VIP Cladding Panels for Buildings: Applications and Conceptual Solutions

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1 Introduction

Over 95 % of new industrial buildings in the UK, and a high proportion of commercial and institutional buildings, rely on steel or aluminium cladding systems for their walls and roofs. These generally comprise an insulating foam or mineral wool core set between internal and external metal faces. The systems are well regarded, but do have performance limitations including low acoustic attenuation and reduced insulation associated with ageing. Depending upon the particular product the systems may rely on unsafe blowing agents, high embodied energy insulants, or materials that generate toxic emissions in fire.

The drive to reduce energy use in new buildings in the UK is led by regulation, namely the Building Regulations Part L, a new revision of which is due in early 2006, with a further revision to follow in 2010. The major change has been the introduction of a whole building carbon dioxide emission approach for both domestic and non-residential buildings, with aggregate savings in emissions of 22% to be achieved over 2002 standards by a variety of means. In practice, as well as achieving better air-tightness, high levels of envelope insulation will certainly be required, with wall U-values of less than 0.3 $W/(m^2{\cdot}K)$ and roof U-values of less than 0.2 $W/(m^2{\cdot}K)$.

Many of the systems will struggle to achieve forthcoming standards, and those that can achieve the standards will be considerably thicker. This will lead to loss of usable floor area, greater self-weight (which will increase production, transportation, construction and structural) costs, and for vertical (wall) and inclined (roof) applications will cause very significant fixing problems due to the eccentricities developed at the connections (this is already a significant technical problem). Particular problems also exist with composite panels where it is difficult to control the rise and cure of deep foam layers.

In view of these issues it is likely that step-changes will be required in building cladding technology to meet regulatory and economic imperatives.

2 Applications

Applications for vacuum cladding systems within new build building envelopes in the industrial and commercial sector potentially exist in at least three categories.

1. Mainstream industrial cladding systems where in terms of cost and performance systems must be competitive with conventional technology, and where the thinness of the panels is not a decisive advantage.
2. Commercial building cladding where ‘thin wall technology’ can increase the net to gross area of the building and consequently deliver higher rental yields.
3. Niche ‘architectural’ applications where the performance and appearance of the panels is advantageous, such as used in conjunction with structural glazing systems.

Of these, the most significant initial opportunities may well be in areas 2 & 3.

2.1 Industrial Cladding

Industrial buildings in the UK are generally clad using either ‘built-up’ or ‘composite’ cladding systems. Built-up systems comprise two metal skins separated by mineral wool insulation and spacer bars. Composite systems comprise two metal skins with a polyurethane (or similar) foam core that adheres to, and rigidly connects the skins.

Figure 1: Industrial Unit. Cardiff

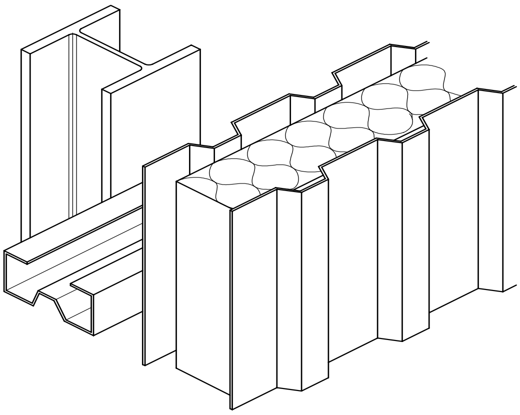

Figure 2: Conventional ‘Built-up’ Cladding System

For the reasons cited in section 1, difficult technical issues surround the adaption of these technologies to meet forthcoming thermal standards. Consequently there is a major new potential application for VIP technology in the sector.

However, since VIP technology is presently considerably more costly than established cladding systems, it appears unlikely that there will be significant early market penetration, although expectations of major future markets appear entirely reasonable. Growth in this sector may be facilitated by prior usage in other sectors where cost is less constrained. Improved production capacity and efficient manufacturing techniques are likely to be essential.

2.2 Commercial Building Cladding

As the thickness of commercial building cladding systems increase, the ratio of net to gross floor area calculated on a building perimeter basis is adversely affected. Conventional wall technology for offices and commercial buildings tends rely on either:

- Infill walls comprising blockwork or light steel studs at 600mm centres, with insulation and a cladding system external to these.
- Large strongback, integral or stick system curtain walls with non-load bearing internal wall linings and insulation.

