External Wall Insulation (EWI) systems for high rise steel framed buildings
Second line of defence with the Alumasc Exicco Pro drained cavity system

Abstract

The presence of interstitial moisture within a framed construction could have a detrimental impact upon the integrity of the structure. Building regulations, insurance providers and technical standards all require the inclusion of a cavity within the building envelope of a framed construction. This cavity acts as a second line of defence against moisture entrapment and corrosion within the structural element of the façade. The practical design implications for an External Wall Insulation (EWI) system of integrating a cavity in the construction are considered here. The importance of robust detailing for moisture control is considered together with conventional building envelope design issues such as thermal performance, structural integrity, fire performance and durability. The Alumasc Exicco Pro system is used as an example to demonstrate how a drained cavity system can be designed, tested and accredited to comply with relevant regulations and standards.

1 Introduction

Modern methods of construction are increasingly changing the way that construction projects are delivered in the UK. Offsite construction and the increased use of timber and steel framed construction are two examples of this. These modern methods are intended to improve the speed of construction (and associated financial benefits) whilst mitigating a key industry constraint – the scarcity of skilled labour resource (e.g. bricklayers).

External Wall Insulation (EWI) systems have historically been employed as a cost-effective method of improving the aesthetic and thermal performance of masonry substrates. However, for EWI to bring the same benefits to framed constructions, there are some important design considerations that must be taken into account; particularly when the construction is classed as high-rise (i.e. greater in height than 18 m).

This paper raises these design considerations and uses the Alumasc Exicco Pro system as an example to demonstrate how an EWI system can be designed to provide robust system solutions that (a) comply with Building Regulations and (b) are accepted by the construction industry’s key insurance providers.

2 Specific requirements of steel-framed construction

Façade designers are accustomed to considering key design characteristics such as structural integrity, fire performance, management of moisture (i.e. water ingress and condensation risk), thermal performance and durability. However, the key differential with framed external wall constructions compared to masonry construction is in the way that the risk of moisture is managed. Here, the design must mitigate the risk that a build-up of moisture in the vicinity of a framed structure could detrimentally impact the structural integrity of the frame.

There are therefore specific requirements imposed by the regulatory authorities and insurance underwriters relating to the integration of a drained cavity within the construction, on the outer side of the framed structure. Systems are not designed to allow moisture ingress. However, experience proves that these issues can occur in practice. A drained cavity behind the system ensures that any moisture can escape without leading to a catastrophic failure of the construction. The cavity can therefore be considered as a second line of defence in the event of failed weathertightness detailing, designed to protect the building.

2.1 Regulatory requirements

Approved Document C of the Building Regulations – England & Wales (Clause 5.17) states that “any framed external wall will meet the requirement if the cladding is separated from the insulation or sheathing by a vented and drained cavity with a membrane with is vapour open, but resists the passage of liquid water, on the inside of the cavity.”

Clause 3.10.1 of the Building Regulations, Technical Handbook (Scotland) states that any wall that is “exposed to precipitation, or wind driven moisture, should prevent penetration of moisture to the inner surface of any part of a building so as to protect the occupants and to ensure that the building is not damaged. For external wall constructions it is important that the wall is designed and constructed to suit the degree of exposure to wind and rain that it may be subject to.”
2.2 Requirements of insurers
The major construction insurers (e.g. National House Building Council [NHBC], Premier Guarantee) both require a drained cavity in the construction:

- NHBC (in Section 6.9, Curtain Walling & Cladding) requires a minimum 15mm wide cavity that is drained and ventilated for timber frame or drained for steel frame;
- Premier Guarantee (in Section 7.7.3, Insulated Render) requires a minimum 25 mm wide drained and ventilated cavity for timber and steel frame.

2.3 Requirements of accreditation bodies
The two main approval bodies also require the inclusion of a drained cavity:

The British Board of Agrément (BBA) requires the system to be tested in accordance with European Technical Approval (ETA) guidelines ETAG004 (The Guidelines for European Technical Approval of external thermal insulation composite systems (ETICS) with render) and be designed with a drained cavity to prevent moisture damage and/or leakage into the substrate.

