested by	PS-TTR	**Date Tested**	31.05.11

Methods of Testing and Analysis	
Method	BS 1542: 1999. Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off.
Comments	Five nominal 200mm square specimens were tested in the dry condition. Two nominal 50mm diameter test areas were prepared from each test piece.
Accreditation	The test was carried out by a newly set up laboratory currently seeking UKAS accreditation. IBIS has audited the laboratory and considers that it is carrying out the test in accordance with the British Standard requirements and that all equipment was within calibration.

Flexural Strength Results	
Condition	Dry
Orientation	Facing upwards.
Pull-Off Resistance Values , MPa	1.17, 0.53, 1.51, 1.23, 1.03, 1.26, 1.29, 1.07, 1.46, 0.99
Mean Pull-Off Resistance, MPa	1.15
Standard Deviation, MPa	0.28
Coefficient of Variation	0.24
Quantile Factor	2.1
Lower Expected Value, MPa	0.60

Remarks

The results relate only to the samples tested and materials properly represented by them.

Issue Date: 12.07.11

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Certificate of Testing & Analysis
Pull-Off Resistance of Material
BS 1542

Client and Sample Details			
Client	TI Tiles International Ltd, Westview House, Devro Campus, Gartferry Road, Moodiesburn, Glasgow, G69 0JE		
IBIS Ref. No	1897-A	**Sample No**	11b to 15b
Source	Advised Aerolite cladding panel.		
Sample Details	Granite with a sandstone facing adhering using resin. Samples had been subjected to 2,000 hours of weather conditioning testing in accordance with ASTM G154-06.		
Sampled by	Client	**Date Sampled**	Not advised
Tested by	PS-TTR	**Date Tested**	31.05.11

Methods of Testing and Analysis	
Method	BS 1542: 1999. Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off.
Comments	Five nominal 200mm square specimens were tested in the dry condition. Two nominal 50mm diameter test areas were prepared from each test piece.
Accreditation	The test was carried out by a newly set up laboratory currently seeking UKAS accreditation. IBIS has audited the laboratory and considers that it is carrying out the test in accordance with the British Standard requirements and that all equipment was within calibration.

Flexural Strength Results	
Condition	Dry
Orientation	Facing upwards.
Pull-Off Resistance Values , MPa	1.19, 1.07, 1.06, 0.62, 0.67, 0.77, 1.13, 1.02, 1.33, 1.19
Mean Pull-Off Resistance, MPa	1.00
Standard Deviation, MPa	0.24
Coefficient of Variation	0.24
Quantile Factor	2.1
Lower Expected Value, MPa	0.56

Remarks

The results relate only to the samples tested and materials properly represented by them.

Issue Date: 12.07.11

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Investigation of Aerolite Cladding Panels

Appendix C
Petrographic Examination Results

Certificate of Examination

Petrographic Examination of Natural Stone

BS EN 12407: 2000

Client and Sample Details

Client	TI Tiles International Ltd
IBIS Sample No	1897-A
Client Sample No	Not advised
Source	Not advised
Sample Details	Advised Aerolite Cladding Panel Samples represent before an after weather condition testing and highest and lowest pull-off test results achieved.
Sampled by / Date	Client / Not advised
Condition / Date Received	Dry / 07.02.11
Examined by / Date	BJH / 09-23.06.11
Thin-Section Details	Four sections, one from each of four samples, taken perpendicular to the outer surface through the full thickness of the product.

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 7 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 6.

Summary Overview

BS 12440 Denomination	Not applicable	
BS 12670 Classification	Granite backing and sandstone facing	
Stone Type	**Granite**	**Sandstone**
Major Minerals	Quartz, Feldspars	Quartz
Minor Minerals	Micas, Opaques	Chert, Rock fragments
Potentially Deleterious Materials	None observed	None observed
Textural Features	Equicrystalline, microperthitic	Siliceous cement with some iron components
Other Details	The resinous glue between the two materials appeared to be sound with no evidence of any partings. There was evidence that the resin had penetrated the sandstone to around 200µm from the contact surface. Some resin penetration of the granite may have occurred.	

Issue Date: 12.07.11

Barry J Hunt
Director, IBIS Limited

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Established 2001

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Petrographic Examination of Natural Stone
BS EN 12407: 2000
A full description of the examination methods is given in Page 7

Client and Sample Details			
Client	TI Tiles International Ltd, Westview House, Devro Campus, Gartferry Road, Moodiesburn, Glasgow, G69 0JE		
IBIS Ref. No	1897-A	**Sample No**	11b to 15b
Thin-Section Details	Four sections, one from each of four samples, taken perpendicular to the outer surface through the full thickness of the product.		

