

**CONTENTS**

- 1 INTRODUCTION**
- 2 TEST PROGRAMME**
- 3 SAMPLE DESCRIPTION**
  - 3.1 Brick Slip Test Panels**
- 4 TEST ARRANGEMENT**
  - 4.1 Wind Resistance**
  - 4.2 Lifting Eye Tensile Strength**
  - 4.3 Chimney Lift Test**
  - 4.4 Soak Coat Water Test**
  - 4.5 Chimney Crown Bond Strength**
- 5 TEST METHODS**
  - 5.1 Wind Resistance**
  - 5.2 Chimney Lift Test**
  - 5.3 Soak Coat Water Test**
  - 5.4 Lifting Eye Tensile Strength, Brick Slip Bond Strength and Chimney Crown Bond Strength**
  - 5.5 Hygrothermal Testing to ETAG004**
    - 5.5.1 Heat Rain – 80 Cycles**
    - 5.5.2 Freeze Thaw – 5 Cycles**
  - 5.6 Brick Slip Bond Strength**
- 6 RESULTS**
  - 6.1 Wind Resistance**
  - 6.2 Lifting Eye Tensile Strength**
  - 6.3 Chimney Lift Test**
  - 6.4 Soak Coat Water Test**
  - 6.5 Hygrothermal Testing to ETAG004**
  - 6.6 Brick Slip Bond Strength**
- 7 SUMMARY**

**PLATES**

## REPORT OF STRUCTURAL TESTING OF PREMIER CUTTING CHIMNEY SYSTEMS

### 1 INTRODUCTION

Premier Cutting supplied Ceram with three types of their pre-fabricated Chimney systems, the Mid Ridge Chimney, the Mono Pitch Chimney and the Gable End Chimney to be subjected to several types of strength tests and soak coat water testing to determine the product's performance.

### 2 TEST PROGRAMME

**Table 1: Programme of Work**

Test Type	Description
Wind Resistance	Applying a serviceability UDL of 1.8kN/m <sup>2</sup> to adjacent faces of the Chimneys and taking one face to failure to determine the whole unit wind resistance.
Lifting Eye Tensile Strength	Tensile loads to be applied to the Chimney lifting eyes until failure to determine the total tensile capacity.
Chimney Lift Test	The Chimneys to be lifted in their entirety via it's installed lifting eyes to establish that they are fit for purpose.
Soak Coat Water Test	A controlled spray of water to cover the Chimneys whilst installed on a mock roof set-up and ran for three days to determine whether any water ingress is occurring.
Chimney Crown Bond Strength	Tensile load applied to the Chimney crown until failure occurs to establish the crowns wind resistance to possible wind suction.
Accelerated weathering in accordance with ETAG004	A 1000x1000mm panel will be subjected to heat rain and freeze thaw cycles before subjecting to bond strength tests to establish the performance of the bonded brick slips.
Brick Slip Bond Strength	Tensile bond strength tests to be carried out on the brick slips of two separate panels. One panel used as a control panel and one panel subjected to hygrothermal testing, the results then compared to establish any difference in performance.

### 3 SAMPLE DESCRIPTION

All chimneys consisted of a 2mm thick stainless steel substrate with three hole perforated brick slips resin bonded. The chimney crown was a separate stainless steel plate which was welded to the main body of the chimney. A ceramic pot was bonded to the crown and sat over a profiled dowel.

All chimneys were supplied at a 50° pitch with the mono pitch and mid ridge chimney having a 120mm cowell with holes at 150mm centres for fixing down to the roof structure. The gable end chimney had a 680mm long cowell to one side.

All chimneys were delivered with a nominally 900mm x 680mm stack by nominally 1300mm tall.

A general view of the mid-ridge chimney is shown in plate 1, likewise the mono-pitch is shown in Plate 2 and the gable end is shown in Plate 3.