The Centre for Window & Cladding Technology (CWCT) Standards for Systemised Building Envelopes, Part 1 – Scope, Terminology, Testing & Classification, Section 1.4 Principles of Weathertightness states that:

- Envelopes of this type have seals at or near both the inner and outer faces. The outer seal should be the primary barrier to water ingress. The inner seal provides airtightness and acts as a secondary seal to water ingress.
- Secondary defence systems are preferred as they are more robust than face sealed walls. They are more tolerant of variations in workmanship and are more durable as their weather performance ultimately depends on an inner seal that is in a less aggressive environment than a face seal.

3 EWI System for framed construction
The Alumasc Exicco Pro system is an EWI system that has been designed for use with either steel or timber framed buildings. As shown in Figure 1, the system comprises (working from inside to out):

- Lightweight steel frame (LSF) with infill insulation (by others)
- Exicco Sheathing Board – fixed to the steel frame
- Exicco Shield breather membrane
- Exicco Rail galvanised steel support rails
- Alumasc Pro dual density non-combustible mineral wool insulation
- Alumasc ETA-approved Insulation Fasteners
- Alumasc Polymer Render – A1 fire-rated – reinforced with alkali resistant, high tensile strength mesh
- Alumasc VBriQ synthetic brick slip finish or Alumasc Silkolitt+ textured silicone through-coloured render

![Figure 1: VBriQ Exicco Pro System Build-up](image)

Depending upon the chosen finish, the system is referred to either as VBriQ Exicco Pro (i.e. with VBriQ synthetic brick slip finish) or Silkolitt Exicco Pro (with Silkolitt+ silicone render finish).
4 How can EWI systems be designed for compliance?
In this section, the key design parameters – structural integrity, fire performance, moisture control, thermal performance and durability – will all be reviewed. Using the example of the Exicco Pro system, it will be shown how EWI systems can demonstrate compliance with regulations, standards and technical requirements.

4.1 Moisture control
As identified in Section 2, the inclusion of a 25mm cavity is required behind the insulation to ensure that any moisture can escape the system without detriment to the system’s durability. The drained cavity is formed through the use of vertical rails that direct any moisture in the cavity to the base of the system.

Consequently, the detailing of the system is integral to the system’s effective management of moisture:

- At the base, provision must be made for moisture to be channelled out through. In the Exicco Pro system, a base rail containing weep holes is used (see Figure 2 (a)). The weep holes create openings totalling no more than 500 mm per linear meter. As such the cavity is considered drained and vented, but importantly, not ventilated (thereby avoiding loss of the thermal benefits of the Exicco Pro system); and
- At openings, it is important to direct any moisture away from potential ingress points. Here, the Exicco Deflection Rail acts as a cavity tray, directing moisture away from the opening and towards the weep holes at the base of the system (see Figure 2 (b)).

![Figure 2 – Detailing for moisture control](image)

4.2 Thermal performance
Lightweight steel frame, by its nature, can lead to the formation of cold bridges in the construction. However, the design of the Exicco Pro system ensures that the thermal envelope around the building is continuous (i.e. without thermal
bridging). As a result, the insulation thicknesses required to achieve target U values tend to be lower than with thermally broken systems.

Table 1 summarises the U values that can be achieved for different combinations of frame depth, infill insulation and Alumasc Pro Mineral Wool insulation within the Exicco Pro system.

Table 1 – Typical Pro Mineral Wool insulation thicknesses to achieve target U values

<table>
<thead>
<tr>
<th>Substrate Insulation thickness (mm) to achieve U values</th>
<th>Target U Values (W/m2K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>100 mm steel frame (insulated)</td>
<td>30</td>
</tr>
<tr>
<td>100 mm steel frame (uninsulated)</td>
<td>80</td>
</tr>
<tr>
<td>150 mm steel frame (insulated)</td>
<td>0</td>
</tr>
<tr>
<td>150 mm steel frame (uninsulated)</td>
<td>80</td>
</tr>
</tbody>
</table>

A further benefit to the external position of the insulation is that the dew point remains outside of the construction in both winter and summer months; avoiding any detrimental effects of condensation on the structure or the system. Outputs from example condensation risk analyses (conducted in accordance with BS 5250:2011, with analysis to BS EN ISO 13788:2002) are shown in Figure 3(a) for insulated and Figure 3(b) non-insulated LSF.