Material Description *(incl. strength, weathering, crystal/grain size, structure, alteration, name, secondary structure)*	Sandstone facing material bonded to granite backing via a resinous product. SANDSTONE: moderately weak, buff, fine-grained, bedded sedimentary rock of arenite composition. GRANITE: very strong, mottled white, grey and black, sometimes pinkish, coarse crystalline, massive igneous rock.

Stone Components (Content / Size Range)					
Sandstone Facing			**Granite Backing**		
Quartz	90	60-200µm	Quartz	50	1-5mm
Chert	5	60-200µm	Alkali Feldspar	32	2-8mm
Rock Fragments	4	100-200µm	Plagioclase Feldspar	17	1-6mm
Quartzite	1	60-150µm	Muscovite mica	1	200µm-2mm
Opaques	< 1	10-100µm	Opaques	< 1	20µm-1mm
Feldspar	< 1	60-200µm	Others	Trace	50µm-1mm

Petrographic Details – Sandstone	
Quartz	Sub-angular to sub-rounded particles of quartz often with evidence of siliceous overgrowth with optical continuity, forming an interlocking texture.
Chert	Particles of microcrystalline and cryptocrystalline silica.
Rock Fragments	Mostly very fine-grained materials including possible siltstone, claystone and shale.
Quartzite	Polycrystalline silica particles that appeared to be unstrained.
Opaques	Black particles probably rich in iron compounds and possibly including pyrite.
Feldspar	Occasional crystals of alkali feldspar, typically orthoclase.
Other Details	Siliceous cement often containing apparent iron minerals.
Petrographic Details – Granite	
Quartz	Unstrained crystals of quartz with slight polygonisation, particularly at crystal edges.
Alkali Feldspar	Principally orthoclase microperthitically intergrown with albite and microcline with distinctive cross-hatched twinning.
Plagioclase Feldspar	Primarily oligoclase exhibiting multiple twinning and albite intergrown with orthoclase. Some evidence of compositional zoning and slight sericitisation apparent.
Muscovite mica	White mica flakes scattered throughout the rock fabric.
Opaques	Black particles probably containing iron compounds.
Others	Traces of biotite mica often altering to apparent chlorite.
Other Materials and Details	
Resin	Between the two stone materials was a thin layer of resin acting as a glue. This resin was isotropic and contained abundant fine carbonate dust with high birefringence. The dust was typically less than 10µm in size. There were no apparent separations visible. Occasional small voids were present. The resin had penetrated the sandstone to around 200µm, thus reducing its apparent porosity. The granite exhibited some evidence of resin penetration. There were no obvious differences between any of the specimens, whether these were before or after weather conditioning or representing weaker or stronger pull-off resistance.

Petrographic Examination of Natural Stone
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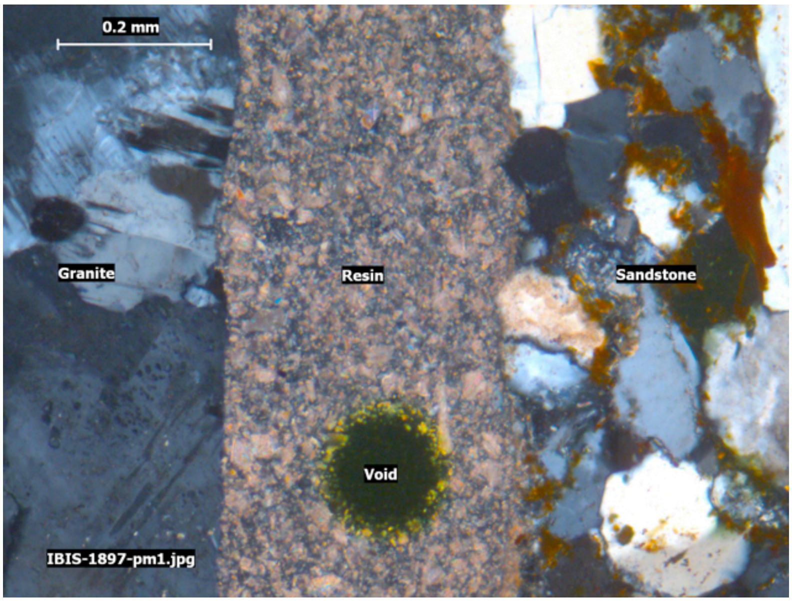
Photomicrographs