### 3.1 Brick Slip Test Panels

Two brick slip test panels were used, one control panel and one conditioned panel. One panel was tested in accordance with ETAG004 under heat rain and freeze thaw conditioning. Each panel comprised of nominal dimensions of 1000mm x 1000mm with brick slips bonded back to the 2mm thick stainless steel substrate.

## 4 TEST ARRANGEMENT

### 4.1 Wind Resistance

All Chimney types were installed on a roof mock-up module in accordance with Premier Cutting Installation specification. A steel portal frame was positioned and fixed to the structures strong floor providing a framework for two hydraulic rams with pivoting loading feet and connected via a common manifold.

A steel reaction frame was fixed to the structures strong floor preventing each roof module being moved due to loading.

A cable linear voltage displacement transducer (LVDT) was fixed to the top of the opposite chimney face being loaded measuring deflection. A second cable LVDT was fixed to the roof module itself, to take into account the overall movement of the roof module.

Load was measured via a calibrated load cell and recorded via a calibrated data logger.

A general view of the Wind Resistance test arrangement can be seen in Plates 4.

### 4.2 Lifting Eye Tensile Strength

A steel loading cage was positioned over the Chimney lifting eyes with a hydraulic pull-through ram and calibrated load cell positioned on-top. An M8 threaded bar was guided vertically through the hydraulic ram, load cell and loading cage and screwed into the lifting eye. The whole system was clamped together using an M8 nut and washer.

Load was recorded via a calibrated data logger

A general view of the Lifting Eye Tensile Strength test arrangement can be seen in Plate 5 and a general view of the failure mode is given in plate 6.

### 4.3 Chimney Lift Test

Two lifting loops were screwed into the Chimney lifting eyes and lifted via an

overhead crane.

A general view of the Chimney Lift can be seen in Plate 7.

#### **4.4 Soak Coat Water Test**

All Chimney types were installed on a roof mock-up module in accordance with the client's installation specification. A scaffold framework was erected, enabling a water spray system to be arranged around each chimney such that the coverage of water was focused on any suspected weak points, the chimney sealant and lead flashing.

A general view for the Soak Coat Water Test arrangement can be seen in Plates 8-11.

#### **4.5 Chimney Crown Bond Strength**

A steel frame work of 50mm box section was positioned and suspended underneath the whole area of the chimney's crown lip. Held in place via 4no M10 threaded bars, one at each corner of the framework, with the other end of the bars connected to a steel loading frame. The steel loading frame was located above the Chimney, positioned on a hydraulic ram, supported by a steel portal frame which was fixed to the structures strong floor.

A general view of the chimney crown bond strength test arrangement can be seen in Plate 12 with a view of the failure mode given in Plate 13.

## **5 TEST METHODS**

### **5.1 Wind Resistance**

Two adjacent faces of each chimney type were loaded to the serviceability load of 1.8kN/m<sup>2</sup> and held for 5 minutes, then inspected for any sign of damage.

One face of each chimney was loaded until failure occurred, the loading rate was such that failure occurred between 5-10 minutes.

### **5.2 Chimney Lift Test**

Each chimney type was lifted entirely off from any support and suspended for a duration of 10 minutes. The whole chimney and especially the localised area around the lifting eyes were inspected for any signs of damage or indications of failure.

### **5.3 Soak Coat Water Test**

The water spray system applied a soak coat of water, covering the complete chimney and relevant connections continuously for a duration of 3 days and monitored via visual inspection for any signs of water ingress on the inside of the roof structure.

The chimney was deemed to pass if no water ingress occurred and classed as failed if water leakage due to the chimney and its connections was present within the roof structure.

#### **5.4 Lifting Eye Tensile Strength, Brick Slip Bond Strength and Chimney Crown Bond Strength**

A tensile load was applied to each sample via a hydraulic pull-through ram until failure occurred, the loading rate was such that failure occurred between 3-5 minutes.