![Figure 3(a) Insulated LSF construction example condensation analysis](image-url)
The graphs demonstrated in Figure 3(a) and 3(b) provide evidence that there is no risk of interstitial condensation. The presence of interstitial condensation is only evident where the blue and red lines cross. The use of a vapour control membrane, of suitable vapour resistivity, behind the plaster boards, is strongly recommended to further ensure that the condensation point is moved to the outside of the building. This is indicated by layer 9 in the above graphs.

4.3 Structural integrity

It is imperative that the façade system is designed for each and every project’s specific conditions by a qualified structural engineer.

First, a structural analysis must be conducted to establish the effects of wind, based on the prevailing wind conditions as calculated by adopting the requirements of BS EN 1991-1-4 Eurocode 1: Action on structures – Part 1-4: General actions – Wind actions together with BS EN 1991-1-4 National Annex – UK National Annex to Eurocode 1 – Action on structures Part 1-4: General actions – Wind actions. These calculations will identify the wind loads that apply not only for the specific location, but also to the different load ‘zones’ on the building.

The next stage is to establish the system’s capacity to resist / transfer the loads to the structural frame. Calculations must demonstrate the system’s capacity to (a) support its self-weight and resist shear loading and (b) resist the calculated wind loads. The system’s capacity to withstand the design wind loads will depend upon several factors:

1. Pull-out resistance of the fixings (both of the rails into the cement particle board / LSF and of the insulation into the rails);
2. Pull-through resistance of the fixings; and
3. Adhesive bond strength of the renders to insulation.

Each factor can be demonstrated through individual testing. However, the capacity of the Exicco Pro system was proven through subjecting it to a dynamic wind uplift test in accordance with ETAG 004: 2013 Guideline for European technical approval of External Thermal Insulation Composite Systems (ETICS) with rendering, Section 5.1.4.3.3 Dynamic Wind Uplift test. The system successfully withstood wind loads of -4.0 kN/m².

A further design consideration is to ensure the structural integrity of the system in the event of a fire. This will be addressed in detail in Section 4.4. However, the system specification must include an additional stainless steel fixing that is to be fixed through the reinforcement layer in each square metre. This will mitigate the risk of collapse of the EWI system in the event of fire.

4.4 Fire performance

4.4.1 System classification

For the system to be suitable for use in high-rise construction, the system must either:

   a) Be of limited combustibility in England & Wales or non-combustible in Scotland (A2-s3,d2) when tested in accordance with BS 13501-1:2007 Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests; or

   b) Prove compliance to BR135 Fire Performance of external thermal insulation for walls of multi-storey buildings, involving a full-scale fire test in accordance with BS8414 Fire performance of external cladding systems.

To ensure that the tested system performs as intended, it is imperative that the stated fire performance considers the interaction of all components. As such, the Exicco Pro system has been tested to BS EN 13501-1: 2007 + A1: 2009 Fire classification of construction products and building elements.

The system achieved an A2-s1, d0 classification:

- The A2 classification translates as ‘non-combustible’ in Scotland and ‘limited combustibility’ in England and Wales;
- The ‘s1’ rating relates to smoke production and is the best performance standard (see Table 2);
- The ‘d0’ rating relates to the formation of flaming droplets (see Table 3) and again indicates that the system attains the best performance standard.

Table 2 – Smoke Production Classification (Tested to EN 13823)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>s1</td>
<td>SMOGRA ≤ 30 m²/s² and TSP600s ≤ 50 m²</td>
<td>Best performance in standard</td>
</tr>
<tr>
<td>s2</td>
<td>SMOGRA ≤ 180 m²/s² and TSP600s ≤ 200 m³</td>
<td>Mid-range performance in standard</td>
</tr>
<tr>
<td>s3</td>
<td>a) No performance declared b) Non-compliance with s1 or s2 criteria</td>
<td>Poorest performance in standard</td>
</tr>
</tbody>
</table>

Table 3 – Flaming Droplet Classification (Tested to EN 13823)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>d0</td>
<td>No flaming droplets within 600 s</td>
<td>Best performance in standard</td>
</tr>
<tr>
<td>d1</td>
<td>No flaming droplets persisting &gt; 10 s within 600 s</td>
<td>Mid-range performance in standard</td>
</tr>
<tr>
<td>d2</td>
<td>a) No performance declared b) Non-compliance with d0 &amp; d1 classification c) Ignotes paper (EN ISO 11925-2 Ignitibility Test)</td>
<td>Poorest performance in standard</td>
</tr>
</tbody>
</table>
As a consequence of the system’s proven fire performance, the Exicco Pro system is “suitable for use on, or at any distance from, the boundary and there is no height restriction on their use” (British Board of Agrément, Certificate 17/5471 PS3).