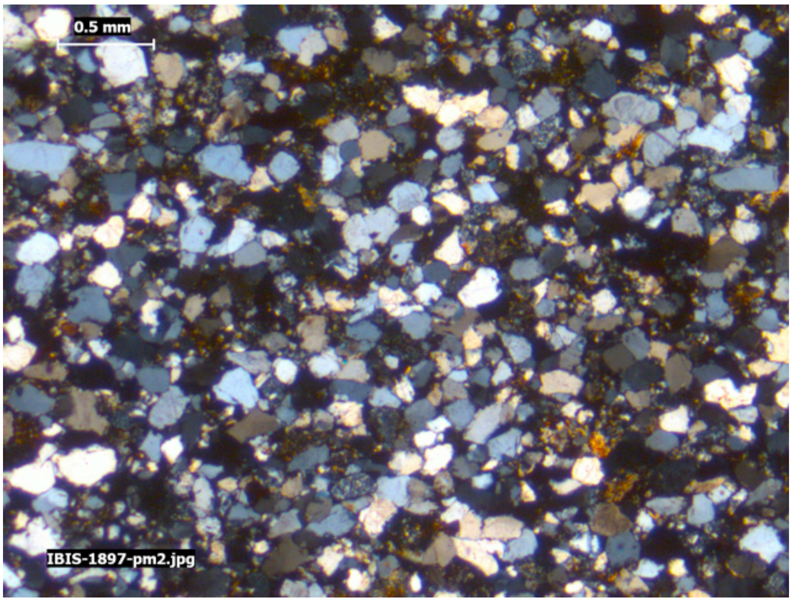
Photomicrograph 1

View of the resin glue with the granite (left) and sandstone (right) indicated.

A small void is visible within the resin that does not appear to affect its performance. The resin is packed with fine carbonate dust filler materials.

There is no evidence of any partings between the resin and stone materials.

Cross Polarised Light



Photomicrograph 2

Typical view of the sandstone and the mostly fine quartz composition.

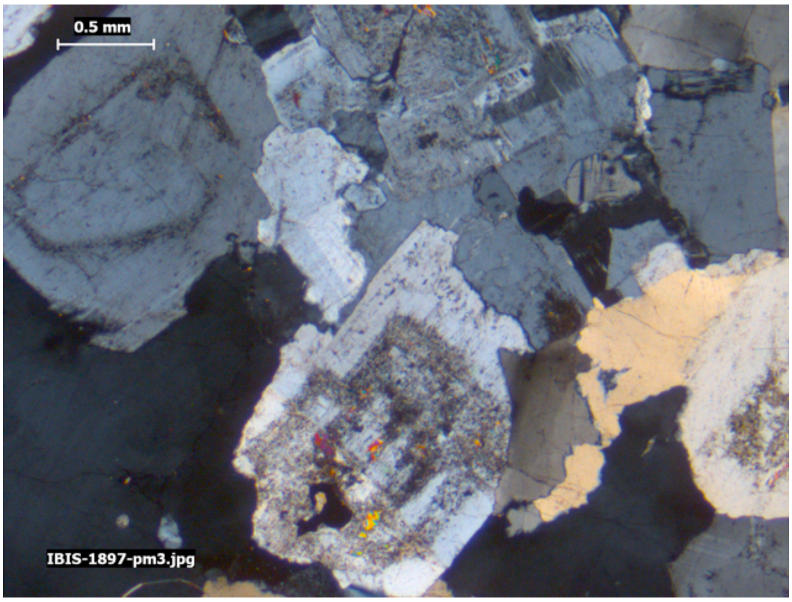
The darker coloured areas are where there appeared to be higher proportions of iron minerals within the siliceous cementing matrix.

Some of the darker areas are actually particles of chert and rock fragments.

Cross Polarised Light

Petrographic Examination of Natural Stone
BS EN 12407: 2000
A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