Both solutions tend to produce a wall thickness in the range 295-350 mm. For example, in the basic case of a composite panel clad office building with blockwork infill walls (which is arguably relatively efficient in that the insulation and cladding is combined), the overall wall thickness is given in Table 1.

Composite panel	70 mm	100 mm
Light steel rails	100 mm	100 mm
Blockwork	100 mm	100 mm
Dry-lining (Gypsum board on dabs)	24 mm	24 mm
Plaster skim	3 mm	3 mm
Total	297 mm	327 mm
U Value	0.35 W/(m^2·K)	0.30 W/(m^2·K)

Table 1: Typical external wall thickness

Figure 3: Typical Commercial Building

The overall thickness of conventional insulated external walls is much greater than that of window areas. Double glazed units are generally in the region 25-35 mm in office buildings, plus the depth of their associated support frameworks. Vacuum insulated wall panels designed to achieve 0.30 W/m^2·K approximate much more closely the width of glazed assemblies, with the panels themselves potentially being as little as 30 mm thick. VIP technology therefore offers considerable opportunities for thinning external walls and improving net to gross ratios. The economic benefits are particularly demonstrable for buildings with high rental values.

Present rental values for centrally located office accommodation in key cities in the central and southern regions of the UK are given in Table 2.

	Bristol	Birmingham	London
New high specification	240	300	850
New medium or refurbished high specification	150	250	500
Mainstream corporate entry level.	90	120	325

Table 2: Typical rental values for office accommodation Q3 2005 in £/(m^2·a)

Given these relatively high sums, the impact of adjustments in net to gross floor areas that may be achieved by reducing the width of external walls are significant. For example, assuming an 8 storey building with 32 x 14m floor plates:

- Total floor area is: 8 x 32 x 14 = 3584 m^2
- Total perimeter area is: 8 x (32+14) x 2 = 736 m
- The floor area given over to conventional 300mm wide external walls in this case is: 736 x 0.3 = 221 m^2

In contrast the floor area required for VIP based external walls assuming 30 mm panel and a 100 mm windpost/lining zone is: 736 x 0.13 = 96 m^2. This represents a saving of 125 m^2.

Assuming that rental income is £ 500/(m^2·pa). (medium specification central London office space), the additional space generates revenue of £ 62500 pa. Over a 60 year building life the net present value of such a saving PV(C) given by the formula:

$PV(C) = C. [1-(1+d)^{-m}]/d$

where C is the rental gained as a result of the reduced external wall width, appearing for m years, with a discount rate of d (assumed to be 3 %). Applying this formula, the net present value of the additional rental income is £ 1,730,000.

Or alternatively using the much simpler seven year rule sometimes used for justifying returns on property investments, the cladding system could be up to £ 437,500, or £ 140 per m^2, more expensive than a conventional system and remain economically justified based on a 4.2 m storey height.

2.3 ‘Architectural’ applications

One significant potential application of thin vacuum panels is in the area of structural or bolted glazing assemblies. Modern forms of these, based on spider brackets and specialised bolts (some of which incorporate rotational devices that allow for flexing of the glass) have become increasingly common. The architectural appearance is crisp, and the connection devices tend to emphasise the lightness of the building envelope. Buildings using large areas of such systems however can be susceptible to overheating, excessive heat loss and glare problems; and whilst the use of prints on the glazing can reduce these, considerable opportunities exist for the use of thin insulated opaque panels used within the glazing matrix.

VIP technology where either VIP units are encapsulated within glass or steel would meet this demand.

Figure 4: Typical modern bolted glazing system.

3 Concept development

Three options were modelled using Heat conduction modelling software.

3.1 Option 1: Hybrid panel

A panel using polyurethane to encapsulate VIP, enveloped in 0.7 mm steel skins.