4.4.2 Cavity fire barriers

Whilst the cavity is vented and drained, rather than ventilated, it is still necessary to ensure that the spread of fire between floors is prevented.

The design of the Exicco Pro system mitigates this risk through the incorporation of (i) non-combustible insulation only at the interface in the cavity and (ii) vertical and horizontal fire compartmentalisation.

The system requires that the Exicco Fire Strip is installed at floor slab and vertical separation partitions (see Figure 4). This is a 120-minute approved intumescent fire strip that, in the event of a fire, is designed to close the cavity and prevent the spread of flame by starving the fire of oxygen.

4.5 Durability

The Exicco Pro system has been exposed to numerous testing regimes to prove its hygrothermal performance, weathertightness and impact resistance to demonstrate the durability of the system.

4.5.1 Hygrothermal Performance

The hygrothermal performance of the Exicco Pro system has been tested in accordance with ETAG 004:2013 Guideline for European Technical Approval of External Thermal Insulation Composite Systems with Rendering, Section 5.1.3.2.1 Hygrothermal behaviour.

A real-life test wall (2.5 x 2.0 m, including a window of 0.4 x 0.6 m) – fully representative of the Exicco Pro system – was tested in a hygrothermal chamber:

- 80 heat rain cycles – heating to 70°C for 3 hours, being sprayed with water for an hour and then leaving for 2 hours
- 5 heat cold cycles – heating to 50 °C for 8 hours before being cooled to -20 °C for 16 hours

During the tests, any deterioration in the system’s characteristics or performance (e.g. blistering, detachment, crazing, loss of adhesion, formation of cracks) would be recorded as a fail. However, the Exicco Pro system passed; showing no signs of deterioration.

4.5.2 Freeze Thaw Performance

The freeze thaw resistance of the system must be established through testing in accordance with ETAG004 guidelines. This test is designed to verify a system’s performance in response to continued severe temperature change whilst the system is wet. The system must withstand 30 cycles (of 8 hours’ submersion followed by 16 hours at -20 °C) without showing any signs of deterioration.

Any changes in characteristics of the surface or edges to the behaviour of the entire system are recorded and reported as a failure. However, again, the Exicco Pro system passed, showing no signs of deterioration.

4.5.3 Weathertightness

Following the completion of the hygrothermal conditioning, weathertightness testing was carried out on the same test wall (in accordance with BS EN 12865: 2001 Hygrothermal performance of building components and building elements – Determination of the resistance of external wall systems to driving rain under pulsating air pressure).
This test verifies the system’s capacity to prevent the passage of moisture to the substrate under varying water spray pressures (from 0 Pa to 1,365 Pa in increments of approximately 150 Pa) for a period of 110 minutes. As the Exicco system passed the test without any indication of moisture ingress, the system is classified as suitable for installation in all exposure zones (i.e. anywhere in the UK).

4.5.4 Impact Resistance

For a façade system to be installed at low level, the system must have been tested and proven to withstand impacts to an appropriate level. These impact tests are designed to reflect the types of incidents that may affect the wall in practical use. For example, hard body tests effectively mimic impact by stones, cricket balls etc whilst soft body tests replicate typical human interaction and contact with footballs etc.

After hydrothermal conditioning, the Exicco Pro system was subjected to the following tests:

1. **MOAT 43: 1987 UEAtc Directives for Impact Testing Opaque Vertical Building Components**, Section 2.2.1 Large soft body impacts. 50 kg / 100 Nm soft bodies impacted the wall and upon inspection, no damage was identified.

2. **EOTA Technical Report 001: February 2003 Determination of impact resistance of panels and panel assemblies**, Section 2 Test method for determining soft body impact resistance. A spherical bag with a mass of 50 kg was swung in a pendulum motion to impact upon the wall. After impact, the wall was inspected and there were no signs of damage.