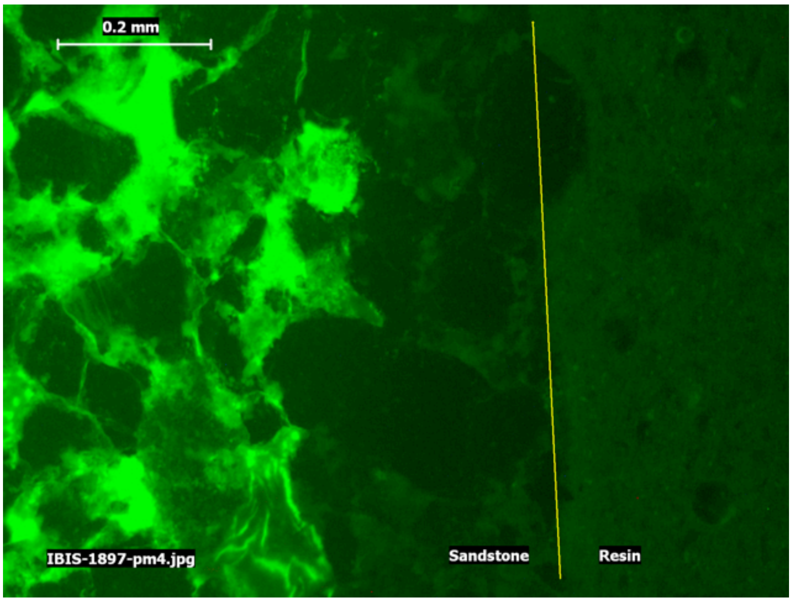


Photomicrograph 3

A reasonably typical view of the granite and the interlocking crystals that comprised mostly quartz and feldspar.

Banding within the feldspar indicates compositional zoning, in addition to being evidence of very slight alteration.

Cross Polarised Light



Photomicrograph 4

A yellow line has been added to this photomicrograph to indicate where the junction between the sandstone and resin was, as there was no separation or other effect to show this.

A dark zone where the resin has impregnated the sandstone is apparent and reaches to around 200µm from the contact surface.

The sandstone otherwise is seen to be quite bright due to its microporosity and thus impregnation by the fluorescent thin-sectioning resin.

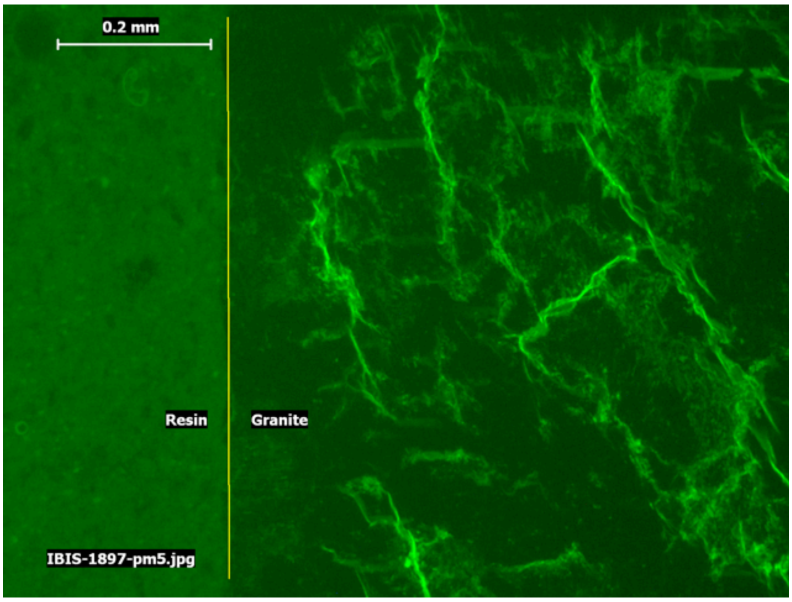
Reflected Transmitted Light

Petrographic Examination of Natural Stone

BS EN 12407: 2000

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs



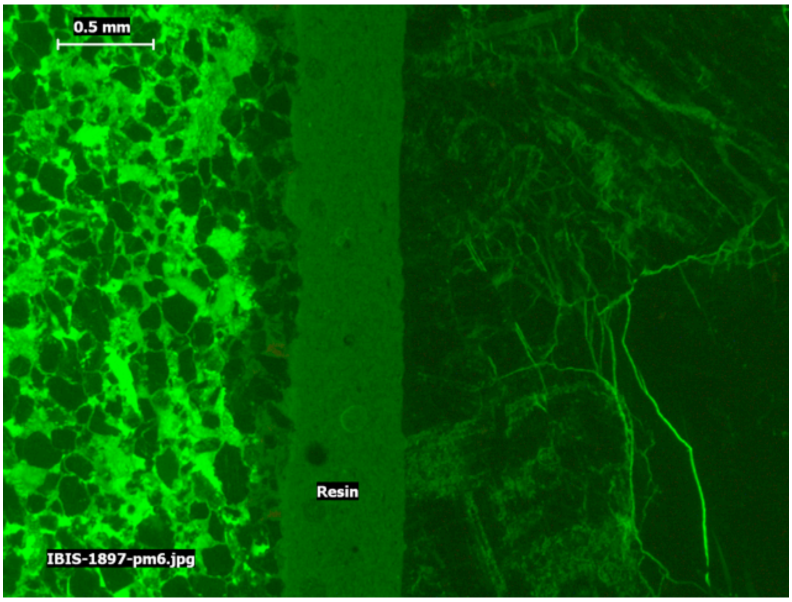
Photomicrograph 5

A yellow line has been added to this photomicrograph to indicate where the junction between the granite and resin was, as there was no separation or other effect to show this.