#### **5.5 Hygrothermal Testing to ETAG004**

One panel was tested in accordance with the method described for Hygrothermal Performance in ETAG 004 March 2000 Guideline for Technical Approval of External Thermal Insulation Composite Systems with Rendering. The testing involved subjecting a panel to repeated heat-rain cycles followed by repeated freeze-thaw cycles at controlled humidity conditions designed to simulate naturally occurring conditions.

The panel was subjected cyclic heat-rain conditions followed by freeze-thaw cycles according to the following programme.

##### **5.5.1 Heat Rain - 80 Cycles**

Heating to 70°C rising over 1 hour and maintaining at 70°C ± 5 at 10-15% RH for a further 2 hours.

Followed by spraying with water (water temp ± 15°C) at 1 l/m<sup>2</sup>/min for 1 hour.

Draining for 2 hours.

On completion of the heat rain cycles the panel was conditioned for 48 hours at a temperature between 10 and 25°C with a minimum RH of 50%.

##### **5.5.2 Freeze Thaw – 5 Cycles**

Exposure to 50°C ± 5 with a rise of 1 hour and maximum 10% RH for 7 hours.

Exposure to -20°C ± 5 with a fall over 2 hours and hold for 14 hours.

The test panel was inspected every 4 heat rain cycles and daily under the freeze thaw cycles to observe changes in the visual characteristics of the panel.

#### **5.6 Brick Slip Bond Strength**

5no 210x60mm steel spreader plates were fixed to the face of 5no brick slips on both the control panel and the conditioned panel. These steel spreader plates were fixed via epoxy resin which was left 24 hours to cure. A steel pyramid reaction frame was positioned so that the centre of the frame was directly over the centre of the steel spreader plate. On top of the reaction frame, a calibrated load cell and hydraulic pull-through ram was positioned. A M12 threaded bar was guided vertically through the whole system and screwed into the spreader plate, the opposite end of the threaded bar clamped the whole system via a M12 nut and washer.

Load was recorded via a calibrated data logger.

## 6 RESULTS

### 6.1 Wind Resistance

**Table 2: Wind Resistance Results**

Chimney Type	Chimney Face	Serviceability Load – 1.8kN/m <sup>2</sup>	Serviceability Deflection (mm)	Failure Load (kN/m <sup>2</sup> )	Failure Deflection (mm)	Mode of Failure
Mid Ridge	Perpendicular to Pitch	Pass	1.34	8.14	44.18	Collapse of roof
	Parallel to Pitch	Pass	~	~	~	~
Mono Pitch	Parallel to Pitch	Pass	0.84	32.18	36.02	Collapse of roof
	Perpendicular to Pitch	Pass	~	~	~	~
Gable End	Parallel to Pitch	Pass	0.99	6.26	51.82	Collapse of roof
	Perpendicular to Pitch	Pass	~	~	~	~

All chimney types withstood the serviceability load of 1.8kN/m<sup>2</sup> and showed no sign of damage.

The Mid Ridge and the Mono Pitch Chimneys showed no sign of damage, due to the roof timber structure failing under load rather than the chimney. The Gable End Chimney failed with general collapse of the roof structure.

### 6.2 Lifting Eye Tensile Strength

**Table 3: Lifting Eye Tensile Strength Results**

No	Failure Load (kN)	Failure Load (kg)
1	33.12	3376
2	29.87	3044
3	35.91	3661
4	34.45	3512
5	31.90	3252
mean	33.80	3445

All lifting eyes showed the same mode of failure, where the steel lifting eye rod dislodges and pulls up through the chimney core and crown.

### 6.3 Chimney Lift Test

**Table 4: Chimney Lift Test**

Chimney Type	Complete Lift
Mid Ridge	Pass
Mono Pitch	Pass
Gable End	Pass

All chimneys were lifted successfully via the appropriate lifting eyes and held for 10 minutes. When lowered, no sign of damage or distress around the lifting eyes was present.