3. **ETAG 004: 2013: Guideline for Technical Approval of External Thermal Insulation Composite Systems with Rendering**, Clause 5.1.3.3 Impact resistance. Finishing coats on the wall were subjected to hard body impacts (3 and 10 Joules) – see Figure 5 – and the results were recorded for the two different finishes as follows:

   - **VBriQ Synthetic Brick Slips** attained Category I resistance. This means that VBriQ Exicco Pro can be used in zones that are readily accessible at ground level to the public and vulnerable to hard body impacts (but not subjected to abnormally rough use).
   - **Silkolitt+ silicone render** attained Category II resistance. This means that Silkolitt Exicco Pro can be used (a) in zones that are liable to impacts from thrown or kicked objects, but in public locations where the height of the system will limit the size of the impact, or (b) at lower levels where access to the building is primarily to those with some incentive to exercise care.

In summary, therefore, the Exicco Pro system – whether finished with VBriQ, (i.e. VBriQ Exicco Pro) or with Silkolitt+ silicone render (i.e. Silkolitt Exicco Pro) – is suitable for use at low levels.
4.6 Summary of performance requirements

Table 4 summarises the regulations, standards and technical requirements of façade systems that are compatible with framed construction and indicates how the Exicco Pro system complies with these performance requirements.

Table 4 – Performance requirements of façade systems on LSF

<table>
<thead>
<tr>
<th>Regulation/Standard</th>
<th>Standard</th>
<th>Compliance Requirement</th>
<th>System Performance</th>
<th>Compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Regulations England &amp; Wales</td>
<td>Approved Document A - Structure</td>
<td>Wind load resistant and structural integrity</td>
<td>Tested and approved by BBA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Approved Document B - Fire</td>
<td>Limited Combustibility or BR135 compliance</td>
<td>A2-s1,d0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Approved Document C - Site Preparation &amp; Resistance to Contaminents &amp; Moisture</td>
<td>Drained cavity / Weathertightness / No Interstitial Condensation</td>
<td>25mm drained cavity. Weathertightness proven through testing. Condensation proven through BBA approved calculation, see Appendix A</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Approved Document L - Conservation of Fuel &amp; Power</td>
<td>Various U-Values</td>
<td>Demonstrated in Appendix A</td>
<td></td>
</tr>
<tr>
<td>Scottish Building Regulations</td>
<td>Section 1.0 - Structure</td>
<td>Wind load resistant and structural integrity</td>
<td>Tested and approved by BBA</td>
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<tr>
<td></td>
<td>Section 2.0 - Fire</td>
<td>Non-Combustible or BRE135 Compliance</td>
<td>A2-s1,d1</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Section 3.0 Environment</td>
<td>Weathertightness / No Interstitial Condensation</td>
<td>25mm drained cavity. Weathertightness proven through testing. Condensation proven through BBA approved calculation, see appendix A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section 3.0 Energy</td>
<td>Various U-Values</td>
<td>Demonstrated in Appendix A</td>
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<tr>
<td>NHBC Standards</td>
<td>Section 6.9, Curtain Walling &amp; Cladding</td>
<td>15mm drained cavity</td>
<td>25mm drained cavity</td>
<td>Yes</td>
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<td>Premier Guarantee</td>
<td>Section 7.7.3, Insulated Render</td>
<td>25mm Drained cavity</td>
<td>25mm drained cavity</td>
<td>Yes</td>
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<tr>
<td>CWCT</td>
<td>Section 1, Principles of Design</td>
<td>25mm Drained cavity</td>
<td>25mm drained cavity</td>
<td>Yes</td>
</tr>
<tr>
<td>LABC Technical Manual</td>
<td>Chapter 7, Superstructure</td>
<td>25mm Drained cavity</td>
<td>25mm drained cavity</td>
<td>Yes</td>
</tr>
</tbody>
</table>

5 Conclusions

The design of all façade systems must take into account structural integrity, fire performance, moisture control, thermal performance and durability. However, the growing use of lightweight steel frame (LSF) construction places a greater emphasis on the control of moisture within the façade construction to maintain the integrity of the underlying structural frame. A key requirement of a façade system that is compatible with steel framed construction is therefore the incorporation of a drained cavity between the structure and the insulated façade system.

There are advocates of systems being direct fixed to the LSF without the need for a drained cavity. However, the building regulations, insurance providers and accrediting bodies all insist upon the presence of a drained cavity as a second line of defence. This poses a number of challenges to façade system designers.

This paper has used the example of the Exicco Pro system to demonstrate how these challenges can be met through good system design, extensive testing and accreditation and robust detailing for the project’s specific requirements.