A darker zone where the resin has impregnated the granite possibly extends to around 50µm from the contact surface.

Crystal grain boundaries and cleavage traces are otherwise demonstrated by the impregnation of the granite by the fluorescent thin-sectioning resin.

Reflected Transmitted Light



Photomicrograph 6

A more general view of the resin between the sandstone and granite and the lack of any apparent separations.

The dark zone of resin impregnation at the sandstone boundary remains quite obvious, whilst that with the granite is diffuse at best.

Reflected Transmitted Light

Petrographic Examination of Natural Stone
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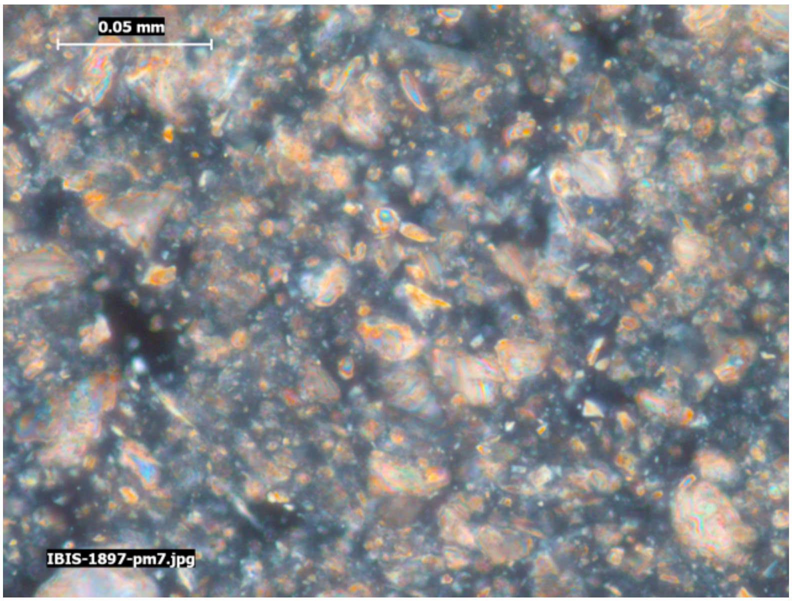
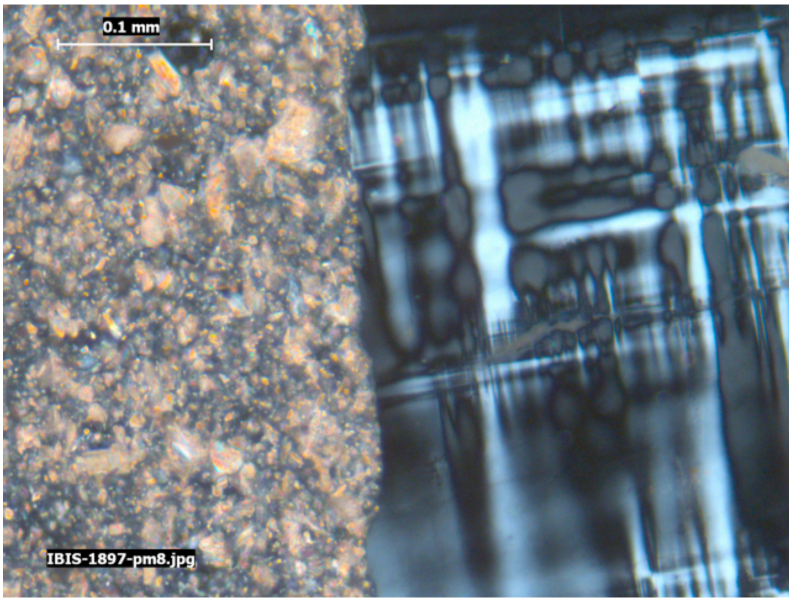
Photographs and Photomicrographs



Photomicrograph 7

Close view of the fine filler material within the resin that appeared to comprise carbonate dust.

Cross Polarised Light



Photomicrograph 8

Close view of the contact between the resin and a cross-hatched microcline feldspar crystal. There is no visible evidence of a separation.

Cross Polarised Light

INDEPENDENT BUILDING INVESTIGATION SERVICES

Petrographic Examination of Natural Stone
BS EN 12407: 2000

Investigation Methods

The submitted sample was subjected to a petrographic examination following the methods given in BS EN 12407: 2000, Natural stone test methods – 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. 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 1% to 10% level; **Trace**: constituent present at below the 1% 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%