### 6.4 Soak Coat Water Test

**Table 5: Soak Coat Water Test Results**

Chimney Type	Day 1	Day 2	Day 3
Mid Ridge	Pass	Pass	Pass
Mono Pitch	Pass	Pass	Pass
Gable End	Pass	Pass	Pass

All Chimneys successfully passed the soak coat water test and showed no signs of water ingress throughout test.

**Table 6: Chimney Crown Bond Strength Results**

No	Failure Load (kN)	Wind Uplift Strength (kN/m <sup>2</sup> )
1	28.2	35.25
2	26.5	33.12
3	29.8	23.84
mean	28.2	35.25

The crown did not detach from the chimney body. Mode of failure was bending and deformation of the crown overhang.

### 6.5 Hygrothermal Testing to ETAG004

The test panel showed no visual deterioration under the accelerated weathering test.

## 6.6 Brick Slip Bond Strength

**Table 7: Brick Slip Bond Strength Results**

No	Control Panel		Conditioned Panel	
	Failure Load (kN)	Stress (N/mm <sup>2</sup> )	Failure Load (kN)	Stress (N/mm <sup>2</sup> )
1	5.21	0.41	5.48	0.43
2	5.45	0.43	5.61	0.45
3	4.98	0.40	5.87	0.47
4	5.68	0.45	4.88	0.39
5	5.12	0.41	5.32	0.42
<b>Mean</b>	<b>5.29</b>	<b>0.42</b>	<b>5.43</b>	<b>0.43</b>

The brick slips on both the control panel and conditioned panel shared a similar mode of failure where the brick slip adhesive/pulled away from the stainless steel substrate.

The bond strength of the sample can be equated to a wind suction load. Under wind load there is no pass or fail criteria, the system will be either adequate or inadequate in any particular situation. So, for example, a system installed on a building at the top of an escarpment in the North of Scotland will be expected to resist much greater wind forces than one in the centre of London. However as an indication, the speed of a 3 second gust of wind in the North of Scotland could reach 56 m/s at 10mm above the ground with a likely incidence of return once in 50years. This is the sort of level we would design for in the UK. This gust has a dynamic pressure equivalent of 0.19N/mm<sup>2</sup>.

The values shown in Table 7 for both the control panel and conditioned panel are in excess of the 0.19N/mm<sup>2</sup> both achieving above 0.40N/mm<sup>2</sup>.

7 SUMMARY

**Table 8: Premier Cutting Chimney Overall Results**

Chimney Type	Wind Resistance Serviceability Load	Chimney Lift Test	Soak Coat Water-Test
Mid Ridge	Pass	Pass	Pass
Mono Pitch	Pass	Pass	Pass
Gable End	Pass	Pass	Pass

**Table 9: Premier Cutting Chimney Mean Loading Results**

Test Sample	Panel Type	Mean Failure Load (kN)	Mean Bond Strength	
			kN/m <sup>2</sup>	N/mm <sup>2</sup>
Lifting Eye Tensile Strength	~	33.80	~	~
Bond strength Brick Slip	Control	5.29	~	0.42
	Conditioned	5.43	~	0.43
Chimney Crown Bond Strength	~	28.20	35.25	~



**Plate 1**  
General View of Mid-ridge Chimney



**Plate 2**  
General View of Mono-pitch Chimney



**Plate 3**  
General View of Gable End Chimney



**Plate 4**  
General View of Mono-pitch Chimney under Wind Load



**Plate 5**  
Testing of Lifting Eye



**Plate 6**  
Failure of Lifting Eye



**Plate 7**  
Chimney under Lifting Eye Test



**Plate 8**  
General View of Gable End Chimney under Water Tightness Testing



**Plate 9**  
Detailing of Lead Flashing for Gable End Chimney



**Plate 10**  
Mon-pitch Chimney under Water Tightness Testing



**Plate 11**  
Detailing for Mono-pitch Chimney



**Plate 12**  
General View of Chimney Crown Pull-off Test



**Plate 13**  
Failure of Crown by Bending of Overhang