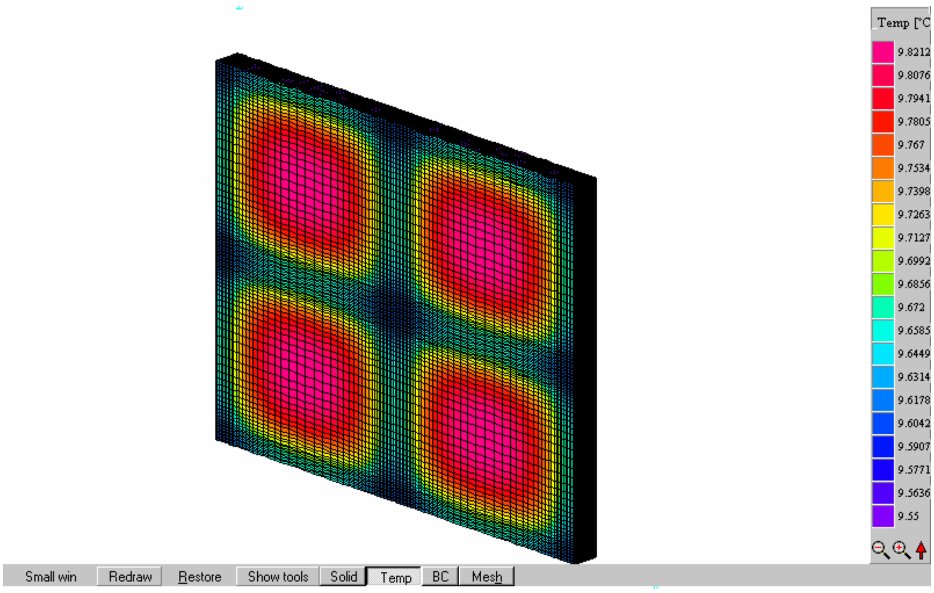

Figure 5: PUR/VIP Composite (4 x 400 mm x 400 mm x 40 mm VIP in 1 m²)

Description	Heat flow W/m^2	Equivalent k W/(m·K)	U-value $W/(m^2 \cdot K)$
Panel with 4 x 40 mm VIP units in PUR	2.0950	0.013	0.210
Panel with 60 mm PUR only	3.5880	0.023	0.359
Panel with 1 large 40 mm VIP unit	1.6320	0.010	0.163
Panel with 60 mm VIP only	0.8191	0.005	0.082

Table 3: Results from Heat3 modelling of hybrid polyurethane/vacuum insulated panel.
Equivalent k = thermal conductivity of whole panel, including effect of other materials with VIP

3.2 Option 2: Structural skin

The inner structural skin is 8mm thick sandwich panel comprising 1mm steel skins and a central plastic core substituted by foamed polyurethane (PUR) in some instances. The outer skin is 0.7 mm thick steel, turned in by 8mm all around the edges for additional strength and neat appearance. The edges of the panel are protected by 5mm of silicone seal, replaced by 1mm Kevlar for one test. A quarter section of a 1200 mm square panel was modelled (i.e. 600mm square with two outer edges). Thermal conductivities used are shown below:

Material	Thermal conductivity λ (W/m·K)
Steel	52
Vacuum core	0.006
VIP film	0.79
Plastic core material	0.3
PUR	0.025
Silicone seal	0.2
Kevlar	0.2

Table 4. Thermal conductivity values

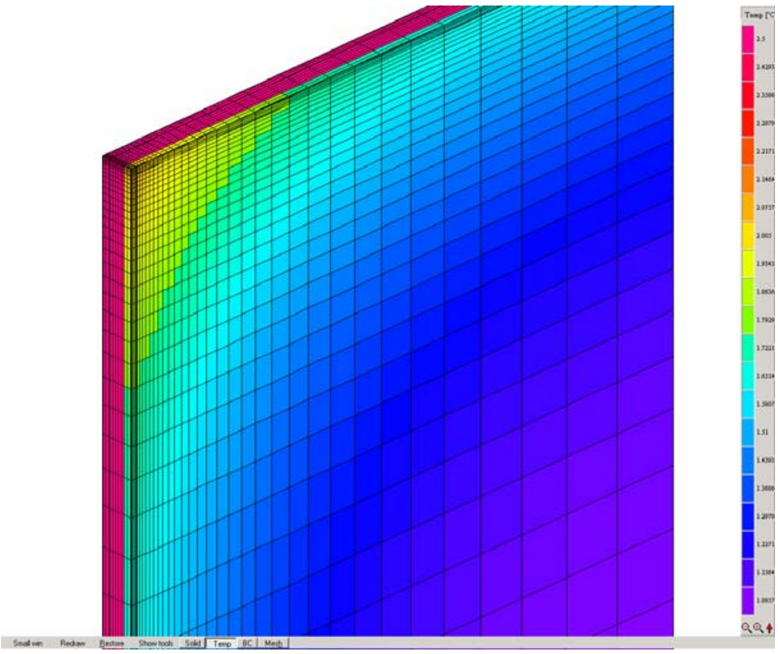

Figure 6: Structural skin vacuum insulated panel

Description	23.3 mm VIP	(32.0 mm total)
	Q W/m^2	U W/(m^2·K)
5mm silicon seal/plastic composite skin	8.346	0.417
As above, but no steel edge fold	7.771	0.389
PUR seal/plastic composite skin	5.755	0.288
Silicon seal/PUR composite skin	7.556	0.378
PUR seal/PUR composite skin	5.420	0.271
1mm Kevlar edge/plastic composite skin	6.571	0.329
No edge seal/plastic composite skin	5.405	0.270
No edge seal/PUR composite skin	5.113	0.256
No edge detail/plastic composite skin	5.372	0.269

Table 5. Results from Heat3 modelling of structural skin vacuum insulated panel

Further calculations were carried out with an 8mm structural skin (32mm total cladding thickness).

Description	Q W/m^2	U W/(m^2·K)
23.3mm VIP, no edge fold, 2mm thick plastic edge trim	6.584	0.329
23.3mm VIP, 4mm edge fold, 2mm thick plastic edge trim	6.739	0.337

Table 6. Further results from Heat3 modelling of structural skin vacuum insulated panel

To achieve a U-value of 0.3 W/(m^2·K), with an edge fold of 4 mm, a VIP thickness of 26.3 mm is required, giving an overall thickness of 35mm.

- Use of a silicon edge seal introduces significant thermal bridging, increasing overall heat flow by over 50 % compared to a panel with no edge seal.
- An 8mm turn around the edge of the outer steel skin increases heat flow by over 7 %
- Current Part L requirement of 0.35 W/(m^2·K) can be met with a 32 mm thick panel of the structural skin design, as long as the skin is not greater than 8 mm, and a 2 mm thick edge seal is used.
- Possible future Part L requirements for 0.3 W/(m^2·K) will need a structural skin panel of 35 mm thickness.

3.3 Option 3: Pultruded box section

30 mm box section with 2 mm wall thickness around all panel edges. Box section filled with PUR foam to reduce thermal edge effect. 30 mm VIP core 4 mm edge fold on both steel skins, which are 0.7 mm thick

Description	30mm VIP	
	Q W/m^2	U W/(m^2·K)
30 mm pultruded box section	6.800	0.340
VIP with no edge detail	4.218	0.211

Table 7: Results from Heat3 modelling of pultruded box section panel

The box section was modified to be 15 mm wide by 30 mm deep, with the wall thickness increased to 3 mm. Very little difference was noted. To achieve a U-value of 0.3 W/(m^2·K), a thickness of 36.4 mm is required.

- The pultruded box section is borderline, the panel as originally modelled just achieving a U-value of 0.34 W/(m^2·K) with a total thickness of 31.4 mm.
- To achieve a U-value of 0.3 W/(m^2·K) with the pultruded section frame, a thickness of 36.4 mm is required.

4 Conclusions

Vacuum insulation technology probably has greatest current potential within the commercial and 'architectural' cladding sectors in the UK, however there is scope for significant use in the industrial sector in the future when greater capacity exists, and efficient manufacturing systems are developed that facilitate cost reductions. The present cost of vacuum insulation based cladding systems is not problematic where procurement cost can be offset against additional rental income in the commercial markets. This arises from thinner external wall thickness and greater usable internal floor area. An additional cost of approximately £140 per square metre of cladding can presently be justified in high rental locations the UK.

Concepts have been developed using vacuum panels as the primary insulant that meet current and future UK Building Regulations. These are suitable for the industrial shed market (although not seen as economically justified at present), the commercial building market (using, for example, conventional curtain walling fixing technology) and the niche 'architectural' market (using internally fixed connections to minimize thermal bridging). Panels of a thickness less than 35 mm can be used to substitute with structural glazing as required.